**Ecole Doctorale des Sciences de l'Homme et de la Société (SHS)**
Centre Interuniversitaire de Recherche en Education de Lille (CIREL - EA 4354)
Equipe Théodile

THESE DE DOCTORAT

Préparée et soutenue le 23 novembre 2020 par

Andrea TUCKER

Pour l'obtention du grade de Docteur en Sciences de l'éducation

# Learning to Collaborate: The Influence of Physical Digital Workspaces on the Development of Collaborative Competencies

Sous la direction de M. Cédric Fluckiger et co-encadré par M. Thierry Gidel

**JURY**

| | | |
|---|---|---|
| Georges-Louis BARON | Professeur émérite, Paris V / EDA | Rapporteur |
| Thérèse LAFERRIERE | Professeure, Université Laval | Rapportrice |
| Pierre DILLENBOURG | Professeur, EPFL | Examinateur |
| Ecaterina PACURAR | Professeure, Lille / CIREL | Examinatrice |
| Cédric FLUCKIGER | Professeure, Lille / CIREL | Co-directeur de thèse |
| Thierry GIDEL | Maître de Conférences, UTC / COSTECH | Co-encadrant de thèse |

**DEDICATION**

This dissertation is dedicated to the memory of François Villemonteix. Over the course of my first year as a doctoral student, François served as my research director, but more than that – he became a mentor, a kind critic, and a friend.

*Great souls die and*
*our reality, bound to*
*them, takes leave of us.*
*Our minds, formed*
*and informed by their*
*radiance,*
*fall away.*

*And when great souls die,*
*after a period peace blooms,*
*slowly and always*
*irregularly.*
*Our senses, restored, never*
*to be the same, whisper to us.*
*They existed. They existed.*
*We can be. Be and be*
*better. For they existed.*

Maya Angelou

**SPECIAL THANKS**

The contributions of the Acadamie d'Amiens, with funding from the numérilab, is truly appreciated. Without their support and funding, this project could not have reached its goal. I would also like to acknowledge the physical, technical and staff contributions from the participating universities and companies: the University of Technology at Compiegne, especially at its Centre d'Innovation, the University of Lille and Ubikey.

I wish to express my sincere appreciation to both Cédric Fluckiger, my thesis director, and Thierry Gidel, my co-supervisor. They both guided and encouraged me through difficult situations. Without their persistent help and support, this dissertation would not have been realized.

I wish to show my gratitude to Georges-Louis Baron, who encouraged me to continue my studies and has been a constant support in my journey.

I am indebted to the two other members of the Cré@tion team: Sandra Cagliesi, who lent her expertise and support as an educator and school liaison. Sabrina Lozai, the research engineer on the project, was integral for her support, implementing our research protocol, and analyzing hours upon hours of data. Our time spent working together has built an unexpected friendship.

I would like to pay special regards to the teachers and schools who participated, especially Nicolas Salzman, who let me intrude on the normal course of his classes to conduct this research. Additionally, I am indebted to the teachers and support staff from the participating high schools and middle schools.

I wish to thank everyone who lent their time to help me finalize my work: Travis Tucker, Erin Coleman, Erin Burcher, Annee Bayeux, John Freshwater, and Sadaf Jardan.

I wish to acknowledge the support and love of my family: my partner, Greg; my mother, Debra; my father, Danny; my brothers and sisters: Melissa, Daniel, Macayla, and Travis. They have encouraged and supported me, even when they were not so certain of the wisdom in my choices. Without them, this work would not have been possible.

**ABSTRACT (ENGLISH)**

This research aims to investigate collaborative methods of working and learning in an educational context. What are the competencies associated with collaboration and how are they acquired? How do technologies that have both physical and digital affordances influence this process? The capacity of an individual to work collaboratively with others is at the heart of current institutional concerns, marked particularly by discourse about how collaborative practices can be facilitated by adapted technologies. To this end, we study how three different forms of physical-digital workspaces influence collaboration in student work groups, including multi-user tactile tables, boards and individual tablets used in various combinations with the aim of proposing a model for collaboration and collaborative competency assessment.

In this dissertation we propose a state of the art on collaboration, collaboration as a competency and physical-digital workspaces. Then, we present our research protocol from a study with 45 university students working on case studies in the context of a course. We propose two models. The first is a model of interactions mobilized during collaborative work. The second is a framework for assessing engagement and the impact of behaviors during collaboration based on five key competencies. Our results show that the form of the physical-digital workspace has an influence on modes of interaction employed by students during their work as well as on the appearance or lack thereof of certain competencies. Most notably, those workspaces which integrate both individual and collective space seem to have the most positive impact on collaborative processes and competency activation related to participation and engagement, communication, and sharing talk time.

**Key words:** Collaboration, competency, Computer Supported Collaborative Learning, Computer Supported Collaborative Work, mediated learning, workspaces

**RESUME (FRANÇAIS)**

Cette recherche vise à investiguer les méthodes de travail et d'apprentissage collaboratif dans la sphère éducative. Quelles sont les compétences associées à la collaboration ? Comment sont-elles acquises ? Comment les technologies qui ont à la fois une nature physique et numérique influencent-t-elles ces processus ? La capacité d'un individu à travailler collaborativement est au cœur des intérêts institutionnels aujourd'hui, marqué notamment par un discours sur les pratiques collaboratives facilitées par des technologies adaptées. À cette fin, nous étudions comment trois formes différentes d'espaces physiques-numérique de travail influencent la collaboration lorsque les élèves travaillent en groupe. Cela inclut les tables et tableaux tactiles multi-utilisateur, ainsi que les tablettes en différentes combinaisons. Nous proposons un modèle de la collaboration et d'évaluation des compétences collaboratives.

Nous élaborerons un état de l'art sur la collaboration instrumentée, la collaboration en tant que compétences et les espaces physiques-numériques de travail. Nous présentons ensuite notre protocole de recherche mobilisant 45 élèves ingénieur travaillant sur des cas d'études dans le contexte d'un cours universitaire. Nous proposerons un modèle de collaboration que nous mobiliserons ainsi qu'un référentiel de compétence pour évaluer l'engagement et les impacts de certains comportements selon cinq compétences clés. Nos résultats montreront que la forme de l'espace physique-numériques a une influence sur les modes d'interactions mobilisés par les élèves. Il y a, par conséquence, une influence sur l'activation de certaines compétences. Notamment, les espace de travail qui intègre un espace individuel et collectif semble avoir une influence positive sur les modes d'interaction et d'activation des compétences lié à la participation, la communication et le partage de temps de parole.

**Mots clés :** Collaboration, compétences, CSCL, CSCW, apprentissage instrumenté, espace de travail

## RESUME (FRANÇAIS - LONG)

**Apprendre à Collaborer : L'influence des espaces physiques-numériques de travail sur le développement des compétences collaboratives**

Cette recherche est au cœur de certaines des préoccupations institutionnelles actuelles, marquées par des discours autour des pratiques collaboratives qui pourraient être facilitées par des formes d'instrumentation numériques adaptées. En effet, la capacité des personnes à collaborer est de plus en plus demandée dans la société, à l'université, et sur le marché de travail (OECD, 2017). Ces transformations ont mis les questions sur la collaboration, en tant que méthode de travail et d'apprentissage, au premier plan des intérêts, notamment à cause des promesse qu'elle semble avoir sur l'efficacité et la créativité (Sanojca, 2018).

Malgré cet intérêt de la part des institutions et des efforts de la part des chercheurs au cours des trente dernières années, la collaboration reste une notion complexe, floue et polysémique (Baudrit, 2007a; Dillenbourg, 1999; Gracia-Moreno, 2017). Par ailleurs, malgré un nombre important de recherches sur les technologies pour faciliter le travail et l'apprentissage collaboratif, apprendre à collaborer et le développement des compétences collaboratives a été peu examiné.

L'objectif de cette recherche articule plusieurs dimensions du travail et de l'apprentissage collaboratif. Premièrement, les notions de compétence et de la compétence transversale (Tardif & Dubois, 2013) qui existent déjà depuis longtemps sont jusqu'à présent largement restés cantonnés aux contextes professionnels. La nature située des compétences (liées au contexte professionnel et les situations dans lesquelles elles seront mobilisées) a laissé la notion de compétences transversales, qui s'appliqueraient dans différentes situations ou contextes, dans l'incertitude. Des questions concernant leur nature et leur évaluation, même leur existence, ont peu de réponses. Les modèles pour leur développement et leur évaluation existent notamment dans le domaine de la didactique professionnelle. Cela nous force de créer de nouveaux modèles ou de faire un pont entre le milieu scolaire et la formation continue. Deuxièmement, à cause de la nature polysémique de la notion de collaboration, son émergence est difficile à identifier et l'évaluation de son efficacité encore plus. Finalement, les instruments utilisés modifient nécessairement l'activité (Engeström, 2014; Rabardel, 1995; Vygotsky, 1978), mais comprendre les

changement que la mobilisation d'un instrument peut induire sur le développement d'une compétence transversale est difficile.

C'est à travers cette recherche que nous souhaitons apporter des éléments de réponses. Qu'est-ce que la collaboration ? Comment l'identifier ? Comment identifier les compétences collaboratives ? Quelles influences ont les artefacts sur la collaboration ? Quelles influences ont ces mêmes artefacts sur le développement des compétences à collaborer ?

Cette thèse a été menée au sein du projet Cré@tion, un partenariat entre l'Université de Lille, l'Université de Technologie (UTC) de Compiègne et l'Académie d'Amiens. Nous mobilisons une technologie développée à UTC appelé le *Halle Numérique*. Cette plateforme est une collection de matériels et logiciels consistant des tables et tableaux tactiles, multi-utilisateur (décrit prochainement dans la partie Outils, questions et méthodologie de ce résumé et plus en détail dans la Chapitre 2). Elle a été développée à la suite de plusieurs projets de recherche visant à faciliter les processus de conception collaboratif pour les ingénieurs. L'objectif du projet est d'appréhender le rôle qu'une telle technologie puisse jouer pour le développement des compétences à collaborer en milieu scolaire, notamment au collège et lycée.

***Cadre théorique pour aborder la collaboration : outils et les compétences collaboratives***

Notre recherche s'appuie essentiellement sur les théories socio-constructiviste (Leontiev, 2009; Rabardel, 1995; Vygotsky, 1978) dans leur dimension sociale et le courant pédagogique de l'éducation nouvelle, où l'expérience des apprenants est prise en compte dans les pratiques d'enseignement. Cet héritage de recherche socio-constructiviste est central à notre approche, avec l'idée que la mise en situation des étudiants puisse leurs permettre d'apprendre à travailler ensemble. Mais la façon dont cela se produit lors d'un travail dit collaboratif et le rôle des outils sont toujours des sujets à investiguer.

## Les paradigmes de la collaboration

Il y a toujours un débat non-résolu autour de la collaboration et la coopération. Discuter de la collaboration en recherche est systématiquement lié à une discussion de la coopération. Au fond, chacun est un processus de travail mobilisé par le groupe afin de réussir un objectif commun. Alors pourquoi avons-nous deux mots différents ? Qu'est-ce qui les distinguent ? Commençons par discuter des paradigmes de la collaboration qui apparaissent dans la littérature sur le CSCL (Computer Supported Collaborative Learning) / CSCW (Computer Supported Collaborative Work). Nous identifions trois manières de penser la collaboration : en tant que méthode d'apprentissage/enseignement, méthode de travail ou une philosophie d'interaction.

| Paradigme | Définition |
|---|---|
| **Philosophie d'interaction**<br>Vivre ensemble | Une façon d'interagir dans le monde, participer dans la société et avancer la société ensemble. |
| **Méthode d'apprentissage**<br>Apprendre ensemble | Une méthode par laquelle les compétences et connaissances sont acquis ou construits au sein d'un contexte social en travaillant ensemble vers un ou plusieurs buts communs. |
| **Méthode de travail**<br>Travailler ensemble | Un moyen de produire ensemble, qui peut se passer dans un contexte professionnel ou non. |

**Figure du résumé 1 : Les paradigmes de la collaboration**

Une des interprétations communes de la collaboration dans la littérature est celui du travail accompli par des processus de partage et de négociation, où la collaboration est produite socialement à travers des interactions et des efforts de maintenir une vision partagée du problème. Dans ces cas, la séparation entre la collaboration et la coopération se pose sur la division de travail entre acteurs (Henri, 2015). D'ailleurs, d'autres chercheurs disent que la coopération est une forme de travail moins complexe qui permet d'apprendre des faits, comme les mathématiques (Bruffee, 1995). Elles pourraient donc servir d'une étape préalable à la collaboration. Les efforts de distinguer les deux restent souvent flou (Baudrit, 2007b), alors la question se pose : est-ce qu'elles sont nécessairement en tension ?

### Le travail globalement collaboratif

Lors des phases initiales de notre recherche, nous avons observé des lycéens et des élèves ingénieurs pendant leur travail en groupe, avec et sans les supports techno-pédagogiques. Là où les recherches en CSCL/CSCW ont séparé et distingué les activités collaboratives et coopératives (Baker, 2015; Baudrit, 2007b; Bruffee, 1995; Dillenbourg, 1999; Panitz, 1999; Stahl, 2006), notre constat est que ces catégories ont du sens sur une échelle d'activité courte et bien définie.

Par contre, nous constatons que le comportement des élèves tout au long d'une séance ne reste pas assigné précisément aux catégories identifiées. C'est pourquoi nous proposons le concept de *travail globalement collaboratif*. Nous entendons par là une activité dont le résultat final résulte d'une collaboration, mais au sein de laquelle les comportements observés incluent d'autres modes d'interaction tels que la coopération, le travail individuel, la présentation de ce travail, etc.

Sur la base de la littérature existante (Baker, 2015; Bruffee, 1995; Roschelle & Teasley, 1995; Shah, 2008; Shah & Leeder, 2016), nous proposons donc cinq modes d'interaction qui permettent de décrire le travail globalement collaboratif de manière plus fine en identifiant le travail individuel, la communication, la coordination, la coopération et la collaboration :

**Le travail individuel** peut être compris comme les moments où un individu prend du recul, au sein d'une activité collaborative, afin de réfléchir et construire ses idées (Teasley and Roschelle, 1995) ainsi que pour effectuer des tâches qui lui ont été confiées par le groupe. C'est un moment privilégié qui permet l'externalisation de la pensée à l'aide d'états intermédiaires de représentation.

**La communication** est la transmission d'un message d'une personne vers une ou plusieurs autre(s) via un canal (Shanon, 1948). Ce mode d'interaction permet aux individus d'introduire de nouvelles informations dans le groupe, donnant un point de départ pour une vision partagée (Teasley and Roschelle, 1995). Par exemple, la communication peut prendre la forme de verbalisations, de messages écrits (emails, sms), de présentations avec support ou l'introduction de notes, dessins ou croquis dans un espace partagé.

**La coordination** désigne l'organisation d'activités (évènements, tâches et actions) pour qu'elles s'agencent et se synchronisent (Baker, 2015). Ainsi, la coordination peut être observée dans des actions de structuration, organisation et division des tâches entre les acteurs afin de répartir la charge de travail. D'après Baker, la coordination pourrait s'étendre jusqu'à « la coordination des représentations » (les représentations individuelles des tâches) approchant la définition de la collaboration mobilisée par un certain nombre de chercheurs dans le domaine de CSCL (Baker, 2015). Pour notre part, nous estimons que ce travail de « coordination des représentations » trouve plutôt place dans le cadre de ce que nous désignons ici par le terme de travail coopératif.

**Le travail coopératif** se produit à la suite de la répartition des tâches et des responsabilités réalisées en vue d'accomplir une tâche collective. En effet, après avoir réparti puis réalisé chacun une partie du travail, il faut effectuer un travail de mise en commun (Baudrit, 2007; Bruffee, 1995; Panitz, 1999). Cette mise en commun nécessite de la négociation et des efforts de synchronisation des représentations de chacun des participants. Ajuster les différentes pièces du puzzle nécessite donc un travail coopératif. Cet effort peut également être nécessaire lors de la division des tâches (la coordination) pour se mettre d'accord de l'approche et de la forme des résultats du travail individuel, etc.

**Le travail collaboratif**, quant à lui, se produit lors de la co-élaboration, la co-construction ou la co-évolution d'un ensemble de tâches qui sont réalisées par l'ensemble des participants dans un but commun (Baker, 2015; Teasley and Roschelle, 1995). À l'issue d'un travail de collaboration, il n'est plus possible de distinguer l'apport individuel de chaque participant, car les contributions de chacun ont été reprises, modifiées, amendées et sont venues s'enrichir les unes avec les autres. C'est ce qui le différencie du travail coopératif qui lui, résulte de l'assemblage de travaux individuels et l'établissement des accords.

### *CIAO : Collaborative Interaction Analysis mOdel*

Les remarques précédentes et la distinction des différents types d'activité au sein d'un travail globalement collaboratif nous ont conduit à proposer un modèle d'analyse, le modèle CIAO. Lors de notre étude descriptive, nous avons observé que les délinéations entre coopération et collaboration ne représentent pas les activités qui se produisaient dans les groupes observés. Ce fait nous a amené à proposer la notion du travail globalement collaboratif. Les groupes intègrent plusieurs modes d'interaction afin de définir et réussir leurs objectifs. Cette observation nous a amené à mieux définir comment identifier ces différentes modes d'interaction et proposer un modèle d'analyse d'interactions collaboratives (CIAO). Ce modèle nous permet d'identifier les processus collaboratifs qui sont mis en œuvre par les groupes. Pour notre recherche, cela nous aide à comprendre l'influence que l'artefact peut avoir sur ces processus en comparant leur émergence entre les différentes groupes et modalités d'espace physique-numérique, que nous abordons à la fin de cette partie de notre résumé.

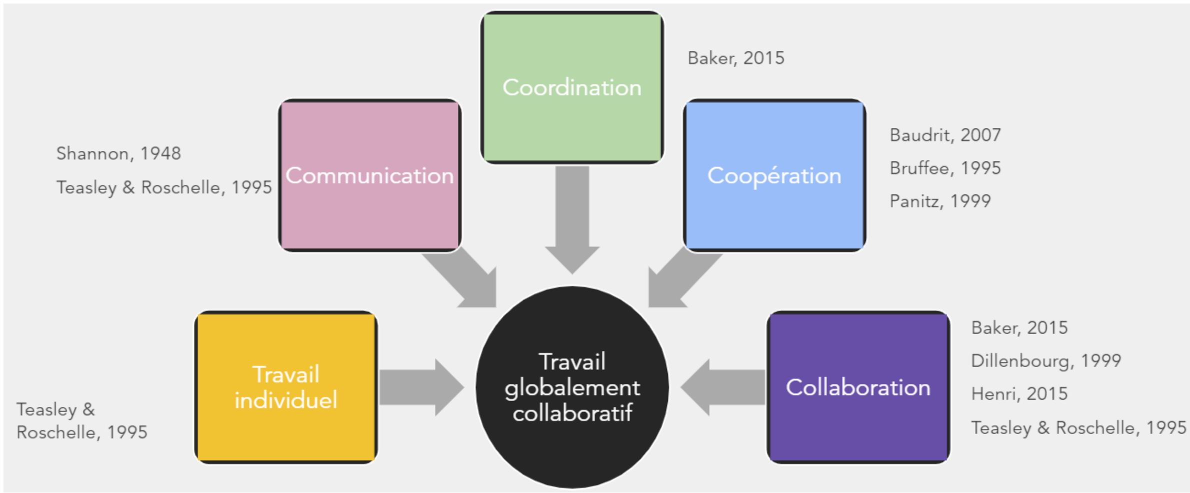



**Figure du résumé 2 : Le travail globalement collaboratif (Tucker et al., 2018)**

Dans ce modèle d'analyse, nous mobilisons la notion de l'enchaînement des actes verbaux et non verbaux. Sizmur (1996) a proposé une catégorisation des actes langagiers qui apparaissent lors d'un travail collaboratif, tel que l'introduction d'une nouvelle idée, l'élaboration, le débat, la négociation, etc. Ces différents actes s'enchainent, par conséquent le thème ou l'idée devient l'unité d'analyse. Par exemple, dans la figure du résumé 3, nous voyons une possibilité d'enchaînement des actes langagiers qui commence quand un individu fait la narration de son activité. Cette narration peut être une communication, mais nous l'identifions comme une communication (signalé par la couleur rose dans la figure du résumé 3) seulement s'il y a une réponse, sinon elle est considérée comme du travail individuel (en jaune) – une externalisation des pensées qui peuvent faciliter la réflexion chez l'individu qui fait la narration. S'il y a une réponse dans le groupe, cela nous indique qu'un message a été transmis.

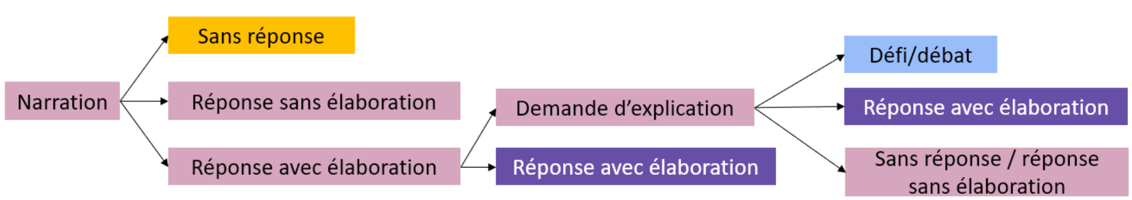



**Figure du résumé 3 : La narration de l'activité comme point de départ**

Si la réponse est simple, sans élaboration (expression d'accord, par exemple), cela reste de la communication. Au moment où il y a une élaboration qui s'enchaine, nous la considérons comme étant de la collaboration (en violet). Au moment que quelqu'un n'est plus d'accord et rentre dans le débat afin de rétablir la vision commune, on se retrouve dans la coopération (en bleu). Nous considérons que la réflexion individuelle/l'expérience de chacun rentre en tension et il faut réassembler/ reconfigurer les pièces du puzzle pour revenir à une vision partagée.

**Figure du résumé 4 : L'écriture d'un post-it (travail individuel) et le transfert du post-it vers l'espace collectif (la communication médiée par l'artefact)**

Cependant, une des limitations de la proposition de Sizmur est son recours unique aux actes de parole. C'est pourquoi notre modèle propose également d'intégrer des éléments non-verbaux, tel que les gestes ou les actions. Cela peut inclure l'écriture (voir la figure du résumé 4), la lecture, la réorganisation des informations, etc.  Par exemple, un individu qui réorganise les notes du collectif de façon individuel peut être pensé comme l'exemple de la narration de la figure du résumé 3. Cela peut-être un moyen de communiquer ses pensées mais aussi comme un travail individuel de réflexion, selon les actions/retours des autres au sein du groupe. Pour d'autres exemples, nous vous invitons à voir le chapitre 4 et Annex 4: Mode of interaction identification examples (French).

### Les compétences à collaborer

La notion des compétences, comme celle de la collaboration, est instable. Cependant, les compétences collaboratives, voir la capacité des élèves à s'engager dans ces différentes modes d'interaction au sein d'un groupe de travail, est au cœur des intérêts institutionnels. Ces discours sont surtout marqués par l'utilisation des nouvelles technologies qui sont supposées faciliter la collaboration. Toutefois, définir et identifier les compétences à collaborer est un défi important. Nous définissons la compétence dans une perspective opérationnelle, en s'appuyant sur les théories principalement francophones. Pour nous, la compétence est : un savoir-agir (Tardif, 2018), constitué de différentes savoirs, savoir-faire et savoir être (Boudreault, 2017; Hatchuel & Weil, 1992; Pastré, 2004) qu'une personne ou un groupe peut mobiliser dans une situation donnée d'après leurs compréhension de cette situation (Wittorski, 1997). Nous essayons ainsi de reconnaître la nature située de compétences, ce qui rend difficile l'élaboration d'un cadre de compétence collaborative transversal qui pourrait s'appliquer en milieu scolaire où on se retrouve souvent avec des situations en évolution (matière, enseignants, paires, outils …).

Dans notre effort de comprendre quelles sont les compétences nécessaires pour la collaboration, nous avons réalisé une revue de la littérature où nous avons fait le choix d'inclure des études de domaines différents mais également avec des buts différents. Par exemple, nous avons inclus des articles de sciences de l'éducation (études dans des cadres professionnel et milieu scolaire), de la médecine, de l'administration public et de la gouvernance collaborative, etc. Nous avons divisé ensuite par la façon dont sont traitées les compétences collaboratives : en tant qu'objet d'étude, cadre d'analyse et des descriptions de la collaboration efficace. Cela nous a permis de suivre les fils rouges qui se retrouvent dans ces différents domaines afin de construire un cadre d'analyse qui pourrait s'appliquer, ou au moins pourrait être adapté, à des situations diverses. Lors de cette étude, nous avons identifié cinq compétences collaboratives :

- **La régulation** : Savoir agir pour gérer, coordonner et évaluer son travail ainsi que le travail du groupe ;
- **La communication et l'écoute** : Savoir agir pour communiquer avec ses collègues d'une manière efficace et adaptée ;
- **Le travail d'équipe** : Savoir agir pour créer de la cohésion dans le groupe afin d'obtenir un objectif commun ;
- **L'intelligence sociale** : Savoir agir pour reconnaître et répondre aux besoins émotionnels des collègues ;
- **Le conflit constructif** : Savoir agir pour surveiller, gérer et résoudre les conflits au sein du groupe.

Une fois identifiés, nous avons utilisé ces cinq compétences pour développer la grille $CO^2$ (COmpétences COllaboratives).

### Le développement des compétences

Avant d'exposer la grille $CO^2$, nous souhaitons discuter brièvement comment les compétences sont développées. En générale, il y a un accord dans la littérature sur le fait qu'il n'est pas possible d'observer directement le développement des compétences. Alors la question se pose : comment le faire ? Tardif (2013), met la responsabilité sur l'élève de produire la preuve de son apprentissage (ex. : la réalisation de son portfolio), mais il reconnaît le besoin de l'évaluer aussi dans le temps.

Samurçay et Rabardel (2004) proposent un cadre d'analyse qui tente d'exposer le processus en milieu professionnel, où les compétences sont traités de ressources en devéloppement constant. Le modèle PAW (People at Work) regroupe le contexte, le sujet, le collectif et les situations dans un système.

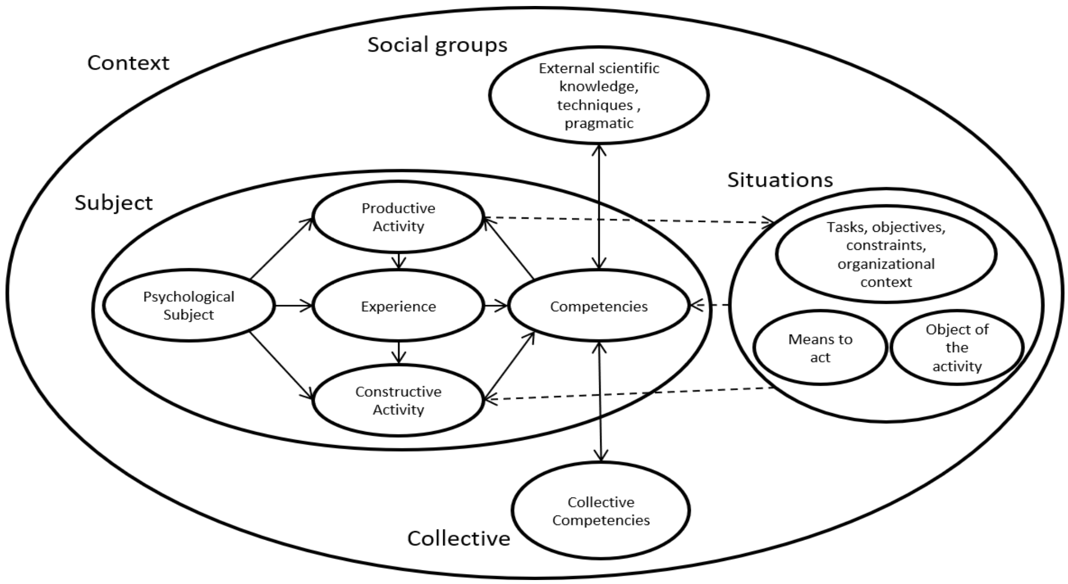



**Figure du résumé 5: People at Work (PAW) (Samurçay & Rabardel, 2004)**

Dans ce modèle, nous voyons que c'est à travers l'activité productive, l'expérience et l'activité constructive que les compétences se construisent chez l'individu. Le modèle suggère également que les compétences des autres et la situation (y compris les artefacts) peuvent aussi influencer ce développement, surtout à travers des modifications de l'activité productive et constructive. Ils peuvent aussi servir de ressources supplémentaires pour les augmenter.

Bien que ce modèle a été fait pour analyser des activité au travail, nous croyons qu'il peut être utilisé également en milieu scolaire pour comprendre le devéloppement des compétences lors d'une mise en situation. Celui-ci inclut l'instrument (Rabardel, 1995), ce qui peut nous aider à comprendre l'influence des espaces physiques-numériques de travail.

Retournons vers la question de l'évaluation de ces compétences : comment se rendre compte de ces processus ?

### $CO^2$ : COllaborative COmpetency Analysis Framework

Nous sommes bien conscientes qu'il y a un problème fondamental avec la mise en place de standards de compétences accompagnés par des efforts d'évaluer contre une telle grille, même si cela est une approche courante. Souvent les compétences sont décrites en termes de comportements qui devraient apparaître dans une situation générale. En revanche, il y a une contradictionentre cette approche et l'idée que les compétences sont situationnelles. Westera (2001) signale qu'une telle approche ne peut probablement uniquement nous dire si quelqu'un n'est pas compétent. Il y a encore d'autres problèmes à considérer aussi pour l'évaluation des compétences - notamment la nature subjective et même parfois éphémère de la compétence. En essayant de prendre en compte ces limites, nous avons appliqué une approche un peu différente dans le sens où nous avons regardé comment les comportements de l'apprenant impactent le groupe, ses processus et sa progression pour accomplir le travail. Cette approche est une tentative de refocaliser sur l'impact des comportements et moins sur la performance d'un comportement spécifique.

Nous proposons une grille opérationnelle de compétence entre -2 et 2. Le -2 représente un impact négatif sur la collaboration, le 2 représente un impact positif et le 0 est neutre. Chacune des compétences que nous avons identifié lors de l'état de l'art sur les compétences collaboratives a été divisé en trois indicateurs. Les différents niveaux ont été identifié à travers la lentille de l'engagement dans l'activité. Nous définissions l'engagement d'après Newmann (1992), en tant qu'un investissement et effort d'apprentissage, compréhension ou maîtrise des connaissances, capacités, etc. Celui-ci met en évidence également le désengagement, identifié par un manque d'intérêt ou une participation superficielle.

| | -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|---|
| **Le conflit interpersonnel** | Est la source des conflits interpersonnels dans le groupe. | Ignore les conflits interpersonnels et ne tente pas de les résoudre. | Tente de résoudre des conflits mais avec difficulté. | Tente d'apaiser les conflits interpersonnels et réussit à faire revenir le groupe au travail. | Encourage la diversité des points de vue et réussi à résoudre les conflits au sein du groupe. |
| **Les besoins émotionnels** | Ne reconnaît pas les émotions des autres. | Reconnaît les émotions mais ne les voit pas comme étant valable ou n'y répond pas du tout. | Reconnaît les émotions des autres mais la réponse est brève. | Reconnaît les émotions des autres et répond d'une façon adaptée. Reconnaît les bonnes idées et encourage les autres. | Remercie ses partenaires pour leurs idées. Identifie les besoins émotionnels des autres et répond d'une façon adaptée. Encourage les individus et le groupe. |
| **Le partage du temps de parole** | Coupe la parole des autres. | Coupe la parole des autres mais se rends compte / demande pardon mais continue de parler | Coupe la parole des autres mais se rends compte / demande pardon et laisse la personne finir | Ne coupe pas la parole des autres | Ne coupe pas la parole des autres et propose une stratégie pour diviser le temps de parole de façon juste. |

**Tableau du résumé 1 : Indicateurs pour l'intelligence sociale (Tucker et al., 2018)**

Par exemple, l'intelligence sociale (le savoir agir pour reconnaître et répondre aux besoins émotionnels des collègues) a été séparé pour des indicateurs du conflit interpersonnel, les besoins émotionnels et le partage du temps de parole (Tableau du résumé 1). Pour plus de détails sur les indicateurs, voir chapitre 6.

Cette grille a certaines limitations. C'est le résultat d'une réflexion *a priori* sur les compétences collaboratives, combinés avec des observations avec des élèves ingénieurs, lycéens et collégiens. Malgré cela, il est important de reconnaître que cette grille n'est ni exhaustive, ni parfaite, pour rendre compte d'une notion de compétence dont nous avons vu qu'elle n'était pas stabilisée. Dans l'avenir, nous espérons continuer à raffiner notre compréhension des compétences collaboratives et apporter des éléments de réponses sur comment nous pouvons accéder à ce que veut dire concrètement être compétent en collaboration.

Par ailleurs, l'application de cette grille à la réalité reste très subjective, c'est-à-dire qu'il est soumis au choix des codeurs. Nous avons tenté d'y remédier en procédant à un double codage. Nous n'avons pas défini complètement ce que le cas idéal ou le pire peut être dans notre grille. Les définitions de la compétence incluent la notion de la situation et du contexte pour une raison très importante. Les tentatives d'inclure toutes les possibilités n'est pas faisable (ou au moins certainement pas dans le contexte de notre projet). Nous croyons que le modèle $CO^2$ peut être encore développé à travers la réflexion et l'observation, ou au moins adapté à la situation. Ainsi, nous pensons à cette grille comme étant flexible et un travail en cours, plutôt qu'exhaustive et finalisé.

### Les espaces physiques-numériques de travail

Quand nous parlons des artefacts et des instruments, il y a un élément souvent sous-entendu : que l'artefact a une nature matérielle, qui prend de l'espace. Quand nous parlons de la technologie, il y a également un élément numérique à prendre en compte. Un espace physique-numérique s'oppose à l'espace numérique dans le sens courant, telle qu'une page de web ou un cours Moodle. Dans notre cas, nous travaillons avec des espaces assez spécifique, constitué de tables et tableaux équipés d'un logiciel (voir collecticiel) qui impose ses propres affordances. Nous proposons, alors, de faciliter notre discussion sur ces espaces avec une typologie *a priori* d'après notre lecture de la littérature existante.

Nous souhaitons ici de distinguer deux dimensions qui sont parfois amalgamées : d'une part un outil ou un support peut être *individuel*, au sens où seule une personne peut écrire dessus ou bien ce même outil ou support peut être partagé, *collectif*, permettant à plusieurs personnes d'interagir simultanément avec ou dessus. D'autre part le résultat de l'activité et les informations produites ou consultées peuvent être *privées*, visibles uniquement par le propriétaire ou *public*, visibles par tous les participants. Cherchant à questionner la manière dont les espaces physiques-numériques influencent l'implication des participants dans la collaboration, nous croisons donc les questions des caractères publics et privés avec les caractères individuels et collectifs des espaces. Dans cette perspective et dans un contexte de travail collaboratif en présentiel, nous identifions quatre types d'espace de travail qui se situent dans le plan défini par deux axes : l'axe individuel – collectif et l'axe public – privé.

- L'axe individuel – collectif fait référence au nombre d'individus qui peuvent interagir dans l'espace donné. Par exemple, des smartphones, tablettes ou ordinateurs sont plutôt des espaces destinés aux activités individuelles alors que les tables ou tableaux de grande dimension équipés de logiciels multi-utilisateurs sont plutôt destinés à des activités collectives.
- L'axe public – privé décrit le nombre d'utilisateurs qui peuvent voir l'activité. Les

espaces privés sont lisibles ou visibles par une seule personne alors que les espaces publics sont lisibles ou visibles par tous les acteurs présents dans le lieu.

Pour notre recherche, nous faisons l'hypothèse qu'un engagement positif dans la collaboration suppose un équilibre entre ces différentes dimensions. En d'autres termes, c'est la possibilité de disposer et d'articuler des espaces plus personnels avec d'autres espaces plus collectifs qui permet une collaboration réussie (Figure du résumé 6).

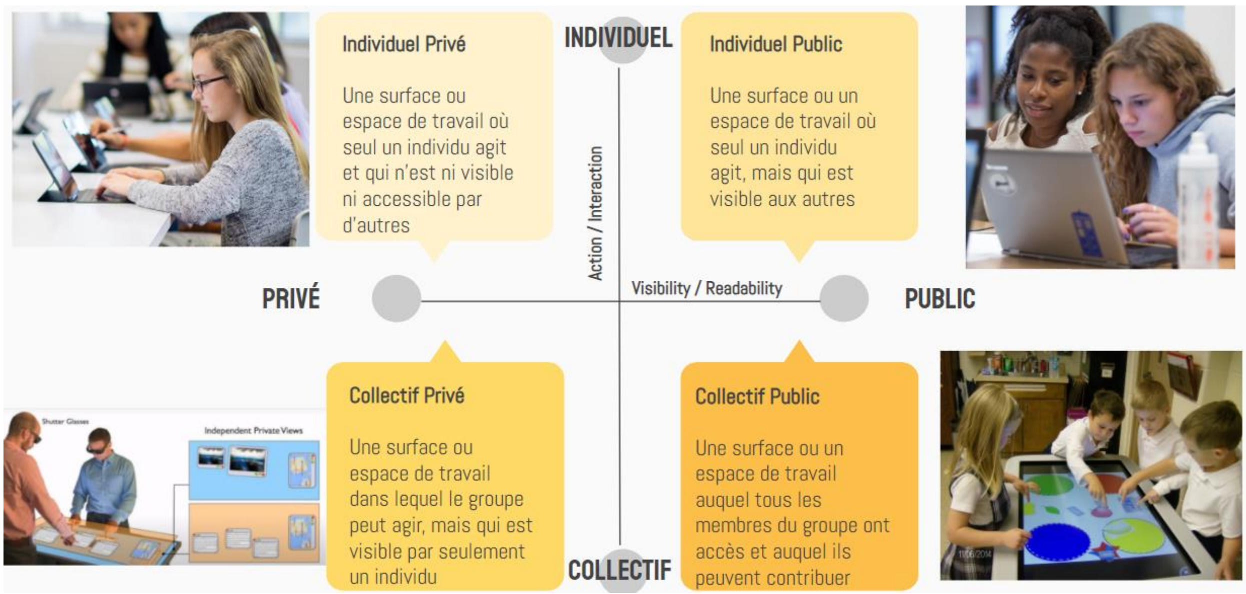



**Figure du résumé 6 : espaces-physiques numériques de travail**

Ces espaces évoluent de manière dynamique et leurs spécificités sont basées sur plusieurs facteurs tels que les paramètres de partage (i.e. un fichier dans Google Drive partagé avec tout ou partie du groupe), une juxtaposition entre l'usage attendu par les designers et l'usage actuel de l'espace de travail, ou les dynamiques sociales qui peuvent influencer l'utilisation (Tucker et al., 2019).

### *Outils, questions et méthodologie*

Les systèmes qui sont utilisés pour notre recherche portaient le nom Tatin (TAble Tactile INteractive) (UTC, 2018), aujourd'hui appelés la plateforme *Halle Numérique*. Développés à l'université de technologie de Compiègne (UTC), ces dispositifs matériels et logiciels ont pour objectif de faciliter la collaboration pendant les séances de conception préliminaires pour les élèves ingénieurs.

Cette plateforme est constituée de cinq espaces numériques composés chacun d'une grande table et d'un tableau tactile. Chacune de ces surfaces horizontales et verticales est équipée de la suite logicielle Ubikey® Office qui permet l'interaction simultanée de plusieurs personnes sur une même surface.

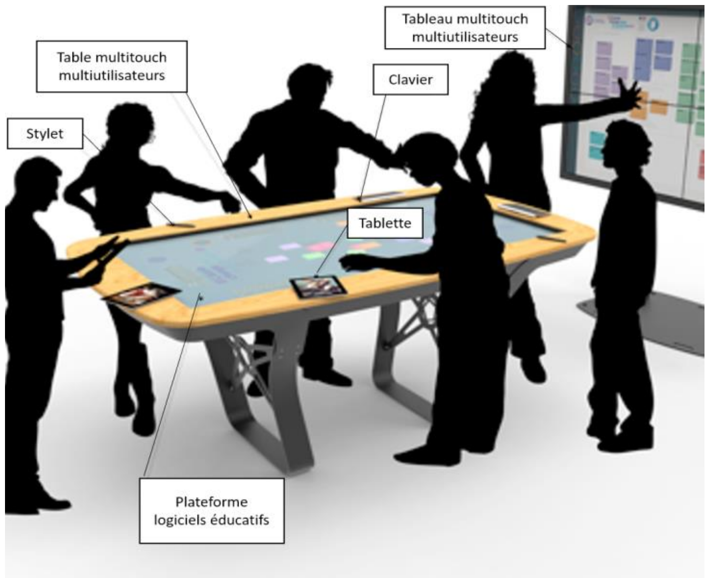



**Figure du résumé 7 : La plateforme de la halle numérique**

Les tables, surfaces horizontales, ont un écran de résolution UHD (3840 x 2160) de 84 pouces (1860 mm x 1046 mm), ce qui permet un espace individuel confortable pour chaque utilisateur. Cela rend possible la réflexion individuelle, la recherche et la prise de notes avec un clavier tactile dans l'espace commun. Ces surfaces horizontales permettent le travail en face à face, avec des croisements perceptifs (communication non verbale, vision périphérique). C'est le lieu privilégié de la production d'information, du foisonnement et de la divergence (Jones et al., 2011). Les tableaux, surfaces verticales, disposent d'un écran UHD (3840 x 2160) de 86 pouces (2042 mm X 1151 mm), ce qui permet une mise en commun et une organisation des informations produites par les participants. Ces surfaces sont le lieu privilégié de la structuration des informations, de la convergence, de la prise de décision (Jones et al., 2011). Ces dispositifs sont reliés au réseau et le logiciel permet la production et un échange fluide des données entre table et tableau ainsi qu'avec tout type de terminal (ordinateur, tablette, Smartphone) disposant d'une connexion réseau et d'un navigateur internet (Guerra et al., 2017).

## Question de recherche et méthodologie

Bien que l'on sache que les artefacts influencent la nature des activités collectives (Gracia-Moreno, 2017; Lenay et al., 2014; Rabardel, 1995), nous en savon encore peu sur l'articulation entre les espaces physique-numérique de travail, l'impact sur les activités des élèves et l'apprentissage de la collaboration lors d'un travail de groupe. Notre objectif est d'analyser l'influence de ces espaces (numériques, tactiles, multi-utilisateur) sur comment les élèves travaillent ensemble et les compétences qu'ils mobilisent. Ainsi, on se pose la question suivante : Comment est-ce que les espaces physiques-numériques de travail influencent-ils les interactions au sein des groupes d'élèves et par conséquence le développement des compétences collaboratives ?

Cette question a donné suite à deux hypothèses :

H1 : Les caractéristiques des espaces de travail ont une influence sur les processus collaboratifs mise en œuvre par les étudiants lors d'une activité collective.

H2 : Les caractéristiques des espaces de travail ont une influence sur les compétences développées par les élèves.

### *Une approche mixte*

Afin de répondre à cette question et d'apporter des éléments de réponses, nous mobilisons le modèle PAW de Samurçay et Rabardel (2004) pour bien distinguer ce qui nous intéresse dans cette présente recherche. Dans la figure suivante, tous les éléments en bleu, tel que les connaissances transmises, la nature de la tâche, le contexte, ... ne font pas l'objet de notre étude. Ce qui nous intéresse est surtout la relation entre l'artefact (en or dans la figure), voir les espaces physiques-numériques de travail, et le sujet (en blanc) – ses activités, expériences, … et éventuellement le développement et la mobilisation des compétences au sein du collectif.

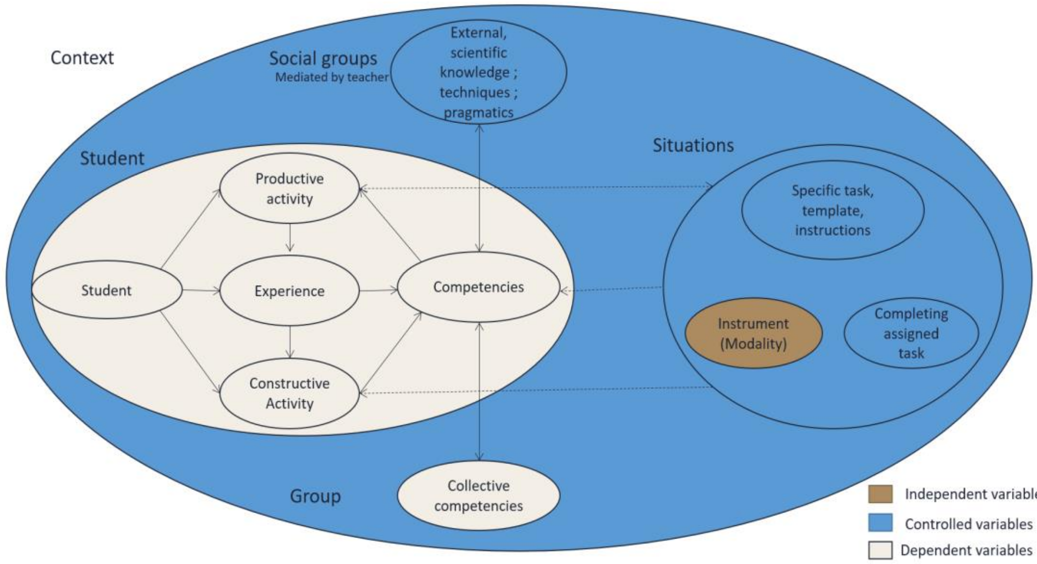



**Figure du résumé 8 : Le cadre conceptuel à travers PAW (Samurçay & Rabardel, 2004)**

Lors de la conception de notre protocole de recherche, nous avons dû faire face à plusieurs défis. Notamment, l'écosystème dans lequel nous avons mené notre étude. Il aurait été possible de faire des séances expérimentales en dehors des cours traditionnel. Cependant, nous avons souhaité utiliser des scenarios authentiques afin de voir les tensions qui peuvent exister en intégrant de telles technologies dans la classe.

Nous avons décidé que des données quantitatives peuvent nous donner une vision plus objective de l'impact que ces artefacts ont sur la collaboration. Cependant, les données quantitatives ne nous permettent pas d'accéder aux éléments encore plus intéressants. Ainsi, nous avons adopté une approche mixte en mobilisant les modèles CIAO et $CO^2$ pour les analyses quantitatives mais également les observations ethnographiques pour mieux comprendre le contexte, condition, préférences et raisonnements qui poussent les actions et interactions au sein du groupe.

***Le protocole de recherche***

Suivant l'approche Design Research Methodology (Blessing & Chakrabarti, 2009), notre recherche a passé par trois phases :

- une phase de clarification de recherche,
- une phase d'analyses empirique (étude descriptive)
- et une phase expérimentale (étude prescriptive).

Finalement, les données ont été analysées pour en tirer nos conclusions. Dans ce résumé long, nous allons nous focaliser sur le protocole de notre étude prescriptive, d'où vient la plupart de nos résultats.

Afin de comprendre comment les différents espaces de travail physiques-numériques influencent la collaboration, la recherche a été faite en utilisant trois modalités d'espace de travail. Chacune de ces modalités utilise la plateforme de la halle numérique, mais avec des ajustements. La figure du résumé 9 montre les trois modalités étudiées.

- Dans la première modalité, il y a une table (espace individuel public) et un tableau (espace collectif public) tels que décrits ci-dessus.
- La deuxième modalité utilise des tablettes mono-utilisateur (espace individuel privé) et un tableau multiutilisateur.
- La troisième modalité n'utilise que le tableau multiutilisateur.

Les tables numériques pour les modalités 2 et 3 ont été désactivées et l'écran a été recouvert par des panneaux de bois afin de permettre leur utilisation comme des tables standards. Avant les trois séances avec les modalités expérimentales, les étudiants ont réalisé une tâche semblable sans l'utilisation des supports numériques. Ils avaient accès à un tableau blanc avec feutres, des notes repositionnables et des stylos. Nous avons demandé aux participants de ne pas utiliser leurs appareils personnels lors de l'ensemble de ces séances.

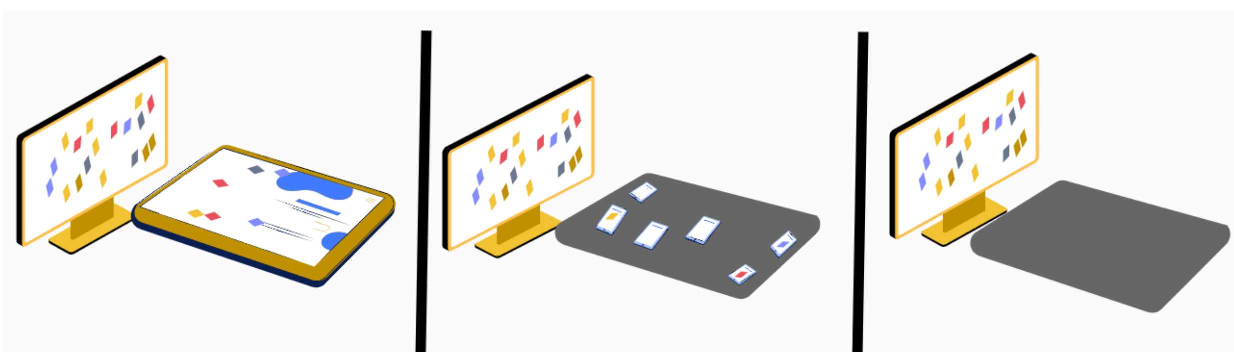


**Figure du résumé 9 : Les espaces de travail physiques numériques (de gauche à droite) : Table & Tableau, Tablettes & Tableau et Tableau**

Les données proviennent de quatre séances différentes. Chacune avait une durée d'environ 1.5 heures. Les groupes n'ont pas changé de modalité entre les séances B, C ou D. Les quatre cas d'étude analysés sont les suivants :

A. Remise en cause d'un sac de farine : Les étudiants doivent identifier et analyser deux situations de vie d'un sac de farine et proposer des solutions alternatives.

C’est une séance non instrumentée afin d’établir un point de comparaison.

B. L’analyse causale de la fonction principale d’un grattoir à glace : Les étudiants doivent analyser une situation où un grattoir à glace est utilisé, comprendre les causes qui nécessitent une telle fonction et les conséquences attendues. À partir de cette analyse, ils doivent proposer des solutions alternatives.

C. Le cas du cartable : Les étudiants doivent répondre à une demande d’un client pour réduire le poids d’un cartable d’élève au primaire sans utiliser de solutions numériques. Pour réaliser cette activité, il faut d’abord déterminer quel outil utiliser, analyser les fonctions des différents composants du cartable et rechercher des solutions, notamment en trouvant des synergies fonctionnelles.

D. Recrutement à partir de CV et lettre de motivation : Les étudiants examinent une demande d’un recruteur insatisfait de ces supports traditionnels. Ils ont une liste de questions auxquelles il faut répondre. Les outils à utiliser sont parfois proposés avec la question, mais il faut aussi parfois choisir un outil d’analyse en groupe avant de l’utiliser. Cette activité nécessite l’utilisation de plusieurs outils d’analyse fonctionnelle afin de préparer les étudiants à un examen.

À la fin de chaque cas, les étudiants présentaient leur production finale au professeur pour évaluation. Le travail a été enregistré (vidéo et audio) et observé par un chercheur.

Pour résumer, nous analysons le travail de neuf groupes d’élèves. Chacun travaille selon une des trois modalités étudiées (trois groupes par modalité) lors de trois séances différentes, ainsi qu’une séance non-instrumentée par le dispositif numérique. Chaque groupe a utilisé la même modalité pour les trois séances instrumentées.

### *L’influence des espaces physiques-numériques sur la collaboration*

#### L’usage des espaces physiques-numériques pendant le travail globalement collaboratif

Nous avons classé les résultats en trois types de travail globalement collaboratif. Un premier type que nous qualifions de travail ‘plus collaboratif’, un second que nous appelons travail ‘plus coopératif’ et un troisième que nous nommons ‘travail équilibré’. Cette typologie a été réalisée à la suite d’une comparaison entre les valeurs brutes des différents modes d’interactions produites lors de l’analyse avec le CIAO. Par exemple, le travail plus collaboratif correspond à un groupe qui aura passé beaucoup plus de temps à travailler en mode collaboratif qu'en mode coopératif et le travail équilibré a des valeurs égales.

### *Séance non-instrumentée*

La séance non-instrumenté a permis d'analyser les neuf groupes d'étudiants travaillant sur la même activité (A). Les modes d'interactions principaux ont varié entre les différents groupes. Certains avaient tendance à coopérer et d'autres ont été classé en équilibré ou collaboratif. Dans chaque groupe, deux à trois élèves étaient responsables de la production de la majorité des idées, avec un temps de partage de parole réduit comparé aux modalités expérimentales. Ces résultats confirment ceux de Jones *et al.*, (2011). Dans les groupes plus coopératifs, les idées ont été produites et discutées fréquemment. Les groupes plus collaboratifs avaient tendance à produire les idées et puis de les co-élaborer, plutôt que de rentrer dans le débat. L'utilisation de l'espace de travail sur le tableau blanc que possédait chaque groupe est très vite devenue un problème, beaucoup d'étudiants s'inquiétant de la perte de certaines parties du travail au fur et à mesure de l'avancement et de l'effacement inévitable des travaux précédents. De ce fait, beaucoup plus de temps a été dédié à la prise des notes au détriment d'activités réalisées en commun.

### *Table & Tableau*

Pour les trois activités, la modalité table et tableau a démontré des niveaux de coopération élevés et a donc été identifiée comme le mode de travail le plus coopératif, par opposition à une mobilisation plus importante de la collaboration que nous avons vu avec le tableau seul, par exemple. La majorité de la production a été faite lors de travail individuel, suivi par des phases de communication pendant lesquels les membres du groupe présentaient et expliquaient les idées qu'ils avaient produites. Ces modes de travail préliminaires ont conduit à des phases de travail coopératif, marquées par la négociation, la confrontation des idées et la modification éventuelle des productions individuelles avec un effort pour réaliser une production commune cohérente.

La table a permis aux élèves de réfléchir sur l'objet de leur activité, rechercher de l'information et extérioriser leurs pensées en forme de post-its, croquis ou par des images trouvées lors de leur recherches en lignes. Dans la figure du résumé 10, par exemple, lors d'une discussion sur les changements potentiels des parebrises pour décourager la formation du givre, un étudiant mobilise un schème d'usage (Rabardel, 1995) où il exemplifie son idée par l'utilisation d'une image trouvé lors d'une recherche. Il trouve une image d'une voiture Formule 1, puis il écrit son idée sur un post-it concernant l'utilisation des casques plutôt que des parebrises comme une solution possible. Celui-ci est un exemple d'un schème d'usage (au sens de Rabardel, 1995) des post-its en tant que moyen d'extériorisation des pensées ou même un outil pour se souvenir jusqu'à que l'idée soit pertinente à être présentée au groupe.

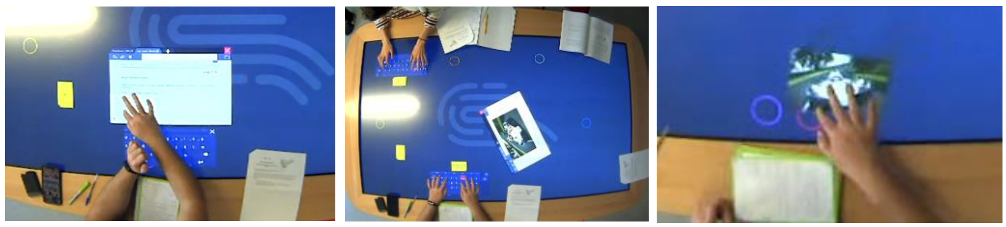


**Figure du résumé 10 : À gauche : L'étudiant fait une recherche en ligne par navigateur ; Au centre : deux étudiants écrivent leurs idées sur la table, l'image recherché est visible dans le navigateur ; À droite : l'étudiant transfert l'image dans un puits pour l'envoyer au tableau.**

Le tableau, cependant, a été utilisé comme une façon de regarder ce qui a été écrit ou produit individuellement. Souvent un des élèves change l'organisation de ces différentes idées, extériorisant leur compréhension de la situation. Cette action donne au groupe un aperçu du raisonnement de cet individu, permets aux autres d'intervenir quand ils se rendent compte d'une divergence et de rentrer dans la coopération.

#### ***Tablettes & Tableau***

La modalité tablettes et tableau a obtenu des valeurs plus équilibrées entre les temps de collaboration et de coopération. L'activité elle-même ressemble beaucoup à ce que nous avons vu avec la modalité table et tableau, mais le travail a été mieux coordonné de sorte que les groupes passaient très vite à des phases de collaboration. Nous constatons ici l'importance des phases de travail individuel, qui permettent aux participants de structurer et d'extérioriser leur pensée à l'aide de notes, schéma et images.

Les étudiants écrivaient leurs idées sur leurs tablettes, les envoyaient sur le tableau où elles étaient discutées et mises en cohérence (coopération). Cependant, dans cette modalité de travail, au lieu de retourner « à leur place » autour de la table, les participants avaient tendance à rester tous debout face au tableau où ils pouvaient développer et formaliser de nouvelles idées ensemble. Les tablettes ont été utilisées pour écrire les idées produites collectivement depuis leur position debout. Les tablettes ont permis à chacun des participants d'avoir un espace de travail individuel privé de production, qui est devenu un espace de production individuel au service du collectif.

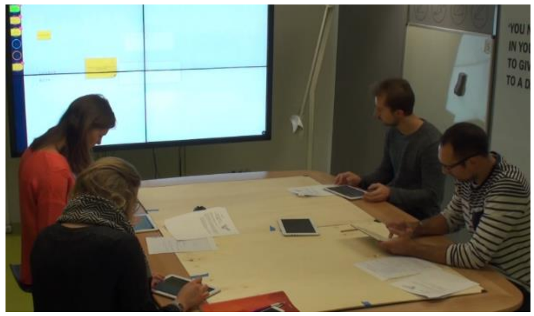


**Figure du résumé 11 : Les étudiants écrivent sur leurs tablettes en début de séance**

***Tableau seul***

La modalité du tableau seul comporte un espace collectif public. Elle a été évaluée comme plus collaborative. Même si le tableau permet théoriquement à plusieurs personnes d'interagir simultanément, la configuration spatiale et sa taille fait qu'en réalité au maximum trois personnes saisissaient des informations de manière simultanée.  De plus la saisie tactile en vertical semble plus complexe ou moins ergonomique que sur une surface horizontale.

Par conséquent, les idées étaient d'abord discutées oralement avant d'être formalisées principalement sous la forme de texte alors que pour les deux autres modalités, les participants avaient des espaces de saisie individuels. Les items introduits dans l'espace collectif public ont donc été saisis par un individu qui se faisait porte-parole d'une production résultant de dialogues impliquant différents membres du groupe (Figure du résumé 12).

**Figure du résumé 12 : Un étudiant écrit les idées du groupe au tableau**

Malgré la taille du tableau, il est difficile d’aligner tout le groupe devant, les participants s’organisant généralement sur deux rangées. Cette organisation spatiale limite de fait la possibilité de contribution simultanée par tous les membres du groupe alors que c’est courant pour les deux autres modalités. Mais c’est aussi cette configuration qui a conduit à une augmentation du temps de collaboration, principalement basée sur des discussions orales et non sur la confrontation d’états intermédiaires de représentation / productions réalisée par les participants lors de travaux individuels.

Enfin, la présence de plusieurs personnes au tableau bloque la vue des autres membres positionnés en arrière. Il est donc nécessaire pour les participants de se déplacer afin de pouvoir lire ce qui est écrit au tableau. Pour les deux autres modalités, nous observons que la plupart du temps une seule personne se déplaçait au tableau à tour de rôle pour positionner les états intermédiaires produits dans les espaces individuels et transférés par les puits.

### Un espace individuel permet une meilleure collaboration

Il est clair que les cas et les préférences de travail d’un groupe ont un impact sur l’utilisation de ces espaces physiques-numériques. En revanche, l’espace et ses affordances ont également un impact sur la façon dont les groupes travaillent ensemble. La présence d’un espace individuel semble avoir l’impact le plus important sur les façons dont les élèves travaillent ensemble, leur créativité et l’engagement avec la tâche.

L’utilisation d’un espace individuel donne à chaque étudiant l’opportunité de réfléchir et extérioriser ses pensées. Gracia-Moreno (2017) avait noté la même chose lors de sa recherche. Quand un étudiant n'a aucun recours à un espace de travail individuel, comme nous l'avons vu avec le tableau seul, ils sont moins poussés à coopérer – c'est à dire de rentrer dans le débat, la négotiation et le conflit épistimique (Doise & Mugny, 1981). Cependant, les groupes qui disposent d'un espace individuel ont pris le temps de réfléchir et noter leurs idées avant d'en discuter avec le groupe. Cela était évident dans les modes d'interactions mobilisés par les groupes utilisant les modalitiés table-tableau et tablettes-tableau.

**La fluidité de mouvement est un atout pour la collaboration**

Les groupes qui ont été jugés les plus efficaces par les enseignants à la fin de chaque cas d'étude étaient ceux utilisant la modalité tablettes-tableau. Cependant, il faut prendre en compte que celui-ci ne représente pas qu'un espace individuel privé, mais aussi mobile. Cela permettait aux élèves d'aller d'un emplacement « shoulder-to-shoulder » (un à côté de l'autre) à un emplacement « around-the-table » (autour de la table) facilement. Quand nous regardons aussi les interactions observées lors de l'étude descriptive, nous avons vu des comportements différents pour les ordinateurs portables. Les étudiants utilisant ceux-ci avaient tendance à rester assis et à passer davantage de temps à regarder leur écran. Bien qu'un ordinateur portable soit considéré comme portable, par nature, il est typiquement placé sur la table et bouge très peu.

***L'influence des espaces physiques-numérique de travail sur l'engagement et le développement des compétences collaboratives***

En revenant à la deuxième partie de notre question de recherche – quelle influence ont les espaces physiques-numériques de travail sur les compétences à collaborer ? – nous avons appliqué $CO^2$ pour analyser les séances de travail pour chacun de groupe d'élèves.

Nous concluons que les espaces physiques-numérique de travail peuvent avoir une influence sur les compétences développées par les étudiants. Bien que d'avantage de données sur une période plus importante seraient nécessaires pour confirmer le développement ou non des compétences collaboratives, nous voyons un impact important sur l'engagement et le niveau d'activation des différents indicateurs du $CO^2$ lors de l'utilisation des modalités étudiés. Comme nous l'avons vu pour la mise en œuvre des modes d'interaction quand nous avons regardé l'activité des étudiants utilisant les modalités intégrant un espace individuel avec un espace collectif, les niveaux d'engagement et d'impact positif sur la collaboration ont été plus important systématiquement. Quand les étudiants n'avaient aucun recours à un espace individuel, nous avons vu plus de désengagement et moins d'impact positif sur le travail du groupe. Ainsi, nous considérons qu'il est important de prendre en compte un accès à un espace individuel articulé à un espace collectif lors de la conception des espaces de travail collaboratif.

***Conclusion***

Dans notre conclusion nous souhaitons aborder deux éléments principaux : les limitations et les contributions de cette recherche.

**Limitations de la recherche**

Lors de notre recherche nous avons identifié quelques limitations et obstacles que nous jugeons utiles à connaitre pour mieux comprendre ses implications. Nous identifions plusieurs limitations, dont deux qui nous semble pertinentes à discuter en détail. Ces limitations inclus : la population utilisée versus les attentes pour la recherche, des pertes de données à la suite de problèmes techniques, des absences des participants et certains choix méthodologiques.

Nous notons une tension entre le désir de comprendre comment les outils techno-pédagogiques que nous étudions peuvent être utilisé en milieu scolaire, surtout au collège et lycée, et la population centrale à la recherche que nous avons exposée ici. Cela est dû notamment à la nature de la technologie que nous utilisons, qui est actuellement peut mobile et pas disponible dans les établissements scolaires. Bien que nous ayons pu incorporer nos observations avec des groupes de collégiens et lycéens pour les modèles CIAO et $CO^2$, nous nous sommes rendu compte que les données de ces deux groupes n'étaient pas suffisantes en termes de quantité et de structure (à cause de la nature des projets adaptés au groupes, leurs niveaux et les enseignants participants) pour répondre à nos questions dans le cadre d'une thèse doctorale. Ainsi, nous avons mobilisé en parallèle les élèves ingénieurs. Entre ces différentes populations, nous avons un corpus de données beaucoup plus important que nous avons discuté dans cette thèse. Malheureusement ce corpus n'est pas complet, par rapport à ce qui avait été prévu, à cause de l'apparition du SARS-CoV-2 dans le monde, ce qui a imposé la fermeture des établissements scolaires en France. Malgré cela, nous avons utilisé environ 55 heures de séances enregistrées avec les élèves ingénieurs. En revanche, la possibilité de généraliser sur les implications pour les lycées et collèges est limité. Dans le contexte de cette thèse, cela n'est pas forcément un problème, car il nous a permis aussi de mieux focaliser notre étude.

Finalement, nous ressentons un manque dans les données sur les compétences : la réflexion des élèves sur leur expérience et leur développement des compétences. Dans l'avenir, nous croyons important d'incorporer des entretiens. Cela permettra aux chercheurs d'avoir plus de contexte et aux étudiants de clarifier leurs méthodes de travail et interpréter leurs propres actions. Nous croyons que l'utilisation des entretiens peut faciliter notre compréhension aussi en termes de l'articulation entre les compétences individuelles et collectives.

### Contributions de la recherche

A travers notre recherche nous considérons avoir contribué des éléments de réponses sur trois questions :

- Comment pouvons-nous prendre en compte la collaboration ainsi que la coopération lors d'un travail collectif ?
- Comment pouvons-nous parler de l'articulation entre l'espace physique et numérique ?
- Comment pouvons-nous évaluer le potentiel pour un artefact d'influencer le développement d'une compétence, notamment les compétences à collaborer ?

#### *Comment pouvons-nous prendre en compte la collaboration ainsi que la coopération lors d'un travail collectif ?*

Il y a un consensus dans la littérature d'aujourd'hui que la différence entre la coopération et la collaboration se retrouve dans la division du travail entre acteurs (Baker, 2015; Baudrit, 2007a; Dillenbourg, 1999). Mais sont-ils nécessairement en tension ? Une séance de travail est-elle soit coopérative, soit collaborative ? Quand le travail est divisé et les élèves font leur travail – ils ne font plus de la coopération, ni de la collaboration – ils travaillent individuellement. Alors, qu'est-ce qu'il y a dans ce processus qui oblige les élèves de « travailler » ou « opérer » ensemble comme le terme « co – opérer » le suggère ? Plutôt que de mettre l'accent sur la division du travail et le travail individuel, peut-être devons-nous le mettre sur ce qui suit : la mise en commun et l'alignement qui est nécessaire au sein du groupe, non seulement pour la coordination mais pour repérer les divergences qui auraient pu apparaitre lors de ce travail individuel. Quand on le regarde de cette façon, la notion des interactions collaboratives prend une tournure différente. Si la coopération décrit la compréhension construite à partir de la divergence, alors peut-être la collaboration peut représenter ce qui est construit de la convergence.

Le *travail globalement collaboratif* utilise cette idée pour articuler les différents processus et modes d'interactions qui sont présents quand les personnes travaillent et apprennent ensemble. La collaboration, la coopération, la coordination, la communication et le travail individuel sert chacun à des buts différents et complémentaires au sein du groupe. Le *Collaborative Interaction Analysis mOdel* (CIAO), est un outil qui aide à l'identification de ces processus de travail globalement collaboratif en démontrant les chaines d'action/interaction potentielles (Tucker et al., 2019, 2018).

***Comment pouvons-nous parler de l'articulation entre l'espace physique et numérique ?***

L'espace est une notion complexe qui nécessite une explication pour être compris. Ce mot peut faire référence à des espaces physiques, des concepts, de l'architecture, le ciel, etc. Lefebvre (1974) a proposé trois types d'espace : physique, mental et social. Cependant, au moment qu'il l'écrivait, la notion de l'espace numérique était dans son enfance. Bien qu'on voie comment notre recherche touche sur les trois niveaux qu'il propose, il y a une articulation très spécifique entre les espaces physiques et les espaces numériques que nous croyons mérite d'être considéré. Les espaces numériques, au moins aujourd'hui, nécessite un outil physique pour faciliter un accès, que cela soit sous la forme d'une table, un ordinateur, une tablette, etc. Il y a une interface physique, mais celle-ci peut être gouverné par des règles physiques ou sociaux. De la même façon, dans un espace numérique, ce qu'on peut faire peut être contrôlé par certaines règles, typiquement lié aux permissions d'accéder (voir) à ou de modifier (agir) des objets numériques. Notre typologie des espaces physiques-numériques de travail a été réalisé à fin d'articuler les formes qui peuvent prendre ces espaces qui ont à la fois une composante physique et numérique.

***Comment pouvons-nous évaluer le potentiel pour un artefact d'influencer le développement d'une compétence, notamment les compétences à collaborer ?***

Une des questions majeures que nous avons essayé de traiter pendant notre étude concerne les moyens d'évaluer le potentiel pour un artefact d'influencer (positivement ou négativement) le développement des compétences collaboratives. Cela amène plusieurs autres questions concernant la nature des compétences, leur développement, transférabilité, évaluation, etc. Bien que nous croyions avoir pu proposer quelques éléments de réponse, nous nous retrouvons avec encore plus de questions. Dans la littérature CSCL (*Computer Supported Collaborative Learning*), peu d'attention a été apporté à la compréhension du développement des capacités des élèves à travailler ensemble – focalisant plus sur les outils ou scenarios qui mène à une collaboration efficace. En revanche, c'est par l'expérience que mobilise ces outils que nous pouvons nous rendre compte des changements sur les processus collaboratifs mobilisé par les élèves, non seulement quand ils utilisent des outils, mais quand ils ne l'utilisent pas ou quand ils choisissent comment collaborer dans l'avenir.

Dans la littérature sur les compétences, nous trouvons qu'elles sont généralement évaluées de façon individuelle. Il y a plusieurs façons faire : les évaluations écrites, l'auto-évaluation, l'élaboration d'un portfolio, l'évaluation de la performance, etc. Quand nous parlons de la collaboration en tant que compétence, elle est nécessairement articulée à d'autres individus. Alors, est-il pertinent d'évaluer un individu pour une compétence collective ? Pourquoi ou pourquoi pas ? Comment le faire ? Quel méthodologie et outils mobiliser ? Nous croyons qu'établir une grille qui identifie si et à quel point les élèves s'engagent dans certains comportements est un bon point de départ, mais qu'il est pertinent de faire l'évaluation sur l'impact de ces actions sur le groupe. Cela nous a amené à créer notre cadre $CO^2$. Bien que ce soit un cadre d'analyse imparfait, c'est un point de départ que nous pouvons mobiliser pour mesurer l'activation des compétences collaboratives à travers l'engagement dans l'activité chez l'individu et le groupe.

Cependant, il y a toujours des problématiques à traiter quant à l'articulation de l'individu et du groupe. Peut-être qu'on ne voit pas que les effets d'une cognition distribuée

(Hutchins, 2000), mais d'une compétence distribuée. Cela implique que l'évaluation d'un individu n'est pas utile, mais ce que peut l'être est de comprendre l'articulation entre l'individu et sa capacité au sein du groupe de partager la charge de la compétence. En revanche, cela veut dire mobiliser ses expériences antérieures pour mieux participer dans le présent, rendant les compétences individuelles importantes de nouveau.

**TABLE OF CONTENT**

**TABLE OF CHARTS**

**TABLE OF FIGURES**

# INTRODUCTION



The capacity of an individual to work collaboratively with others is at the heart of current institutional concerns, marked particularly by discourse about how collaborative practices can be facilitated by adapted technologies. In fact, the capacity to collaborate is demanded more frequently in society, in the workplace and even in universities and schools. These transformations have put questions about collaboration, as methods of working and learning, at the forefront of societal interests, notably due to the promises it carries for increased efficiency and creativity (Sanojca, 2018).

Despite this and efforts by researchers over the last thirty years, collaboration is still a notion that is complex, unclear, and polysemic. Even with a good deal of work around technologies designed to support collaborative work and collaborative learning, learning *to* collaborate and the development of collaborative competencies have been largely disregarded; even fewer researchers have tried to understand how technology may influence the development of collaboration skills. It is here that we find our subject: the interdependence between workspaces, the emergence of collaboration, and the development of collaborative competencies.

This research goal is complex for its content and its multiple facets. To begin, while the notions of competency and transversal competencies have long existed at various levels of education (Tardif & Dubois, 2013) they remain more or less entrenched in professional contexts. The situated nature of competencies (linked to their professional context and the situations in which they are activated) has left the notion of transversal competencies, those which apply to multiple situations and contexts (where collaboration is typically classed), in limbo (Tardif, 2013). Questions about their nature, existence, and evaluation have few answers. Models for the development and analysis of competencies exist notably in professional didactics, forcing the creation of new models or a bridge between non-professional education (primary, secondary) and professional development. Secondly, because of its polysemic nature, the emergence of collaboration is difficult to identify, and the evaluation of its efficacy even more so. Lastly, instruments used within an activity necessarily modify the way in which the activity is completed (Engestrom, 2014; Rabardel, 1995; Vygotsky, 1978), but understanding how these changes influence the development of a transversal skill is challenging. However, this triply situated project may permit us to better understand collaboration, the forms it can take, and open new paths to the development of artifacts which better support collaboration and the development of skills related to it.

## CRÉ@TION PROJECT AND THE *HALLE NUMÉRIQUE* PLATFORM

This dissertation is part of the Cré@tion Project, which is a partnership between the University of Lille (UL), the Université de Technologie de Compiègne (UTC) and the Académie d'Amiens (the board of education for the regions of Somme, Oise and Aisne, France). The project uses technology available at UTC in the *Halle Numérique* (Digital Hall) platform, a collection of technological devices consisting of tactile, multi-user tables and boards (described in greater detail in Chapter 2). The platform was developed as part of a series of research projects aimed at facilitating collaborative design processes for engineers. Our goal is to ascertain the role that such technology can play in the development of collaboration skills.

The *Halle Numérique* currently contains five cubicles with the system (Figure 1). The table surface is made up of an Ultra High Definition (UHD) screen, (3840x2160 pixels) at 84" (1860x1046 mm). The size allows for a comfortable space for each individual user at the table, making individual reflection, research and note taking with a virtual keyboard possible within a common space. While there is no software limitation to the number of keyboards that can be opened on the screen, designers indicate that the space is ideal for six adults. These spaces allow for face-to-face work, with perceptive crossing (non-verbal communication) and is used most frequently for the production of information, and the proliferation and divergence of ideas (Jones et al., 2012). The board also has an UHD screen (3840x2160 pixels) at 86" (2042x1151mm). According to previous research, the board space is most used as a space for convergence. It allows group members to have the same view of the information they have produced, facilitating decision making processes

(Jones et al., 2012; Rogers & Lindley, 2004).

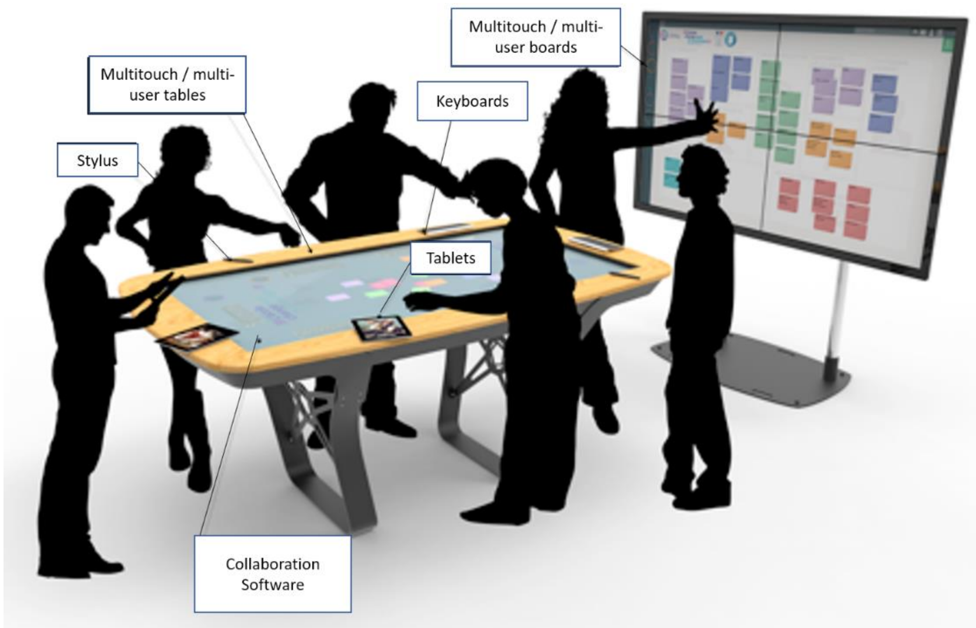



**Figure 1: The *Halle Numérique* Platform**

In addition to these two surfaces, any device with an internet connection and browser can connect to the session. While the possible interactions are fewer (limited to the contribution of new notes, modifying the color or form before being sent), these spaces permit participants to use their personal devices. Items such as tablets or smartphones also allow the user to move more freely around the space, while retaining the possibility to contribute.

UTC began using the *Halle Numérique* within a number of engineering courses, implementing problem-based case studies and project-pedagogy to encourage students to learn collaboratively. However, it was quickly noticed that students did not necessarily have the skills required to work collaboratively when they arrived, so teachers and researchers began to wonder about the development of those skills prior to and during collaborative-learning sessions. There was also an interest in the region for the use of this new technology as a potential tool for collaborative pedagogy, but also as a medium for the development of collaboration skills. However, with little known about these processes, more information was needed. As such, the Cré@tion project was put into place with two goals:

1. To understand how these devices impact the learning to collaborate
2. To evaluate whether or not this technology could potentially be introduced into

schools, keeping in mind issues related to implementation, impact on teacher activity, training, cost, infrastructure, etc.

From a design-based research perspective (Blessing & Chakrabarti, 2009; Sanchez & Monod-Ansaldi, 2015), the project sought to analyze the usage of these instruments (tactile tables and boards, adapted collaborative groupware, tablets, etc.) in a shared environment (co-located) and within a pedagogical context using case studies and projects in order to understand in what ways they could be used to encourage creativity, collective production and the development of agentivity of the users (Engeström, & Sannino, 2013; Engestrom, 2014).

This research was financed by the Académie d'Amiens, as part of the missions set out by the DNE (*Direction du numérique pour l'éducation*, a governmental body that is part of the ministry of education, whose mission is to support pedagogical innovation and technology uses in schools) and the "*numéri'lab*," a subdivision of the DNE focusing on the development of research in this domain.

## LEARNING TO COLLABORATE: AN ECONOMIC AND POLITICAL INJUNCTION – INTRODUCTION TO OUR RESEARCH QUESTION

In this section, we explain the socioeconomic and political context in which this research is situated. We will examine cultural changes, work-place changes, new political policies and finally we explore some of the technological changes in these environments relative to our study.

The MacArthur Foundation launched an initiative in 2006 with the aim of understanding "how digital technologies are changing the way young people learn, play, socialize, and participate in civic life" (Jenkins et al., 2009). Jenkins et al., have termed today's cultural space a "participatory culture." This refers to a culture with:

> *"relatively low barriers to artistic expression and civic engagement, strong support for creations and sharing one's creations, and some type of informal mentorship whereby what is known by the most experienced is passed along to novices. A participatory culture is also one in which members believe their contributions matter, and feel some degree of social connection to one another (at the least they care what other people*

*think about what they have created.)"*

This takes several forms including: participation in online communities; producing "new creative forms," such as digital sampling; collaborative problem-solving, defined as working in teams to complete tasks and develop knowledge; and circulations, shaping the flow of media. They go on to identify a number of skills related to this participatory culture, including distributed cognition, collective intelligence and networking (Jenkins et al., 2009). With today's technologies and platforms (YouTube, Facebook, Instagram, Twitter, blogs, podcasts, etc.) the barriers to contribute and be heard have been dropped, online communities are the "new normal" and the skills necessary to engage in them are not the same as the cultural skills which were necessary only 30 years ago.

Similar changes are occurring in the workplace, with some companies flattening (Rajan & Wulf, 2006) or decentralizing the decision making processes. For structures such as holacracies, this means that employees are expected to participate more, making the organization more democratic (Kumar S. & Mukherjee, 2018). Other organizations are moving towards management-by-project systems, but keeping hierarchy in place (Gareis, 1989). These changes in companies reflect the changing technology and culture, as those who have grown up in a "participatory culture" have been joining the workforce. These new systems of working are calling on employees to be autonomous in their own work, but they are also considered to be "collaborative," asking employees to work together to solve complex problems and create innovative solutions. While technical skills are still necessary, these new structures have led to a change in strategy for recruitment and training, with HR departments favoring soft skills such as collaboration.

In regard to the political context, a number of changes have been introduced by the National Education Ministry in France and the European Union related to collaboration skills development, especially in relation to digital literacy. This has been spurred on by the recent publication of a study carried out by the Organization for Economic Co-Operation and Development (OECD).

In France, the minister of education publishes documents relating to teaching and learning priorities at each grade level and in different domains (such as languages, literature, art, mathematics, etc..). In 2015, the program for cycles two, three and four included 23 mentions of collaboration, 42 for cooperation and 174 for collective activity. References appeared on 174 pages of the 382-page document. These were most often qualified with words such as tool, support, environment, device, creation, technology and resource (Villemonteix et al., 2018).

In the European Union, as part of the Europe 2020 strategy, a database classifying competencies, skills, qualifications, and occupations was put into place. Amongst the 16 "skills groups," we find digital communication and collaboration, which is defined as the following: "communicate in digital environments, share resources through online tools, link with others and collaborate through digital tools, interact with and participate in communities and networks, cross-cultural awareness (ESCO, 2018)." Collaboration also appears as an element in a number of cross-sector, sector-specific and occupation specific competencies, in fields as diverse as education, healthcare, biochemical manufacturing and food services.

In 2015, the OECD added a section to their PISA study to evaluate collaborative problem-solving capabilities of students in member countries. This was the first time a study of this kind was carried out. With major shifts in workplace structures, from individual to collective/project-based (Gareis, 1989), there is a marked need to prepare students for their future careers, in which technology and teamwork play a key role (OECD, 2017b). The PISA2015 results showed that not even one in ten students in participating countries have the collaborative problem-solving skills necessary for the changing socio-economic environment.

Based on these results, it should not be surprising to learn that the usage of collaborative/collective/cooperative learning activities in schools is rare, with individual student work and lectures still taking up the majority of classroom time. However, some efforts to change this are being made. Technologies which are sold as collaborative have begun appearing in classrooms around the world. For example, the Smart Table 442i (Figure 2), made by the same company which makes the Smartboard (Smart Technologies Corporation), is a 42" interactive table "allowing up to 8 students to collaborate on lessons at the same time." This table is appearing in classrooms across the US and Europe (Figure 3).


**Figure 2: Smart Table 442i [1]**

**Figure 3: Smart Table 442i in classrooms: (Left) Photo taken in classroom in North Carolina (2018); (Right) Photo taken in Nogent-le-Roi, France (2014)[2]**

Despite the appearance of these technologies in classrooms, collaborative activities are not common. There are a number of different reasons for this:

- Putting into place such activities is difficult for teachers, from an organizational perspective. Efficacious projects are often interdisciplinary, where teaching is still very much a solitary profession.
- Teachers are constrained by tight timelines, curriculums, and objectives, which

[1] https://www.smartboard.fr/produit/table-interactive-smart-table-442i/, accessed 4/5/2019
[2] Left: Photo credit – Debra Tucker (Retired North Carolina primary school teacher); Right - http://nleroi.canalblog.com/archives/2014/08/28/30382742.html

prevent them from diverting or integrating new methods.

- Teachers may not possess the knowledge, skills, or resources necessary to put in place collaborative group work, especially those which integrate new technologies. Additionally, a teacher's own experience with collaboration may lead to mistrust of collaborative methods.
- There is a relative consensus in the literature that when teachers do attempt to implement collective activities, asking students to work collaboratively does not guarantee that collaboration will occur (Dillenbourg, 2002).

Collaboration is influenced by a number of other factors, including elements both inside and outside of the teacher's control. For example, within the teacher's control are their directions, interventions, and tool choices. Outside: individual personalities, work preferences, group composition, friendships, and cultural elements, etc. have an influence on the activity of the group.

The work that has been done in regards to collaborative pedagogy (Barron et al., 1998; Blumenfeld et al., 1994; Krajcik et al., 1994) and in CSCL (Stahl, 2004; Teasley & Roschelle, 1995) all, expressly or inadvertently, draw attention to a need to better understand what is meant by collaboration skills, how these skills are learned and how they are transferred between different modalities.

Given a cultural and economic preoccupation with collaboration, participation in authentic group activities is seen as integral both at school and in the workplace. Furthermore, based on research at MIT, collective activity isn't simply a perceived benefit, but a real one. Working in groups, especially those which are diverse and encourage shared-talk-time, has been shown to improve problem-solving capabilities by increasing collective intelligence (Woolley et al., 2010a). However, the perception itself seems to have been enough to spur movements towards implementing collaborative technology into workplaces and classrooms alike. Classrooms, especially, are seeing more and more tactile technology, such as tablets, smartboards, and more recently multi-user tables like those seen above (Figure 3).

Although we know that tools influence the nature of collective activities (Gracia-Moreno, 2017; Rabardel, 1995), very little is known regarding what that means concretely for the articulation between different types of work surfaces and the impact on student activity/learning during collaborative group work. The aim of this research is to identify key elements related to collaborative work and analyze the impact that the use of such workspaces (digital, tactile, multi-user tabletop, and board) has. In particular we seek to understand how the use of different types of work surfaces (individual / collective, private / integrated into public space, horizontal / vertical / mobile, digital / analog) impact the collaboration process. As such, we ask the following question:

> How do physical-digital workspaces influence interactions within student work groups, and by consequence, the development of collaborative competencies?

To respond to this question, we have set the following research objectives:

1. Identify indicators for the collaboration process which can be used with or without technology;
2. Identify general/transversal collaborative competencies;
3. Characterize activity mediation during collective group work on different types of workspace modalities (individual / collective; private / integrated into public space; horizontal / vertical / mobile; digital / analog);
4. Form an understanding of how different workspaces influence the development of collaboration skills.

**Research Phases**

Due to the nature of the research method, design-based research (Blessing & Chakrabarti, 2009; Sanchez & Monod-Ansaldi, 2015), this study was broken up into several phases. The first phase, from November 2017 to June 2018, served as a period of appropriation of the Cré@tion project's context and goals. At this time, partnerships were already forming and projects beginning with a class of students from a technical high school in France. This, in combination with the use of the platforms by university engineering students, allowed for an initial investigation, familiarization with the technology, positioning of the research and eventual development of indicators to allow us to understand different parts of the collaboration process.

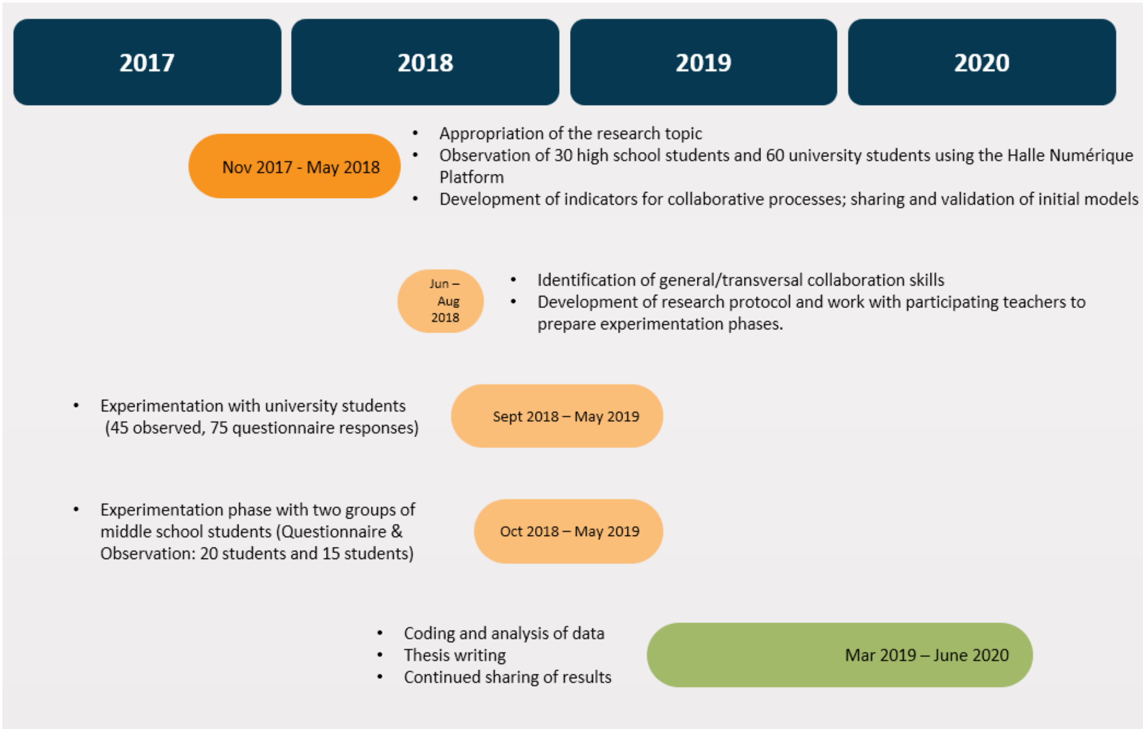



**Figure 4: Research phases**

The summer of 2018 (June to September) was used to develop a framework of collaboration skills, the protocol for the upcoming experimental phases and work with participating educators to structure their time with students in the *Halle Numérique*. This moved into two separate, but parallel phases during the 2018-2019 school year. Phase 3 worked with three classes of university students in the same engineering course, while phase 4 worked with two separate groups of middle school students. The data from phase 4 is not used as part of this dissertation to allow us to focus our analysis. This data will be treated in follow-up publications.

Finally, the last phase (5) continued coding work, which had begun earlier to allow us to exploit early data in order to share results, as well as work on this dissertation and continued sharing of more complete data.

## CHAPTER ORGANIZATION

This research regarding physical-digital workspaces and their impact on collaborative processes and the development of collaboration skills is laid out in four parts, as follows:

- The first presents our theoretical framework, focusing on the themes of: learning through experience, activity mediation, paradigms of collaboration, the differences between cooperation and collaboration, collaborative competency and physical-digital workspaces. This chapter presents two important theoretical results from our study, which have resulted from our review of the literature as well as observation. These results became an integral part of our theoretical framework as we continued our research. The first is physical digital workspaces. This is a term that we propose, along with a typology, that aims to describe settings which have both a physical and a digital element. Simply focusing on digital workspaces or physical workspaces would not work for this present research because both are present and intricately linked. Additionally, we will briefly discuss the notion of *globally collaborative work*, which is then detailed further in Part three where we go on to present the CIAO framework (Collaborative Interaction Analysis mOdel) which operationalizes this definition. In *globally collaborative work* we propose that collaboration and cooperation are too simple to accurately describe the interactions seen when people work together and instead propose five modes of interaction which emerge during *globally collaborative work*: individual work, communication, coordination, cooperation and collaboration.
- The second part of this dissertation has two major points: the first pertains to the technology used to investigate our research question: the *Halle Numérique* platform. We begin by examining the emergence of tactile technology, tabletop systems and research in these areas, then we move on to describe the *Halle Numérique* platform in detail, with a critical analysis of its functions. Secondly, we address our research question, methodology and research protocols for the Descriptive and Prescriptive Study phases.

Parts three and four our dedicated to the major themes of our research results:

- Part three focuses on the influence of physical-digital workspaces on collaborative processes, or how students work together and interact with each other over the course of the work session. We begin by presenting CIAO (Collaborative Interaction Analysis mOdel) which we developed and use to analyze student work, giving examples of the five modes of interaction (individual work, communication, coordination, cooperation, and collaboration). We explain how they can be observed and differentiated from each other. Then, we discuss patterns which emerged based on this analysis model and observations in relation to the different physical-digital workspaces we tested.

- Part four focuses on the influence of physical-digital workspaces on engagement and collaborative competencies. One of the major hurdles we needed to overcome was how to determine the impact of these spaces on competency development and engagement in the activity. Based on our literature review of collaborative competency, current models for evaluating competency and our observations over the course of our descriptive study, we developed a framework which we will present in this part. The COllaborative COmpetency ($CO^2$) framework can be used for measuring engagement and competency activation during collaborative work. While imperfect, this framework has allowed us to identify some differences between the three different workspaces that we tested in terms of the quality of the collaboration and the potential for competency development.

Finally, in our conclusion we review the major results from our dissertation and present a critical assessment of our methodology and contributions and possibilities for future research.

# PART ONE: POSITIONING OUR RESEARCH

## PART ONE INTRODUCTION

In this first part, we present a review of the literature related to our subject and research question, which aims to understand how physical-digital workspaces influence the emergence of collaborative processes and the development/learning of collaboration skills. We begin by positioning the research in the socioconstructivist paradigm. Next, we examine activity mediation theories. We then go on to address the polysemic notion of collaboration, tackling the division between “collaboration” and “cooperation” which exists within current literature. Next, we discuss collaboration as a competency and the PAWs model (Samurçay & Rabardel, 2004), which describes competency development. This is followed by a state of the art on collaborative competencies and a proposal for a generalized collaborative competency framework based on that research. Finally, we discuss a physical-digital workspace typology.

## CHAPTER 1 THEORETICAL FRAMEWORK



### *1.1 Learning through Experience: Positioning*

This research uses notions of collaboration coming from essentially cognitivist theories, in terms of their social dimension, and from progressive education, where experience is at the heart of teaching practices. Beginning in the early 20$^{th}$ century, Russian psychologist Vygotsky (1930), who was writing primarily during the 1920s and early 1930s, began describing learning as a personal and social processes, with development being tightly interwoven with speech. Around the same time in the United States, Dewey, an American philosopher, also began down a similar path. He believed that development occurs during social interactions, “reciprocal give-and-take,” arguing that “all human experience is ultimately social […] it involves contact and communication." It is thus through "co-operative enterprise" and using "social intelligence" to generate purpose that learning occurs (Dewey, 1938a). In their research, Doise and Mugny (1978), have demonstrated that one of the key mechanisms for cognitive development is epistemic conflict between individuals and according to Perret-Clermont (2001), personal experience leads to learning, but requires social validation.

Moving beyond groups in the classroom, Dewey believed that education and "co-operative" inquiry played an important role in developing active participants in democratic processes. (Dewey, 1938a) Likewise, Célestin Freinet believed that "it is through living and working in a team or in a group that you learn to live in a group." (Freinet, 1964) In their research on communities, Lave and Wenger also observed a similar transformation: "As an aspect of social practice, learning involves the whole person: […] not only a relation to specific activities, but a relation to social communities […] becoming a full participant, a member, a kind of person" (1991).

This socio-constructivist movement is central to how we have approached the topic of learning to collaborate in an instrumented environment. Engaging students in collective activities should permit them to learn about not only the topic at the forefront of the activity, but also ways to work together.

How this takes place, the role played by others, and the tools used has long been a subject of discussion and the formation of several models of activity mediation. The principal objective of the Cré@tion project, in which this dissertation is embedded, is to understand the impact multi-user devices have on students' collaboration skills, returning us to the fundamental question of how these objects can be put to the service of their users (Rabardel, 1995).

### *1.2 Activity Mediation*

In order to embark on an anthropocentric analysis of the *Halle Numérique* platform (the tactile table and boards which we describe in detail in Chapter 2), we will begin by looking briefly at the development of activity mediation theories, beginning with Vygotsky, Leontiev, and Engeström then finishing with Rabardel's model, the last of which serves as our primary lenses for analyzing student's mediated activity in this dissertation. We feel that it is interesting to discuss the heritage and development of these activity mediation theories as each carries some interesting points of reflection for our present study.

Lev Vygotsky's cultural-historical theory, developed during the 1920s, was a response to the dialogues dominating psychology in western academia at the time, most notably biological or evolutionist theories of development. Coming from a Marxist viewpoint, Vygotsky proposes cultural-historical theory which put emphasis on the role of society and language along with the use of tools in cognitive development (Veer & Valsiner, 1994; Vygotsky, 1978). For Vygotsky, a tool is an emancipating instrument, one which allows 'man' to push back against nature (Veer & Valsiner, 1994), as "a means by which human external activity is aimed at mastering and triumphing over, nature" (Vygotsky, 1978). Early on in his writings, he separated tools from signs, but positioned both as potential activity mediators. This inclusion of cognitive constructs (signs) essentially means that all activity is mediated. This mediation fundamentally changes how an activity is performed : "the use of artificial means […] fundamentally changes all psychological operations just as the use of tools limitlessly broadens the range of activities within which the new psychological functions may operate" (Vygotsky, 1978).

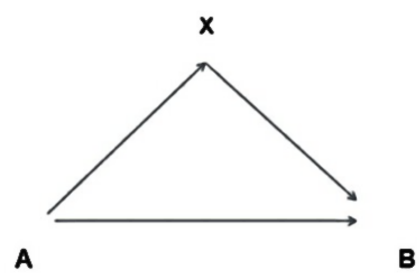



**Figure 5: Vygotsky's model of natural and artificial memory**

Figure 5 shows Vygotsky's representation of using memory devices, an artificial process, versus a natural process. The A to B line represents a stimulus - response formation (a natural process). Overtime, a natural memory link is formed between the two, so that when A happens, B is expected. X comes into play as a device to aid in the formation of the memory, such as using an acronym to recall information or tying a string around your finger to remember to perform an action (Veer & Valsiner, 1994). These statements and ideas from Vygotsky point to the possibility that the "artificial means" is likely to have an impact on the "psychological operations", which could include the student's construction/reflection of meaning, ideas, schema, or even competency. If true, it is not farfetched to believe that the form and affordances of a tool used to work with others could impact one's development of collaborative competencies.

Picking up on these ideas from Vygotsky, Leontiev proposes a hierarchical view of activity which focuses on motivation, the notion that activity is driven by the object and motivation plays a major role in the individual's behavior. He views activity as a response to a social need (Leontiev, 2009). According to Engeström, Leontiev's contribution allows for a better understanding of an individual's actions within an overall collective activity (Engeström, 2014), but he does not address the role of instruments in the process, an aspect criticized by both Engeström and Rabardel, who say that Leontiev does not go far enough.

Engeström continues in this vein of thought, proposing a new model, Cultural Historical Activity Theory (CHAT), in which the division of labor, community, and rules are added, extending the work of Vygotsky and Leontiev, forming a systemic picture of collective activity.

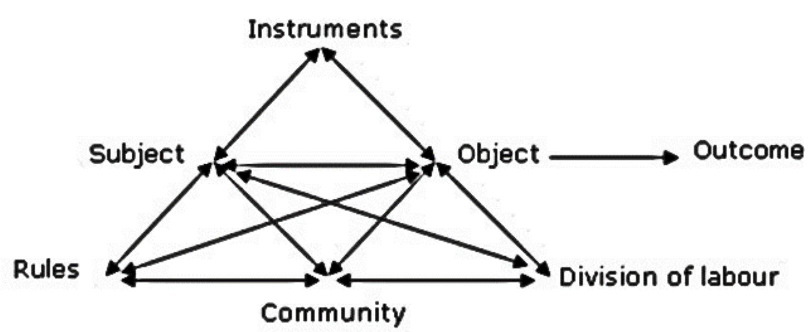



**Figure 6: Cultural Historical Activity Theory Model (Engeström, 2014)**

However, for our present study, this model cannot stand alone:

> *"The central elements, this psychological dimension that Leonnt'ev [sic] was talking about, have gotten lost and activity theory has become rather a very, very general way of describing what people do and the things that intervene or mediate activity. We have lost sight of this very penetrating and insightful idea of the relationship between the way we are as continuously changing beings and the activity we engage in."* (Roth et al., 2012)

Roth et al., (2012), go on to refer to Engeström's model as a heuristic for orienting oneself to important elements in the world that one should be aware of in order to be able to transform them.

While this model is useful to understand the larger context of the activity in which participants in this present research are engaged, it poses problems for a psychological approach to instrumented activity. Rabardel, on the other hand, sees a need to understand individual activity in function to group activity. While Rabardel's primary model focuses on the Subject-Instrument-Object interaction, he goes on to propose an extension which, in light of the appearance of groupware and other forms of collective work, can be used to understand individual instrumented activity within a collective context: Figure 7.

***Instrumented Activity Situations***

We will begin by defining the terms used by Rabardel and discuss his model more closely. We will mobilize this model and Rabardel's categorization of schemas as a lens to analyze and understand the activities observed in our empirical research phase. Firstly, it is important to understand that Rabardel's **subject** is an individual who acts within the given situation. "**Other subjects**" are other individuals who are acting within the same situation, participating in the collective activity, but who are separate from the subject. The **object** is that which is being acted upon and finally the **instrument** is the artifact being used. Rabardel chose to use the term "artifact" as it is more neutral than other possible choices, such as "tool," which already carries with it the weight of its supposed uses. An artifact becomes an instrument once it is put into use by the subject to act upon an object; the usage infers the development of a **schema** related to the usage of the artifact, again implying that using an artifact to act upon an object introduces a change or transformation of the subject/self – a notion that is very relevant to our present study to understand if and to what extent physical-digital workspaces used for group work may impact collaborative competencies. The process of an artifact becoming an instrument that may have this impact is referred to as **instrumental genesis**.

Another important notion proposed by Rabardel in this context are the processes of **instrumentation** and **instrumentalization**, these refer to the how the functions of a tool influence the subject and how the user adopts and adapts the artifact to fit their needs, potentially leading to the emergence of new functions (**catachresis**). However, our goal here is not to pinpoint these processes or the emergence of new functions. Though they certainly are present, we will focus more on the relationships between the subject, object, and other subjects where the artifact serves as an intermediary, which brings us back to the notion of schema.

It is the emergence of schema in connection with the artifact that makes up the instrument. Here, Rabardel relies on Piaget's notions of schema as representational models. Rabardel defines schema as "an active organization of lived experience which integrates the past" (Rabardel, 1995). For him, they serve as instruments to organize activity, giving purpose to actions undertaken by an individual or group. He distinguishes two levels: action schema and usage schema. They are distinguished as being relative to the primary or secondary tasks. Usage schema are related to secondary tasks, like those relative to the artifact itself. For example, a car has two pedals: a break and an accelerator. The use of the break to stop and the accelerator to go are usage schemas. An action schema is related to the primary activity, incorporating many usage schema to accomplish the task at hand. In our example, the usage schema related to the use of the break and accelerator come in to play in the action schema of driving.

According to Rabardel (1995, pg. 94), schemas are multifunctional, fulfilling:

- Epistemic functions: turned toward the comprehension of the situation.
- Pragmatic functions: turned toward the transformation of the situation and the obtention of results.
- Heuristic functions: orienting and controlling the activity.
- And collaborative functions: a means of transformative action directed at another's activity.

Rabardel's model allows us to take into account how a subject makes use of an artifact, how that tool influences the subject and the object and, in light of our use of groupware, the mediating role of the instrument between the collective and the individual or the collective and the object.

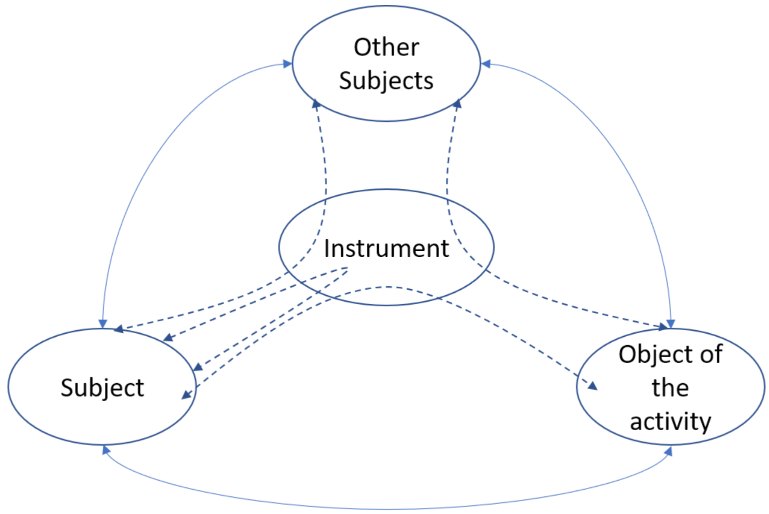



**Figure 7: Situations of Collective Instrumented Activity (Bourmaud, 2006; Rabardel, 1995)**

In Figure 7, each line represents a specific mediation: solid lines are direct, where dotted lines are mediated by the instrument. For example, speaking directly to other subjects is a direct interaction (assuming there is no auditory device between the two), where communicating via a written message is mediated by an instrument (paper and pencil, email, etc.). In this case the use of the paper and pencil as an instrument changes the way the activity is performed. Likewise, other mediations which pass through the instrument take on new aspects in their performance because the instrument is used.

***Communication in co-located computer-mediated collective activities***

In the previous section, we saw that the introduction of an artifact and the process of the artifact becoming an instrument (instrumental genesis) changes the way in which an activity is performed. These changes also influence the nature of interactions between group members and with the tool itself. The learning environment is modified by the affordances of the tool (Gracia-Moreno, 2017). Johansen (1988) formulated a matrix to conceptualize Computer Supported Cooperative Work (CSCW) systems (Figure 8) in which he hypothesized that teams need different tools based on the time of work (synchronous or asynchronous) and location (co-located or separated), the affordances of which would overcome difficulties presented by each situation. When students work together in different places or at different times, communication largely occurs through written means (email, chat messages, etc.). This means students have more time to develop their thoughts, but also more opportunities to diverge from the group's goals or vision.

Baker (2015) states that “the longer the duration of individual cooperative work, the more each contribution will ‘drift’ away from the others and the harder it will be to achieve final integration.”

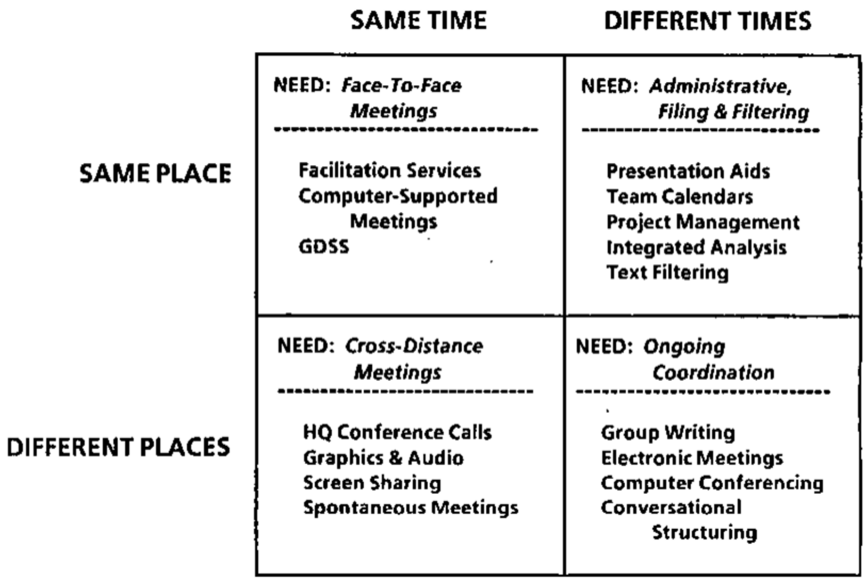



**Figure 8: Team needs and groupware solutions (Johansen, 1988, pg. 21)**

However, when a group is co-located and working simultaneously, the introduction of digital resources leads to new means of communicating ideas using verbal communication, body language and non-verbal mediated communication (ex.: using the artifact to write or show examples). An artifact which can be used for non-verbal communication has an advantage in that it removes the necessity to wait for an opportunity to intervene verbally (Hymes & Olson, 1992). Hymes and Olson identify five common hindrances to group brainstorming processes, including:

- *limited airtime:* “when only one person can speak at a time, there is limited time for each individual to contribute,”
- *production blocking:* “because of limited air time, individuals often have to hold on to their contributions until they get a chance to report them, and as a result they might forget them, or they might decide not to offer them; in either case, the act of holding on to them will prevent them from thinking of other ideas,” and
- *cognitive inertia:* “at each moment only one line of ideas is being generated, since they are reported serially; groups will therefore tend to pursue fewer

different kinds of ideas (Hymes & Olson, 1992)."

In our research, the spaces fall into the same-time, same-space category. The digital hall platform and the different modalities tested offer different workspaces which afford both verbal and written forms of communication (where multiple people could potentially be writing simultaneously), along with the use of images or drawings to help communicate ideas. Additionally, they allow for different movements around the room and the work surfaces, which must also be taken into account.

### *1.3 Paradigms of Collaboration*

There is still an unresolved debate around the notions of collaboration and cooperation. Their similarities make them difficult to distinguish at times, and some researchers feel that it is a pointless endeavor to try to do so. The division itself may find its roots in their genesis in two different historical and philosophical domains (Baudrit, 2007b; Bruffee, 1995; Panitz, 1999). Efforts to separate the two notions began in earnest in the 90s. Preferences amongst educators for one or the other was said to demonstrate a difference between their assumptions about the role of the teacher, the nature of the learner and authority (Matthews et al., 1995). At their core, both are processes in which groups work together towards a common goal. In this chapter, we will take a closer look at their particularities, beginning by examining the different paradigms of collaboration.

Based on our reading of the literature, we feel that collaboration can be thought of in three different ways, which we have termed as "paradigms": As a method of learning/teaching, a method of working, or as a philosophy of interaction/living.

| Paradigm | Definition |
|---|---|
| **Philosophie of interaction** Living Together | A way to interact in the world, participate in society, and advance society together. |
| **Method of Learning** Learning Together | A method by which competencies and knowledge are acquired or constructed within a social context by working together towards one or more common goals. |
| **Method of working** Working together | A way to produce together, which may or may not occur in a professional context |

**Table 1: Paradigms of Collaboration**

These paradigms sometimes bleed together. For example, in collaborative governance, collaboration becomes both a method of working and a philosophy of interaction. The existence of these different paradigms is one of the reasons it is difficult to propose a standard definition of collaboration and make the associated competencies and skills explicit: they are doubly situated, linked not only to their contexts but to their intentions.

### *Collaboration: A Method of Learning & Teaching*

In this first paradigm, collaboration is talked about as a way in which we learn together with the goal of producing knowledge or competencies for group members. This can take the form of communities, learning groups inside the classroom, or simply a "situation" (Dillenbourg, 1999).

The basic definition proposed by Dillenbourg (1999) for collaborative learning is a situation in which two or more people learn or try to learn something together. However, this definition falls short, so he adds elements of symmetry: of action, knowledge, and status. This introduces the notion that these learning situations can be more or less collaborative when the situation is asymmetrical. "Situations depicted as collaborative are generally rather symmetrical, while other situational labels are used for highly asymmetrical situations with respect to actions (control, coordination,…) or with respect to expertise (tutoring, teaching, coaching,…) (Dillenbourg, 1999)."

Other researchers talk about collaborative learning as a method which must be carefully structured beforehand, while also granting a large degree of freedom during the activity in order to achieve the desired learning outcomes. Cousinet's method of free work in groups places the learner at the center of the learning activity as part of the progressive education movement, relying on the idea that children are predisposed to scientific inquiry and that the role of the teacher is to allow children to explore in a social environment. As such, the teacher prepares activities beforehand and becomes a "good collaborator," only intervening when requested or to correct "fundamental knowledge" (Bruffee, 1995) such as spelling (Cousinet, 2011).

### *Collaboration: A Philosophy of Interaction*

In this paradigm, we see philosophers, pedagogues, psychologists, etc. using collaboration as a means to live together, produce in order to advance society, and forward cultural development.

For those interested in collaboration as a learning method, this is often one of the goals in addition to the primary subject being studied in the context of the learning group. Dewey, for example, preferred a collaborative approach to inquiry because of its resemblance to democracy (Dewey, 1938b). This idea that collaboration resembles democracy further pushes the notion of equality amongst participants, as one key characteristic is that all citizens are political equals (Dahl, 1973). Dewey, like Cousinet and Freinet (1964), believed that engaging children in group learning, would form the basis for them to eventually become active participants in society. Panitz puts the emphasis on the importance of personal responsibility and participation. For him, it is a manner to live and behave which includes respect for others and the recognition of the contributions of peers (Panitz, 1999). This notion can also be found at the heart of the work Vygostky, Leontiev, and Engeström, all of whom consider collaborative, or at least collective, activity to be essential for cultural development.

***Collaboration: A Method of Working***

Collaboration as a working method stands in tension with the other two paradigms. As of today, the majority of companies are hierarchical in nature, with few exceptions, despite moves to flatten organizational structures (Rajan & Wulf, 2006). As such, there is a tension between learning to work collaboratively in the classroom, in society, and then in the workplace, where equality of action and voice is in constant tension with the power structure.

Projects have become one of the most common working modes since the 90s (Gareis, 1989), making collaboration skills some of the most sought after in job markets (OECD, 2017a). In this paradigm, we see collaboration as a method of working together to produce something in a professional setting, most often in the context of projects. Blogs and professional social media sites are teeming with articles about how to improve collaboration in the workplace, kill unnecessary meetings and develop collaboration skills. Searching "Collaboration in the Workplace" yields some 159 million results (January 2019). Companies, including Google, have begun including collaboration in their project management and design models (Google Developers, 2014), but this is not a stretch as collaboration appears in more standardized approaches to project management, simply making up major steps in the process (Gidel & Zonghero, 2006).

Learning to collaborate during professional training programs in healthcare and engineering have become major points of interests for teachers and researchers in these, and other, domains. Collaborative learning bleeds into collaboration as a working method in these environments, as it takes on the role of both learning method and a competency to develop (See Collaborative Competencies: State of the Art).

### *1.4 Cooperation or Collaboration*

One of the recurring interpretations of collaboration is that of work completed in a group by processes of sharing and negotiation, where learning "is socially produced through interaction and continuous effort to maintain a shared understanding of the problem" (Henri, 2015). In these cases, the separation between collaboration and cooperation becomes clearer because of the emphasis on the division of labor. "To cooperate means at least to share a common goal towards whose achievement each participant in the group will strive. But this is compatible with dividing up the tasks into subtasks and assigning individual (or subgroup) responsibilities for achieving each of them" (Baker, 2015).

Cooperative learning occurs as subtasks are confided to each group member (Henri, 2015). However, the complexity of the work will be different during cooperative and collaborative learning because of this division of tasks. For example, according to Brufee, there are two types of knowledge targeted by cooperation and collaboration: fundamental knowledge and non-fundamental knowledge. For him, fundamental knowledge can be established and justified by facts or through social accord, such as mathematics, historical events, etc. This type of knowledge can be achieved through cooperative learning. On the other side, non-fundamental knowledge is more ambiguous and puts the authority with the teacher, such as questions of ethics. It is necessary to reason and judge to reach a response. For Bruffee, this is the kind of knowledge which can be approached through collaborative learning (Bruffee, 1995; Panitz, 1999).

Unifying elements of cooperation and collaboration have been proposed by several authors, Baudrit (2007), carried out a comparative study on cooperative versus collaborative learning, publishing the following table:

| Distinguishing Criteria | Cooperative Learning | Collaborative Learning |
|---|---|---|
| Exchanges Interactions | Structured (Principle of interdependence) | Not structured (sharing, pooling of knowledge) |
| Teacher Control | Real (Observation of groups) | Weak (Student autonomy) |
| Student Responsibility/ Empowerment | Guaranteed by interdependence | Uncertain (At each member's discretion) |
| Equity amongst students | Impossible (Heterogenous nature of groups) | Improbable (Free organization of groups) |
| Student roles | Risk of specialization | Risk of excessive division |
| Learning Targets | Fundamental knowledge linked to different scholastic activities | Non-fundamental knowledge: critical eye, reasoning, collective discovery |

**Table 2: Comparison between collaborative and cooperative learning (Baudrit, 2007) (Personal Translation)**

The differences between cooperative and collaborative learning are still difficult to distinguish (Baudrit, 2007b), even with a direct comparison, which begs the question: are these notions necessarily in a state of tension? If we return to the learning targets, is it not possible to target fundamental knowledge before the more complex non-fundamental knowledge? In this manner, Brufee proposes that cooperation is a preface to collaboration (1995). Coming from a background of information and library sciences, Shah (2008) proposes a model of collaborative information finding that starts with a base of communication and becomes gradually more complex as it approaches collaboration, with contribution, cooperation and cooperation making up the areas in between. He refers to this as the C5 model of collaboration (Shah & Leeder, 2016). Due to the goal of Shah's research, understanding information and resource sharing, he does not rely on the same definitions for cooperation and collaboration that we do, but the notion of nested interaction is one which merits development in this context.

### *1.5 Globally Collaborative Work*

As observations were underway during our descriptive study, we found that while researchers in CSCL/CSCW, and other fields, have sought to differentiate between collaborative and cooperative work/learning (Stahl et al., 2006), these delineations only seemed to make sense on the scale of a short, well defined activity. Student behavior does not necessarily fall into the neat lines that have been drawn. Nor, when looking at the work performed, do the definitions necessarily fit. According to Baker (2015), collaboration and cooperation are closely linked, in that "cooperation will usually require at least some collaboration, if only to agree initially on an understanding of what the task is and how it is to be divided up amongst participants, as well as to integrate individual contributions in the final joint problem solution."

We have observed that work can be *globally collaborative*. That is to say that the end result may be collaboration, in the sense that there is a production realized by the entire group, but the behaviors that can be observed during *globally collaborative work* include cooperation, individual work, presentation of that work etc. As such, we propose five modes of interaction which break *globally collaborative work* into its finer details: individual work, communication, coordination, cooperation & collaboration. In the section below, we define each of these and then go on to present the targeted production of the different modes as well as some elements regarding the complexity of the interactions that make them up. See Table 3.

**Individual work** can be understood as those moments when an individual retreats from the group in order to reflect and construct their ideas (Teasley & Roschelle, 1995), as well as work performed on tasks with which he/she was entrusted by the group. This "retreat" can also take place while still within the group setting, often taking the form of reading, writing or reflecting.

Using the most basic definition of **communication**, it refers to the transmission of a message from one point to another via a given channel (Shannon, 1948). This mode of interaction allows individuals to introduce new information into the group, creating the point of departure for a shared vision (Teasley & Roschelle, 1995). Communication can take the form of providing information orally, via messaging (email, chats), longer presentations or adding written notes into shared spaces.

**Coordination** denotes the organization of activities (events, behaviors, tasks, and actions) in such a way that they balance and synchronize (Baker, 2015). As such, coordination is seen in different actions of structuration, organization and division of tasks in order to facilitate the work. According to Baker, coordination can also extend to the point of "coordinating representations," (individual representations of tasks), approaching the definition of collaboration used by a number of researchers in CSCL (Baker, 2015). However, we propose a different vision of the work of "coordinating representations", placing it within the area of cooperative work.

**Cooperative work** is produced following individual work, often preceded by the division of tasks amongst group members (Baudrit, 2007a; Bruffee, 1995; Panitz, 1999). Once the work on these tasks is put into place, cooperative activity appears as the pieces are put back together. This pooling of individual work necessitates negotiation and new efforts to synchronize each actor's representations; it is in these efforts of reconciliation that cooperation can be observed. It is in this interaction mode that we see socio-cognitive conflict, due to the role it plays in the synchronization process.

Finally, **collaborative work** designates the co-elaboration, co-evolution, or co-construction of tasks and ideas by participants in order to reach a common goal (Baker, 2015; Dillenbourg, 1999; Henri, 2015; Teasley & Roschelle, 1995). The most fundamental difference between collaboration and cooperation relates to how the production is constructed: together (in the case of collaboration), to the point that it is difficult to determine who contributed what; separately (as in cooperation), followed by integration.

All or some of these modes of interactions are mobilized, in a non-linear manner, by participants during work sessions and over the course of long-term projects. Some groups divide into sub-groups, which then follow similar patterns within themselves. The project, environment, individual competencies, methods, and tools used, intervention or instructions given by a teacher or animator, etc. influence the behavior of participants and as such, the emergence of these modes of interaction.

| | **Targeted production** | **Complexity of interdependency** |
|---|---|---|
| Individual work | The individual works through reflection, aiming at the construction of ideas and meaning with the goal of eventually re-introducing the elements he judges useful for the group. | Factors such as individual personalities and group cohesion (such as psychological safety (Edmonson, 1999)) can influence how individual work is completed. For example, in terms of personality, an introvert (C. G. Jung, 1946) may produce written notes, where an extrovert may narrate his activity and readjust based on the reactions of peers, using them as a sort of mirror (J. H. Jung et al., 2012). |
| Communication | Each member of the group has different information or skills. It is necessary to present them in order to resolve problems. As such, the objective of this mode of interaction is to introduce new information into the group. | Since no member has all of the necessary information to complete a task, it is necessary to work with others to achieve results. The capacity of each individual to present his work, ideas, and arguments is essential. It is also vital that this information is received. |
| Coordination | The group must choose how it will work together or divide work between individuals in order to progress. In collective sessions, coordination discussions allow for the definition of tasks and identification of responsibilities. | Each person (or sub-group) has a specific objective. The division of work risks putting these objectives in tension with those of other members. Success depends upon the clear definition of tasks and planning for their completion. |
| Cooperation | The division of tasks (such as the decision to have individuals writing their ideas separately for a brainstorming activity) necessitates a pooling of work that was completed individually (or in sub-groups). This combining requires the establishment of consensus after having considered the information, opinions, and arguments of each member. | In order to be successful, it is necessary to include all group members in the negotiation. There is a risk that the conversation may be dominated by some participants, while the others are withdrawn, which may compromise the consensus. |
| Collaboration | The group works together to co-produce: a shared vision of concepts, of a problem, solutions, strategies, a new product which is concretized through writing, models, reports or presentations, etc. | Success depends upon the capacity of the group to co-construct problems, objectives, solutions, and results in a way that includes all participants. The risk being that one individual could take over, compromising the collaboration. |

**Table 3: Complexity and interdependencies of modes of collaborative interaction (Tucker et al., 2018)**

## Actions and interactions during collaboration

In Chapter 4, we will go into detail about how we operationalized these definitions to create CIAO (Collaborative Interaction Analysis mOdel) in order to understand the impact of physical-digital workspaces on collaborative interactions. However, in this section, we examine the overarching components of actions/interactions which occur during globally collaborative work, specifically the structure and elements of collaboration which would lead to the production of new ideas and learning, both individual and collective. We have used these elements to establish criteria for identifying modes of interaction for globally collaborative work, which we develop further in Chapter 4.

Defining collaboration as the co-elaboration and co-evolution of tasks, ideas, and concepts in order to create a joint product, means necessarily that participants are dependent upon each other (interdependent) to ensure their goals are reached. Interdependence refers to the belief of group members that there is value in working together (Johnson & Johnson, 2011). This can take the form of positive interdependence, leading to the group working together, or negative interdependence, leading to competition. The structure of the activity plays a key role in whether or not a group will work together or compete. This includes the task design, availability of resources, evaluation, etc. When positive interdependence is fostered, group members take on responsibility for their own as well as the group's performance. Members are more likely to participate and share resources, facilitating the production of new ideas and positive forward motion in the group.

Generating new ideas is a major part of the collaborative process. Established guidelines for brainstorming, a technique used to generate ideas, include quantity over quality, withholding criticism, welcoming "wild" ideas and combining/improving upon ideas (Osborn, 1957). Often, ideas produced are not clear or do not fit into the vision of other group members, leading to conflict. This is one of the key mechanisms which has been identified for cognitive development. Socio-cognitive conflict, specifically epistemic conflict which calls into question group members' perspectives and creates a disequilibrium, can lead to the creation of new knowledge and cognitive tools (Buchs & Butera, 2004; Doise & Mugny, 1981). In order for development to occur, communication needs to take place during the "elaboration phase" of a notion (Mugny & Doise, 1978). The "elaboration phase" here refers generally to the time during which a concept is being built and its conceptualization within the group's problem space (Teasley & Roschelle, 1995) is being established. This can involve different kinds of activity. Kobbe et al. (2007) identify four major collaborative activities:

- Elaboration: "relating new ideas and concepts to that which is already known, making it personally more meaningful, and expanding it in multiple ways, such as adding details, giving examples, making analogies, creating visualizations and predicting outcomes”;

- Explanation: “articulate[ing] the explainer’s reasoning and elaborate[ing] the concept”.
- Argumentation: “[generating] claims or assertions and their justification with evidence”.
- and question asking.

Chi & Wylie (2014) identify three activities linked to cognitive engagement, which they use to analyze collaborative activities: notetaking, concept mapping, and self-explaining. Notetaking, consists of writing verbatim (at the lowest level), summarizing, adding inferences, underlining or highlighting text. It is a common activity in which students engage, individually or as a group. Concept mapping refers to “graphical representations of knowledge where concepts are represented as nodes and are connected through labeled relations.” These too can be built individually or as a group. Finally, self-explaining is “the activity of explaining an idea or concept aloud to oneself as one learns, or one can think of it as trying to make sense of the learning material” (Chi & Wylie, 2014). At its core, self-explaining seems to be a solitary activity, but it can also appear in a group activity. In this context others will often jump into complete ideas or attempt to clarify for others, becoming a dialogue starter which permits participants to engage in socio-cognitive conflict and convergence processes.

***Categorizing participant interventions during collaboration***

The ideas presented here pertain to how researchers have gone about classifying collaboration in the past. It is the idea of branched and overlapping discourse moves, combined with actions taken by students, such as writing or moving objects in a shared space, which help to form the basis of the analysis model we propose in Chapter 4.

Collaborative activity is a complex research object, leading to the creation of numerous categorization techniques, which are often similar in that they rely on discourse analysis, but which take into account different levels of the activity. Malmberg et al., (2018) conducted experiments using students working in collaborative groups in an effort to understand what multi-channel data could reveal about collaborative processes. They analyzed physiological data (electronic-dermal activity), facial expressions, and video observations. For their research, they proposed a 5-phase model which included:

1. work instructions: receiving information about the task to be completed
2. learning environment: discussing how to use the learning environment in light of instructions
3. searching for information: internet searches related to completing the task
4. adding information: placing relevant information into the activity space
5. communication: discussing contents and criteria for accomplishing the task
6. off-topic discussions: talk irrelevant to the task

Phases 1-4 were sequential, imposed by the script laid out for the activity. Meanwhile, 5-6 could occur at any time during the activity. Additionally, they coded conversations based on three interaction levels: low-level, high-level, and confusion. Low-level interactions were classified as "reading and processing of information to acquire knowledge, accompanied by low interaction." High-level interactions were classified as "activities related to the construction of meaning, such as generating new ideas, elaborating ideas, critiquing ideas, and connecting them to prior knowledge." Finally, confusion "involves markers of metacognitive monitoring and prompting of other group members to regulate learning" (Malmberg et al., 2018). While the phased model is an interesting idea, the designated phases seem to relate more to the scripting than to the collaboration itself, making it difficult to apply outside of the study in which it is used.

The most common way of analyzing collaboration relies on the analysis of dialogue (Gracia-Moreno, 2017; Sizmur, 1996; Soller, 2001; Wegerif, 2015; Wegerif et al., 1998; Zumbach et al., 2005). Zumbach et al., propose nine actions which initiate collaborative events, integrated into action chains including: Proposals (or counter proposals), asking for help/advice, shifting focus to a new aspect, encouraging partner or peer group/group cohesion, referring to emotional/motivational processes, coordinating a task, reflecting on group processing or analyzing group performance, constructing meta-knowledge/reflecting on knowledge distribution, and dragging text blocks into a shared workspace.

| | | | |
|---|---|---|---|
| B1 | ask for help advice [2,3,4] | inform [2,3] | |
| C1 | shift focus to a new aspect [2] | agree/ accept [1,3,7] | |
| | | or | |
| C2 | | clarify/ negotiate [1,2,3] | agree/ accept [1,3,7] |
| D1 | encourage partner or peer group [2,5,8]<br>support group cohesion [2,5,8] | | |
| E1 | refer to emotional-motivational process [2,4,5,8] | acknowledge [1,2,3,7] | |
| | | Or | |
| E2 | | Answer (referring to contribution) [2,3] | |
| F1 | coordinate task (steps for solution) [8,9] | agree/ accept [1,3,7] | |
| | | Or | |
| F2 | | clarify/ negotiate [1,2,3] | agree/ accept [1,3,7] |

**Figure 9: Portion of classification framework (Zumbach et al. 2005)**

The different columns in Figure 9 represent the initial action, the reaction of a second person and then the reaction of the first actor to the second. This particular segmentation is linked to the use of pairs of students in their study. Groups of more students produce increasingly complex interaction strings, adding challenges to the categorization process. In such conditions, strings may not be perfectly linear, but rather interrupted by other contributions. Groups may spontaneously divide themselves, leading to the simultaneous development of different interaction strings (ex. [B1] and [F1] occurring at the same time).

Similarly, Sizmur proposes a branched model of collaborative interaction, consisting of 3 types of responses: Not elaborated, elaborated individually, and elaborated collaboratively.

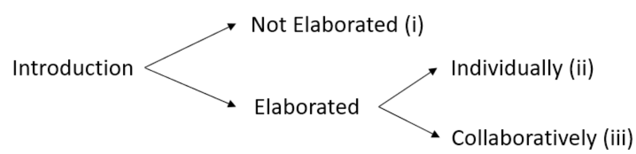



**Figure 10: Exchange types (Sizmur, 1996, pg. 186)**

He goes on to define discourse moves present in collaborative interactions, based on the content and intention of the move. They are as follows:

1. **Opening:** an initiating move that "opens up the discussion" of meaning. Often characterized by a question.
2. **Introducing an idea**: an initiating move, except when following an opening (thus constituting a response). Introduces a new idea to be discussed.
3. **Supporting idea:** a responding move that approves of or maintains a topic for discussion. No elaboration is included.
4. **Elaborating on the idea**: a responding move, which may lead to additional moves. Adds new content to the discussion.
5. **Challenging ideas**: may be initiating or responding. Rejection of a previous idea.

6. **Retracting idea**: as indicated, retracting an idea involves removing it from discussion, either by changing it or reconsidering it.
7. **Integrating ideas**: reconciling two conflicting ideas or making links between existing ideas
8. **Eliciting support:** explicitly asking for support, i.e. "do you agree?"
9. **Eliciting elaboration:** requesting more information or stating that something is not clear in an attempt to get more information.
10. **Hedging**: conceptually between a supporting and retracting move, it is an evasive strategy to a request or challenge. It can also be used to soften a statement.
11. **Query Loop**: the query loop describes a series of moves which do not add or elaborate. For example, asking someone to repeat something or provide general information. However, it can lead to elaboration.
12. **Feedback:** acknowledgement.

This idea of branched and overlapping discourse moves, combined with actions taken by students, such as writing or moving objects in a shared space, help to form the basis of the analysis model we propose in Chapter 4.

### *1.6 Collaborative Competencies*

Collaborative competencies are at the heart of current institutional concerns, marked by discourses about the ways in which collaborative practices can be facilitated by new technologies. In fact, collaboration skills are more and more in demand in our society, at school, in university classes, and in the workplace (OECD, 2017a). In 2015, the PISA study, carried out by the Organization for Economic Co-operation and Development, studied collaborative problem-solving competencies in students amongst member countries for the first time. Researchers measured the ability of individual students to engage in activities with two or more participants to solve a problem by sharing knowledge, competencies, and effort. Researchers concluded that there is a need to continue developing collaborative problem-solving skills around the world; they suggest a few methods to do so, including collaborative problem-solving exercises and increasing diversity within the group.

However, the definition of collaborative problem-solving skills limits the OECD's research to a specific focus of collaboration: solving a presented problem. We take the position that collaboration is much broader, especially in the contexts in which it is in demand, encompassing not only problem solving, but learning, working, and living. It is in this context that we ask the question: What are collaborative competencies? Even though there exist numerous efforts to discern what makes collaboration effective, the competencies surrounding it are still blurred, often a hodgepodge of other competencies that are themselves, unclear. As such, in this section we present a state of the art on collaborative competencies and attempt to make them explicit. We begin by exploring the notion of competency, reaching our own definitions, then examine literature regarding competency development and evaluation. In this step, we examine a number of competency and analysis frameworks related to collaboration in various fields. We look specifically at studies which use collaborative competencies as an object of study, as an analysis framework and finally at researchers who discuss what efficacious collaboration looks like. We elected to mobilize different viewpoints and research domains because collaboration and collaborative competency are such polysemic notions. This approach allows us to find the common elements between these disparate sources. Based on this state of the art, we infer five key competencies related to "collaborative competency" that we use later to form our $CO^2$ (COllaborative COmpetency evaluation framework).

**Defining Competencies**

In the anglophone literature around competence and competencies, a great deal of the discussion around competence is situated in linguistics. The nature of competence has been debated since at least the 1950s, when Noam Chomsky introduced the notion that competence and performance should be distinguished. For him, competency referred to an underlying structure and rules (Chomsky, 1971). From his perspective, competency is invariant, resembling something like Plato's ideal forms on the plane of linguistic knowledge. However, performance relates to the application of those norms, which may be imperfect and vary based on the speaker's ability to access the competence (Westera, 2001).

Westera, identifies two distinct forms that competence can take in education: theoretical and operational. In the theoretical perspective, competence is defined as cognitive structures that lead to specific behaviors. From the operational perspective, it refers to a "broad range of higher-order skills and behaviors that represent the ability to cope with complex, unpredictable situations" (Westera, 2001).

Despite little cross referencing between the anglophone and francophone literature regarding competencies, there does seem to be a convergence in terms of how competence is discussed, from either a theoretical or operational perspective with operational being the most popular. Much of the francophone literature surrounding competency comes from didacticians and occupational psychologists interested in professional development and training in the workplace, such as Pastré, Barbier, Leplat, Wittorski, etc. Tardiff is one of few researchers interested in the applications of a competency-based approach in universities, with the goal of preparing students for professional realities (Tardif & Dubois, 2010). Traditionally, schools have used a knowledge-based objectives approach, rather than a competency-based approach.

According to Richard Wittorski, competency is an area of study in which there are few anchor points agreed upon by researchers (Wittorski, 1997). This is not surprising as the concept has undergone numerous changes over the years: Under scientific management, Taylorism, competency took on a behaviorist hue, referring to a capacity to execute. For many years, competency was evaluated in terms of behaviorist constructs (Norris, 1991). We can still see this today in the modern form of learning objectives in schools (i.e. Students will be able to + action verb) (Tardif, 2013). According to Pastré, the crisis which overtook the Taylorian vision of management brought with it the belief that operators act with intelligence. As work situations became more complex and dynamic, workers needed to be able to analyze and solve problems which had multiple dimensions, but in hindsight, researchers realized that seemingly simple tasks also necessitated the development of basic and complex competencies. As a result, competency today is seen from a more constructivist viewpoint, taking cues from Piaget (Pastré, 2004).

Wittorski defines competency as a contextualized process which generates a final product, performance.

> "[…] competency is produced by an individual or a collective in a given situation and is socially recognized. It corresponds with the mobilization in the moment of certain knowledge combined in a specific manner in function to the actor's perception of the situation (Wittorski, 1997) (Personal translation)."

This definition is very different from Chomsky's. While both position competence as a resource, for Wittorski it is a production, rather than a perfect construct from which the user can pull, indicating a constructivist viewpoint on Wittorski's part versus Chomsky's psychological nativist positioning.

Taking the operational perspective as defined by Westera (2001), we define competencies as an "ability to act" (*savoir-agir*) (Tardif, 2018) made up of *saviors* (theoretical knowledge…), *savoir-faire* ("know-how", knowledge-in-action, procedural knowledge…), and *savoir-être* ("know how to be", personal qualities, production of adapted actions…) (Boudreault, 2017; Hatchuel & Weil, 1992; Pastré, 2004) which a person or group can mobilize to act in a given situation, based on their understanding of that situation. We have used the original French, paired with the translation and brief explanation in English, for clarity of expression. Having mobilized definitions primarily from francophone sources for this definition, the terms have concise meanings that do not translate cleanly into English and may even be used in English on occasion.

The contextualized nature of competency, "in a given situation," has an enormous influence on existing competency frameworks for collaboration. As we will discuss later on, they are heavily influenced by the context in which they are developed. This begs the question of whether or not it is possible to construct a generalized competency framework due to their situated nature. We believe that there are threads which link these frameworks together, invariants in the sense of Piaget, which can be used to construct a generalized framework, so our goal in the following section is to do just that. First, we will discuss paths to competency development and an analysis framework: PAW (People at Work), which positions competencies as a resource.

**Competency Development and Evaluation**

How learners develop competencies is a complex topic with a variety of models. Richard Wittorski proposes five developmental paths:

1. Logical action (trial and error).
2. Iterations of activity and reflection on the activity.
3. Retrospective reflection on the activity.
4. Reflection on the activity prior to it (anticipative).
5. Controlled transmission and production of knowledge.

Each path produces slightly different types of competencies, such as incorporated gests, action analysis or methodologies (Wittorski, 1997). Pastré reduces this to three: on the job (by experience), retrospective reflection, and controlled transmission. He insists that alternating and combining the three pathways is the most efficacious route to competency development (Pastré, 2004). In the classroom, Tardiff recommends integrating transdisciplinary (uniting multiple disciplines) learning situations with a high degree of authenticity, in which students are confronted with cognitive conflict and forced to establish a new equilibrium (Tardif, 2013).

Unfortunately, it is generally agreed upon that observing the development of competency directly is not possible. Which begs the question: how can we understand, assist in the development of and evaluate competencies? Tardif puts the burden on the student, who must furnish proof of his/her learning, in the form of a self-evaluation, such as a portfolio, but recognizes the need to evaluate in a videographic (overtime) rather than photographic manner, while taking the situation into account (Tardif, 2013). Samurçay and Rabardel (2004) propose the PAW (People at Work) model to understand competency development. It is a framework to assist in the analysis of the process as it occurs in the workplace. In this model, competencies are treated as a resource that is available, but under constant development. The choice to integrate competencies into a larger systemic model is logical, as they cannot be directly observed or reduced to performance.

**People at Work model**

This model's primary goal is to allow for an in-depth analysis of real activities in the workplace, but we believe it can also be used to analyze activities in the classroom, especially as it relates to the development of competencies, rather than the transmission of knowledge. For our research, this model allows us to analyze student working activity from several angles (See Figure 29): first, that of the situation, which is imposed upon each group. It is the situation itself that is being modified in this research, specifically the instrument used to complete tasks. Tasks, instructions and other constraints will remain constant. Second, by the individual subject, allowing us to understand his/her productive activity and the construction of collaborative competencies. This will include analysis on the vertical access, taking into account other group members and collective competencies. Finally, the role of social groups, which is mediated by the teacher in the case of pedagogical work, will vary only slightly within the same population, remaining largely constant, especially in terms of knowledge and techniques.

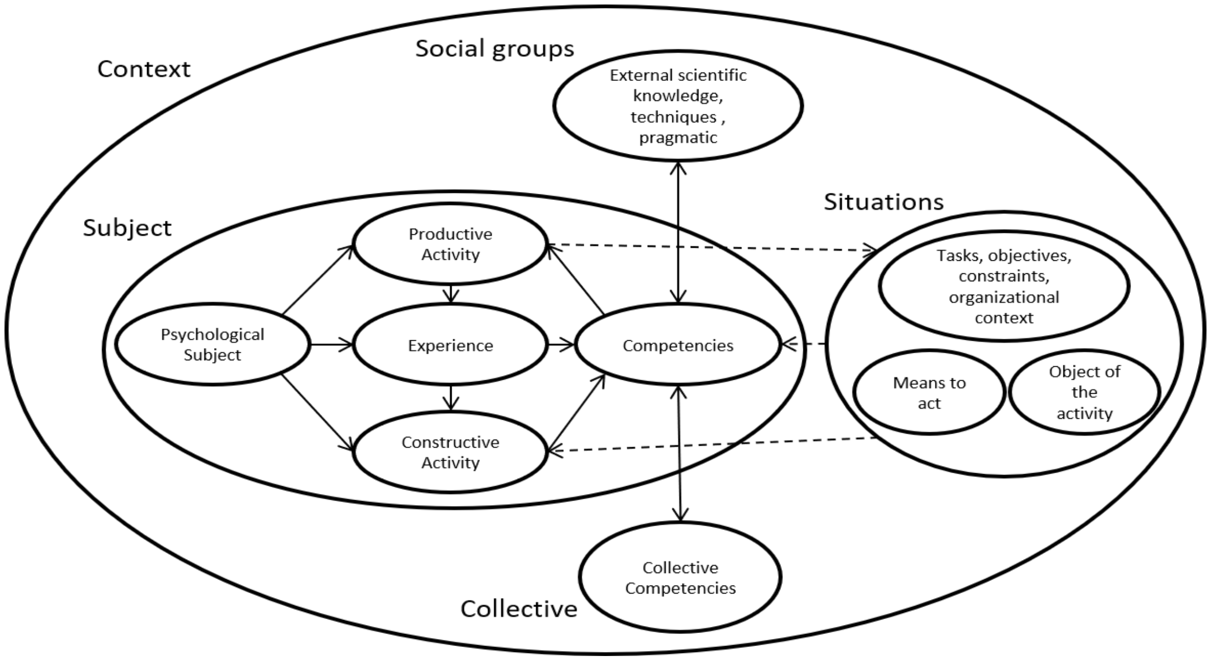



**Figure 11: People at Work (PAW) model (Samurçay & Rabardel, 2004)**

As we discuss the different sections of the model (Figure 11), we will integrate a concrete example, without going into too much detail:

**Context** refers more broadly to elements that impact the productive activity, even if they do not have an immediate influence, but may have an influence on a medium to long term scale. Samurçay and Rabardel give the example of company politics, human resources, and economic factors to illustrate this.

> *Example:* Michelle is an industrial engineering student participating in our study. She elected to take the course based on a larger context, including university policies and recommendations. Michelle was required to complete an internship in a company before enrolling. There are expectations about her attendance, grades and attitude which may also impact her activity.

The individual subject takes center stage but is integrated into a larger social and work context.

The **subject** is divided into several entities:

- **Psychological subject**: the individual as an intentional actor in his/her work and development.
- **Productive activity**: the finalized activity, controlled by the psychological subject in order to complete tasks, consisting of epistemic and pragmatic functions,

allowing the subject to understand and transform the situation.

- **Experience**: a product of productive activity and a basic building block from which are built concepts, representations, operational invariants, schemas, etc.
- **Constructive activity**: activity during which the subject constructs and evolves their own competencies in function of the situation in which they are acting. This is fed by experience and driven by the subject.
- **Competencies**: a resource that the subject can call upon for productive activity, which are shaped by the psychological subject's experience and constructive activity.

The **collective,** in this model, only accounts for collective competencies, which are articulated with those of the subject. They serve as resources for managing productive and constructive activity. One example given by Samurçay and Rabardel of a collective competency is the development of collective work modalities, such as co-action, cooperation, etc. These individual and collective competencies nourish each other and co-evolve.

> *Example*: Within the class Michelle aligns herself with others to form a group, each member comes with their own experiences, interests, goals, and competencies. Not all of her group mates are industrial engineers, some are from other specialties such as technical humanities, information technology, etc. As such, they may have other contextual influences and social groups.

**Social groups**, or communities, in this model refer specifically to knowledge, norms, and rules related to the profession, which can be influenced (i.e. become knowledge/norms, etc.) by the competencies developed by the individual or group. Initially, this seems to be the most out of place for our purposes, but we believe that it plays an important role, especially if students take on a project with real-world impacts, such as a microenterprise or a small team of engineering students consulting on a project. The impact from social groups on the activity is likely the goal from a pedagogical perspective but may simply have a low to medium impact in the inverse.

> *Example:* Michelle's professor for this course has provided a number of texts and information coming from social groups related to value analysis and design thinking. There was a controlled transmission of information via text supports and

lectures prior to the group's formation.

**Situation** is broken into a minimal schematic of objects, means/tools, and the task in terms of objectives and conditions. As such, situations refer to the place where the work is completed, but also its nature, impacting in turn the constructive activity of the subject. The situation and the subject's competencies are also reciprocally determinative, in that the subject's competencies will inform the subject's interpretation of the situation and the productive activity acting upon it.

*Example:* Teachers assigned a specific task to students with specific objectives, constraints, and output expectations. In this case, the group needed to read the case study and work together to analyze the situation using the methodological tools presented in class, then propose solutions based on their analysis. The object of the activity is two-fold and may vary based on perspective. From Michelle's perspective, the object is to fill out the model provided, develop a better understanding of the tool and to demonstrate her understanding of that tool when the teacher is present. From the teacher's perspective, the first explicit objective expressed to the students is to perform a productive activity, thereby gaining experience and reflecting on that activity in order to increase Michelle's and the group's competency when it comes to using this value analysis tool. The second is to, implicitly, encourage the group to work together and develop good collaboration habits, influencing collaborative competency as well. This took the form of instructions and recommendations about how to work together, which Michelle's followed. Finally, the means to act provided to the group consisted of the tactile table and board system with all of its affordances and constraints. The board also had a canvas of the model to fill out.

As Michelle and her group work through the project and develop new ways of working together to complete their task, Michelle is an intentional actor in her work and development. Michelle externalizes her thoughts using the table and board as a tool of reflection and communication, while viewing what others are writing or saying as well. This activity, interaction, and observation of others' activity are used as the building blocks from which Michelle can build concepts, representations, operational invariants, schemas, etc. which may serve as resources (competencies) for future activity.

## Collaborative Competencies: State of the Art

In our effort to discern collaborative competencies and the skills which make them up (*savoir*, *savoir-faire,* and *savoir-être*), a literature review was conducted using research databases such as JSTOR, ScienceDirect, CAIRN (a French language research database), Google Scholar and ResearchGate. The search terms included "*compétences collaboratives*", "collaboration skills", "collaborative competency", "collaborative competencies", "collaborative work", and "collaborative learning". We made the decision to include these last two terms in order to develop an indirect look at collaborative competencies which dominate today's literature on the topic. These terms produced studies in which collaborative activities, the "right" actions, appear in analytical frameworks of efficacious collaboration from which we can extract certain components of collaborative competency.

First, we will look at what our research turned up as we began searching for papers to include in our state of the art. We believe this gives some interesting insights into the ever-increasing popularity of collaborative competency as a topic and the terms used to describe it. We also use this as an opportunity to compare the French and English resources available on the topic. However, our primary focus is on those papers which were selected from a few different research domains. This was a methodological choice made in an effort to incorporate diverse viewpoints into our definition of what it means to be competent in collaboration.

### *Collaborative Competency in Numbers*

To gain a better understanding of the existing literature on collaborative competencies, we searched Google Scholar to for results to April 2019, using both French and English search terms. The graph below represents that search, in terms of indexed data (which may vary slightly from year to year as new items are indexed or removed). Results were limited to one of two languages (French or English), quotation marks were used to find exact phrase matches, and reference items were not included.

"*Les compétences collaboratives*" in French corresponds with several possible translations in English: competency, skills, and abilities. We also chose to examine the prevalence of the term "collective competencies" because they are similar notions. However, collective competencies are usually treated as a product of collaborative competency, where collaborative competency is individual and collective competencies are attributed to a group (Policard, 2014).

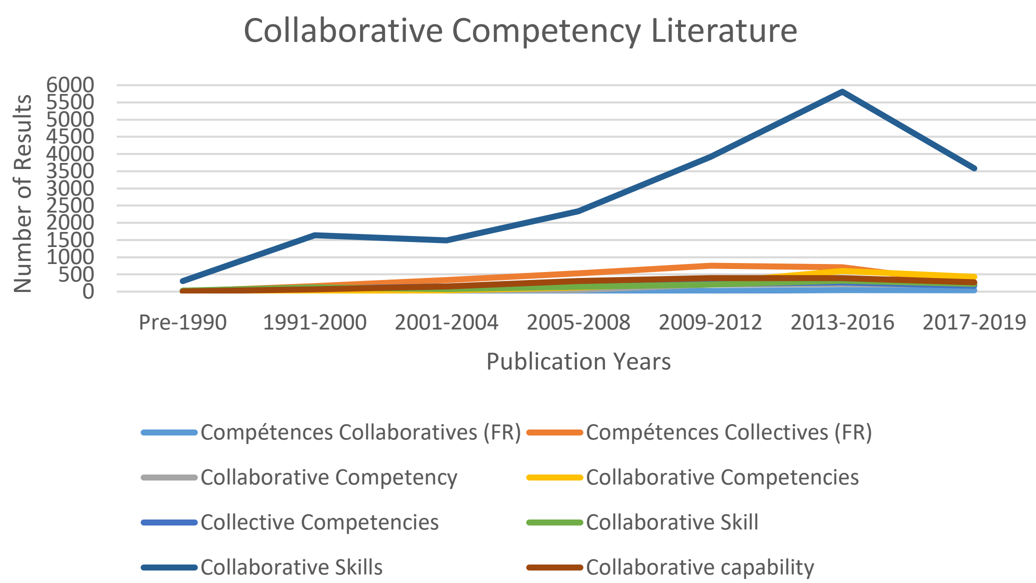



**Figure 12: Anglophone and francophone literature about collaborative competencies from Google Scholar.**

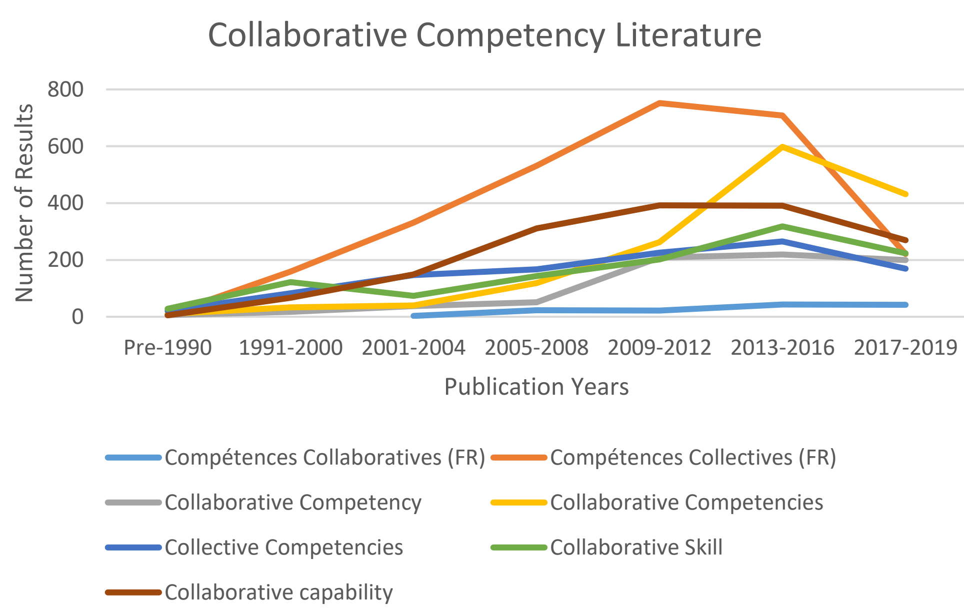



**Figure 13: Anglophone and francophone literature about collaborative competencies from Google Scholar without the "Collaborative Skills" category.**

There are some immediate limitations using this method, such as indexing which occurs later, causing an increase in the same numbers as time goes on; occasionally the same article may appear twice, though citation searches were excluded. However, we felt that these did not prevent us from getting a relatively clear picture of the current literature on collaborative competencies. The search for 2017-2019 covers results up to April 2019. We can see a drop in this last category because not all research from this period would have been indexed and available using the method employed to create this graph, but the trend is otherwise generally upward.

With this quantitative search, we can observe that: (1) interest in the subject has greatly increased in the last 30 years, going from no research to a few hundred articles a year for most terms (a high correlation with technological changes); (2) the literature doesn't address a single competency or skill, but rather a plurality; (3) there is a strong preference for the term skill in anglophone literature, where the Francophone literature prefers *compétences collectives*. Sanojca (2018), attributes this anglophone preference to a difference in level: when talking about processes, the term competency is favored, however for a specific task, the term skill is used more frequently. As for the Francophone preference for "collective" competencies, this seems to be linked to the context in which the competencies are developed, highlighting their social and situated nature, attributing them to the group in which they are developed rather than to an individual. A similar search for "effective collaboration" reveals an even more impressive array of results, with more than 11,000 from 2017 to April 2019 alone.

The most recent studies come notably from medical fields where interprofessional care is topical. Out of the first 100 results for "collaborative competency" between 2017-2018, we find nine references in educational sciences, one in writing, one in economics, 11 in management, four in engineering sciences and 74 in medicine.

From these results, studies which looked more in-depth at collaborative competencies and skills were selected based on context, language (an effort to include Francophone as well as Anglophone references) and domain (education, public administration, management, and healthcare) in order to provide an array of examples. They were then divided into 3 categories to structure our discussion:

- Collaborative Competencies as an Object of Study;

- Collaborative Competencies as an Analysis Framework; and
- Effective Collaboration.

***Collaborative Competencies as an Object of Study***

In this section, we look at research which specifically sought to identify collaborative competencies. The selected works come from a variety of sectors. For practical reasons, we limited this section to five texts, three of which come from educational sciences and two from public administration. For those hailing from educational sciences, the context and objectives of each study are very different. This was a methodological choice, which we believe allows us to form a more complete framework, taking into account different contexts and goals. The first reference focuses on the development of collaborative competencies in adults during a training program, the second to competencies desired by students in their partners in primary school, and finally a competency framework designed to evaluate collaborative competency on a large scale. As for the two coming from the sector of public administration, the first presents results of a questionnaire sent to civil servants in positions of power in the United States and the second is the result of a state of the art on collaborative governance which proposes a temporal vision of competencies to develop in public administration students.

**Sanojca, 2018: Competencies over time, scale, and levels**

The most recent competency framework comes from the doctoral thesis of Sanojca in educational sciences. Defended in 2018, Sanojca completed an in-depth state of the art on collaborative competencies, using sources available up to 2016. She proposes an analytical framework with three dimensions: an organizational level, an organization over time and a gradation based on competency level.

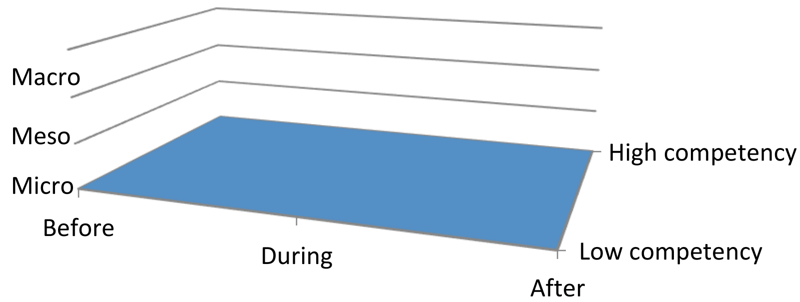



**Figure 14: Competence analysis paradigms (Sanojca, 2018)**

Studies addressing collaborative competencies as an object of study tend to examine one of these three dimensions. Studies which are concerned with organizational competencies examine them on three levels: micro (interindividual elements, teams), meso (organizational elements) and macro (societal elements). Those which are interested in the organization of collaboration over time tend to use a before-during-after model. Finally, certain studies are more interested in the gradation of competencies, from low to high (Sanojca, 2018).

When developing her own competency framework, Sanojca preferred a temporal approach, strongly linked to her definition of collaboration as "a process of constructing [interpersonal] links in order to voluntarily create a collective work." This definition differs from our own in that it puts the establishment of a network of actors at the forefront in order to begin and maintain the collaboration, a notion heavily linked to its context, attached notably to aspects of project management. In her results, Sanojca proposes a tryptic of competencies, made up of antecedents (attitudes), implementation processes, and results (expected production).

| **Antecedents** (Attitudes) | **Implementation processes** | | | **Results** (Expected Production) |
|---|---|---|---|---|
| Have a collaborative mindset<br><br>Have humility and a measured ego<br><br>Be benevolent | **Evaluate / Start**<br>Know how to engage partners<br><br>Co-build the project structure | **Animate**<br>Animate the group to facilitate work<br><br>Be attentive to others and their ideas | **Implement**<br>Develop and maintain a network of actors<br><br>Manage information (share, make visible) | Care about the common good<br><br>Act to obtain common objectives |

**Figure 15: Collaboratives Competencies (Sanojca, 2018)**

To create this framework, Sanojca used observations and salient elements mentioned by adult learners in questionnaires and interviews during a hybrid training program (online, in class and at work). She recognizes that these competencies are influenced by the nature of the collaboration (the objective) as well as the context (the specific situation of each adult learner). As such, they may not transfer to other situations. In fact, there are numerous competencies that were left on the cutting room floor; out of 35 initially appearing on a first draft, only 11 survived to make it into the final tryptic presented above. Notions of leadership, trust, and negotiation, amongst others do not appear here because they were not brought up by the adult learners, nor did they appear in the training session.

We find that one limiting element of this study is displayed in the Sanojca's antecedents, elements which were not addressed in the training session and rarely cited in her data. Due to the research terrain, in a professional training which was sold as one to learn to cooperate, learners may have auto-selected themselves, limiting participants to those who already have a positive attitude towards collaboration. It is also possible that learners were interested in concrete methods and actions that they could learn during training, rather than potential attitude changes over the long term. In the end, Sanojca recognizes the complexity of collaboration, proposing a vision of collaborative competencies necessary for the facilitation of a project from start to finish.

**Ladd et al., 2014: Collaborative Competency in Young Students**

Moving on to the second study, we change from training for the workplace to primary school. During their research, Ladd et al., (2014) sought to understand collaboration skills necessary for young students, according to skill preferences for partners in collaborative work. To complete this study, researchers used in-class observation to create a taxonomy of collaboration skills, divided into ten categories:

- staying on task
- communicates and listens
- cooperation
- provides support
- attempts to solve disagreements

- emotional and behavioral control
- attentive/responsive to others
- character/conscientiousness
- relational/partner attributes
- and finally, task features/preparation.

Afterwards, students underwent questionnaires and interviews, classifying these in terms of their importance. In the top spot were social competencies related to the work (focusing on the task, continuing to work until the task is finished). In second place were social skills related to conscientiousness (contributing to the work, justly dividing tasks, attempting to resolve conflicts, and regulating negative emotions.) Finally, cooperative skills (sharing ideas, taking turns) and social support (motivating colleagues) were also highly rated.

This study is interesting for its context, which is very different from that of Sanojca. Even though the methods were close (observation, interviews and questionnaires) the results vary largely because of the contextual difference and the objectives of the activity undertaken by students vs. adults in training.

**Hesse et al., 2015: Collaboration Skills Indicators**

The last text from educational sciences is that of Hesse, Care, Buder, Sassenberg, & Griffin (2015). They sought to define competencies for collaborative problem resolution in order to propose a competency framework for schools. They define collaboration as "the activity of working together towards a common goal (p. 38)". This definition approaches our own, including elements of communication (the exchange of knowledge or opinions), cooperation (an agreed upon division of tasks), and reactivity (active participation). Competencies were chosen based on 3 criteria: (1) the possibility to evaluate them on a large scale, (2) the possibility to gradate them for use by teachers (low to high), and (3) teachability. Researchers grouped the competencies into two large categories: social process skills (those which make up collaborative competency) and cognitive process skills (those which make up problem solving competency). We have reproduced those related to social process skills below.

Even though one of the criteria for the selection of competencies in this framework is the possibility to teach them, this is not discussed in depth, apart from a short section regarding the usage of "well defined activities" which force interdependent action. As with many other researchers interested in learning to collaborate, for Hesse et al., it is by doing that competency is developed.

| Element | Indicator | Low | Middle | High |
|---|---|---|---|---|
| **Participation** | | | | |
| Action | Activity within environment | No or very little activity | Activity in familiar contexts | Activity in familiar and unfamiliar contexts |
| Interaction | Interacting with, prompting and responding to the contributions of others | Acknowledges communication directly or indirectly | Responds to cues in communication | Initiates and promotes interaction or activity |
| Task completion / perseverance | Undertaking and completing a task or part of a task individually | Maintains presence only | Identifies and attempts the task | Perseveres in task as indicated by repeated attempts or multiple strategies |
| **Perspective Taking** | | | | |
| Adaptive responsiveness | Ignoring, accepting or adapting contributions of others | Contributions or prompts from others are taken into account | Contributions or prompts from others are adapted and incorporated | Contributions or prompts from others are used to suggest possible solution paths |
| Audience awareness (mutual modelling) | Awareness of how to adapt behavior to increase suitability for others | Contributions are not tailored to participants | Contributions are modified for recipient understanding in light of deliberate feedback | Contributions are tailored to recipients based on interpretation of recipients' understanding |
| **Social Regulation** | | | | |
| Negotiation | Achieving a resolution or reaching compromise | Comments on differences | Attempts to reach a common understanding | Achieves resolution of differences |
| Self-Evaluation (Metamemory) | Recognizing own strengths and weakness | Notes own performance | Comments on own performance in terms of appropriateness or adequacy | Comments on expertise available based on performance history |
| Transactive Memory | Recognizing strengths and weaknesses of others | Notes performance of others | Comments on performance of others in terms of appropriateness and adequacy | Comments on expertise available based on performance history |
| Responsibility Initiative | Assuming responsibility for ensuring parts of task are completed by the group | Undertakes activities largely independently of others | Completes activities and reports to others | Assumes group responsibility as indicated by use of first-person plural (we) |

**Table 4: Social process skills (Hesse et al., 2015)**

### O'Leary et al., 2012: Attitudes in Collaboration

Moving on to the domain of public administration, O'Leary, Choi, & Gerard ( 2012) investigated collaboration skills sought after by high-level civil servants in the United States via a confidential, online questionnaire. They used open questions asking about experiences with collaboration. Unfortunately, the response rate was only 5.05%, a non-significant result, making it difficult to generalize. However, we believe that it can be used in combination with other research.

The results were divided into the following categories: individual attributes, interpersonal skills, group process skills, strategic leadership capacity, and technical/substantive knowledge based on their literature review. The individual attribute identified as the most important by responders was open-mindedness, defined as being open to new ideas, the ideas of others, to change, and a willingness to help others succeed. The next few, by a very wide margin, were patience, self-confidence, flexibility, generosity, persistence, and diligence (amongst others). For interpersonal skills, being a good communicator and attentive to others were the most important aspects. Results from this study lean heavily on attitudes (*savoir-être*). This is likely due to the question framing, seeking to know what attributes are sought after in employees.

**Morse & Stephens, 2012: Skills for Collaborative Governance – Collaborative Competency as Part of a Process**

Morse & Stephens (2012) presented a framework for competencies that they believe should be taught to public administration students to help expand collaborative governance practices. They define collaborative governance as public work or society management in terms of processes and institutions which are carried out across organizational boundaries.

<table>
<tr><th>Assessment</th><th>Initiation</th><th>Deliberation</th><th>Implementation</th></tr>
<tr><td>Issue analysis<br>Environmental assessment<br>Stakeholder identification<br>Strategic thinking</td><td>Stakeholder engagement<br>Political/community organizing<br>Building social capital<br>Process design</td><td>Group facilitation<br>Team building and group dynamics<br>Listening<br>Consensus building<br>Interest-based negotiation</td><td>Developing action plans<br>Designing governance structures<br>Public engagement<br>Network management<br>Conflict resolution<br>Performance evaluation</td></tr>
<tr><th colspan="4">Meta-Competencies</th></tr>
<tr><td colspan="2">Collaborative mind-set<br>Passion for creating public value<br>Systems thinking</td><td colspan="2">Openness and risk taking<br>Sense of mutuality and connectedness<br>Humility or measured ego</td></tr>
</table>

**Table 5: Collaborative competencies for collaborative governance (Morse & Stephens, 2012)**

In their article, they identify four phases of collaborative governance and competencies linked to each one, as well as six meta-competencies which appear in all phases. This is another example of a temporal approach, in which the process plays a key role in determining collaborative competencies. Here again, we also see both general (listening) and domain specific elements (political/community organizing).

### *Collaborative Competencies as an Analysis Framework*

In this section, we look at two examples of collaborative competency positioned in an analysis framework for research.

### OECD, 2017: Observable Actions in Collaborative Problem-Solving for Determining Skill Level

The first, which we discussed briefly in the introduction, is the OECD's framework for their 2015 study on collaborative problem-solving skills.

| | **(1) Establishing and maintaining shared understanding** | **(2) Taking appropriate action to solve the problem** | **(3) Establishing and maintaining team organisation** |
|---|---|---|---|
| **(A) Exploring and understanding** | (A1) Discovering perspectives and abilities of team members | (A2) Discovering the type of collaborative interaction to solve the problem, along with goals | (A3) Understanding roles to solve the problem |
| **(B) Representing and formulating** | (B1) Building a shared representation and negotiating the meaning of the problem (common ground) | (B2) Identifying and describing tasks to be completed | (B3) Describe roles and team organisation (communication protocol/rules of engagement) |
| **(C) Planning and executing** | (C1) Communicating with team members about the actions to be/being performed | (C2) Enacting plans | (C3) Following rules of engagement, (e.g. prompting other team members to perform their tasks) |
| **(D) Monitoring and reflecting** | (D1) Monitoring and repairing the shared understanding | (D2) Monitoring results of actions and evaluating success in solving the problem | (D3) Monitoring, providing feedback and adapting the team organisation and roles |

**Table 6: Collaborative problem-solving skills Matrix (OECD, 2017b)**

To complete this evaluation, researchers put together a competency matrix, crossing collaboration with problem solving. It consists, most notably, of observable action, allowing for measurement on an international scale. As such, the elements are limited to saviors-faire (knowledge in action) for practical reasons (OECD, 2017b).

### Manilall & Rowe, 2016: Collaborative Competencies in the Healthcare Industry

Within the context of education for healthcare professionals, Manilall & Rowe (2016) developed a competency framework for physical therapy students by combining several existing ones, including the Physician Competency Framework, Essential Competency Profile for Physiotherapists in Canada, and Core Competencies for Undergraduate Students in Clinical Associate, Dentistry and Medical Teaching and Learning Programmes in South Africa. The definition of collaboration in the most recent version of the Physician Competency Framework is the following: “As Collaborators, family physicians work with patients, families, communities, and other health care providers to provide safe, high-quality, patient-centered care.” This definition has a heavy impact on the “key competencies” and “enabling competencies” defined by Manilall & Rowe.

| Key competency | Enabling competency |
|---|---|
| Establishes and maintains interprofessional relationships, which foster effective client-centred collaboration | Respecting and understanding the roles and responsibilities of other healthcare professionals towards patient-centred care<br>Fostering collaboration with other relevant stakeholders in patient care |
| Collaborates with others to prevent, manage and resolve conflict | Identifying issues that may result in conflict and employing collaborative skills to resolve them<br>Demonstrating a respectful attitude towards colleagues and the interprofessional team to foster positive relationships<br>Reflecting on improving the functioning of the interprofessional team |
| Effectively and safely transfers care to another health professional | Being able to assess when the patient should be transferred to another healthcare provider<br>Demonstrating the use of written and verbal communication for safe transfer |

**Figure 16: Collaborative Competencies for Physical Therapy Students (Manillal & Rowe, 2016)**

This particular framework was put together in order to evaluate responses to interview questions given to physical therapy professors and students. The questions were about the best ways to develop collaborative competencies in class. This is an illustration of the competency frameworks we see in the healthcare sector which put the emphasis on respect in professional relationships. The authors do not further develop the framework.

***Effective Collaboration***

Much of the research on collaboration does not attempt to identify collaborative competencies to predict or prescribe, but rather identifies ideal behavior as a framework for analysis and evaluation, particularly in CSCW and CSCL, of a particular technology with the goal of supporting collaborative work or learning. The frameworks developed by these researchers permit us to take a deductive approach to extrapolate certain *savoirs, savoir-faire* and *savoir-être* associated with collaborative situations.

**Soller, 2001: Categories of Conversational Learning Skills in Effective Collaboration**

Typically, collaboration is examined and measured in terms of dialogue, especially the coming and going of the conversation, and more rarely, through body language. Often, the group is the unit of analysis because of the social nature of collaboration (Baker, 2015; OECD, 2017; Roschelle & Teasley, 1995; Soller, 2001; Yang, Wegerif, Dragon, Mavrikis, & Mclaren, 2013; Zumbach, Schönemann, & Reimann, 2005). Actions which facilitate and encourage group thinking are at the center of these frameworks. We find this in the work of Soller (2001), who identified three groups, divided into subgroups of collaborative conversational learning skills.

| | | |
|---|---|---|
| **Active Learning** | **Request** | : Ask for help/advice in solving the problem, or in understanding a team-mates comment. |
| | **Inform** | : Direct or advance the conversation by providing information or advice. |
| | **Motivate** | : Provide positive feedback and reinforcement. |
| **Conversation** | **Task** | : Shift the current focus of the group to a new subtask or tool. |
| | **Maintenance** | : Support group cohesion and peer involvement. |
| | **Acknowledge** | : Inform peers that you read and/or appreciate their comments. Answer yes/no questions. |
| **Creative Conflict** | **Argue** | : Reason (positively or negatively) about comments or suggestions made by team members. |
| | **Mediate** | : Recommend an instructor intervene to answer a question. |

**Table 7: Collaborative conversational learning skills (Soller, 2001)**

These skills are translated by specific activities which lead to effective collaborative learning: participation, social anchoring, active learning conversations, analysis of group processes and performance, and helping colleagues effectively. Soller proposes that these elements can be used to create an intelligent system which uses predetermined phrases to support collaborative learning activities.

**Wegerif, 2015: Actions Associated with Effective Collaboration when Learning to Learn Together**

In a presentation about *Learning to Learn Together* – L2L2, Wegerif (2015) uses the example of the Deepwater Horizon oil spill as a moment where experts struggled to resolve problems over the course of several months. As such, the question "Have they been trained to do this?" was posed. That is to say, have these experts learned to work with others to understand and resolve problems together? For Wegerif, the importance of relationships within the group was an asset. According to his L2L2 theory, effective collaboration includes:

- open sharing
- encouraging others to participate
- active listening

- considering the suggestions of others
- discussing alternatives before making decisions
- assuming responsibility as a group for decisions.

**Wooley et al., 2016: Contributing Factors to Collective Intelligence**

Moving towards organizational behavior, there is evidence that suggests that social sensitivity plays a key role for collective intelligence. (Engel et al., 2014; Woolley et al., 2010b) This is defined as the capacity for the group to generate performance on a wide variety of tasks. If performance is the result of competence, according to Wittorski (1997), then that which contributes to the manifestation of collective intelligence should be considered a possible component of collaborative competency. According to two studies carried out by Woolley et al., collective intelligence does not correlate with individual intelligence of group members, but rather to the social sensitivity of its members, conversational turn-taking and the proportion of women in the group (an element which they hypothesize reinforces the social sensitivity element.) Often used interchangeably with emotional intelligence, social sensitivity can be defined as the "personal ability to perceive, understand, and respect the feelings and viewpoints of others (Bender et al., 2012)."

From these different researchers we've looked at through the lens of effective collaboration, we identify four essential elements in collaboration: effective communication, group cohesion, social sensitivity, and respect for interlocutors. The objectives of Soller, Wegerief and Woolley were not to identify collaborative competencies, but the actions which are produced, or which influence effective collaboration. As such, there are a number of missing elements. For example, the studies mentioned are limited to moment, to problem resolution on the short term, missing important elements for collaboration, such as its organization over time or the previous attitudes of participants.

***Towards a Generalized Collaborative Competencies Framework***

The typical position held by researchers is that collaborative competencies develop naturally over the course of activity or during a controlled experience. A table summarizing each competency framework that we have seen, divided in terms of *savoir, savoir-faire* and *savoir-être* is available in **Annex 1: Summary of competency frameworks in terms of**

**their savoirs, savoir-faire and savoir-être**

As we are looking for the common threads throughout these, we performed a thematic comparison of these works, there are several elements that align between them.

- **Communication and listening** are included in nine out of ten, using notions of sharing, active listening, and adapted messaging. Woolley is the only one to not discuss this element directly, but rather addressed conversational turn taking. This element links communication to teamwork and participation.
- **Cooperation** or **teamwork** were brought up in eight studies. This included notions of justice, talk-time sharing, sharing of leadership roles and benevolence.
- **Participation** also plays a key role, appearing in seven frameworks, in terms of speech acts, contribution of ideas and reliability.
- **Constructive conflict** appears in five studies, as a capacity to manage or resolve conflicts, engage in negotiation, or find compromises. We also include elements of open-mindedness and a willingness to try new approaches in this category.
- **Coordination or activity management** appears in four studies. Notions of evaluation of activity and effective collaboration/work appear with these.
- **Social regulation**, or notions of managing colleagues as resources, appear in four frameworks. This appears in the form of creating networks, managing differences and knowledge/skills of individuals within the group.
- There are also three *savoir-être* that are repeated: **empathy** (O'Leary et al.; Ladd et al.; Woolley et al.), **humility** (O'Leary et al.; Sanojca; Morse et Stephens) and **persistence** (O'Leary et al., Ladd et al., Hesse et al.).

The three most important notions, appearing in the work of nearly all of the chosen works are communication, cooperation/teamwork and participation. Certain others also appear with high frequency, but often the context and objective of the articles used limited the elements that appeared. For example, the OECD study and Hesse et al., do not include elements such as "work well with others" because they are looking for a way to evaluate collaboration objectively. For this reason, they use actions which are observable and concrete in their frameworks.

| Category | Competency | Savoir | Savoir-faire | Savoir-être |
|---|---|---|---|---|
| Regulation: Autoregulation / Socially shared regulation | Take action to manage, coordinate and evaluate his/her own activity as well as that of the group | Time management strategies<br>Planning<br>Performance monitoring methods<br>Reflection and evaluation tools<br>Social regulation (managing human resources)<br>Technical elements related to the topic at hand | Reflect<br>Participate<br>Scheduling<br>Offer a plan<br>Implement plans<br>Adapt plans or roles<br>Ask others to participate<br>Evaluate progress<br>Recognize and mobilize others' skills | Responsible<br>Participatory<br>Involved |
| Communication & listening | Take action to communicate with colleagues in an effective and adapted manner | ICT (Information and communication technologies)<br>Models of communication | Express his/herself<br>Share and explain ideas/information<br>Ask for information<br>Listen to the ideas of others<br>Give feedback<br>Adapt to the audience<br>Choose the correct tool or method of communication for the situation<br>Understand non-verbal communication | Attentive |
| Teamwork | Take action to create cohesion in order to obtain a common objective | Team organizational methods | Ask others for their opinion Reserve judgement<br>Take turns / divide work fairly | Engaged<br>Collaborative<br>Reliable |
| Social intelligence | Take action to recognize and respond to the emotional needs of colleagues | Motivation theories | Observe others and recognize their emotions<br>Respond to emotions in an adapted manner<br>Motivate colleagues<br>Share talk time | Attentive to the needs of others<br>Empathetic<br>Benevolent |
| Constructive conflict | Take action to monitor, manage and resolve conflicts within the group, taking into account the needs of all members | Methods of negotiation and conflict management / resolution | Negotiate<br>Accept being wrong<br>Resolve disagreements<br>Try new approaches<br>Monitor shared representations to resolve conflicts | Open minded<br>Willing to try new approaches |

**Table 8 : A comprehensive framework of collaborative competencies**

The goal of this subsection is to propose a comprehensive collaborative competencies framework, integrating different contexts and collaboration needs. We've tried to do this by integrating examples from project management (working together), school (learning together), and public administration (living together). However, it's necessary to recognize that the specificity of each of these situations could not be included.

Rather, the goal of this framework is to create a basic framework which can be built upon to include situation-specific elements.

**Regulation**

Here, regulation refers to two overlapping elements: autoregulation and socially shared regulation. It relates to the capacity of an individual and a group to structure, evaluate and maintain its activity.

The associated competency is to “Take action to manage, coordinate and evaluate his/her own activity as well as that of the group.” This includes methods, actions and attitudes linked to the management and coordination of the activity. This list in Table 8 is not exhaustive and can be modified in function of the situation.  For example, we did not include elements linked to the construction of a network of actors, even though it appears in the work of Sanojca and Morse & Stephens and there are occasions where it can be necessary in school projects (such as the establishment of a micro business managed by students.) However, this would be a rare necessity linked to a specific situation in learning or the workplace, so it could therefore be added to adapt to that specific context.

**Communication & listening**

He who says “collaboration” today, also says information and communication technology. The inverse is also true, as we pointed out in the context section, in the programs issued by the national education minister in France (Villemonteix et al., 2018) and the European competency frameworks (ESCO, 2018), the two are inextricably linked.

Using a classic, stripped down definition of communication from (Shannon, 1948), we define communication as the transmission of a message from one point to another via a channel in a way that is timely and adapted to the audience. Listening is the act of paying attention to the communications of others, receiving those transmissions.

The competency which we associate with this category is to “take action to communicate with colleagues in an effective and adapted manner.” This includes, but is not limited to, knowledge of communication tools and models for effective communication. To be considered competent, an individual should be able to share information, express themselves in a manner that is adapted to their audience, choose the best communication tool (written/oral, etc.), listen attentively to others and understand non-verbal communication and cues.

**Teamwork**

We define teamwork as “taking action to create cohesion in order to obtain a common objective.” At its surface, this category risks to be the most tautological, but in breaking it down, we find elements that are unique to this category and pertinent for collaboration. This competency includes knowledge of team organization, engaging others in the work (by asking for their opinions, reserving judgement on new ideas, taking turns and dividing work fairly.) This category also relates to trust-building to create group cohesion and a psychologically safe environment (Edmonson, 1999) to encourage participation and risk-taking. While epistemic conflict is desirable, relational conflicts are not (Buchs & Butera, 2004; Doise & Mugny, 1981), as such, the capacity to avoid or quickly resolve relational conflicts also plays a key role in this competency.

**Social intelligence**

Social intelligence is the capacity of the individual to perceive, understand and respect the emotions and viewpoints of others (Bender et al., 2012). As such, this competency entails the ability to “take action to recognize and respond to the emotional needs of colleagues.” This includes understanding motivational theories, observing others and recognizing emotions, then responding to those emotions in an adapted manner. It also includes encouraging colleagues and sharing talk time to allow all viewpoints to be expressed.

**Constructive conflict**

Finally, constructive conflict refers to the individual’s capacity to “take action to monitor, manage and resolve conflicts within the group, taking into account the needs of all members.” This includes learning methods related to negotiation, conflict management and conflict resolution. To be considered competent, an individual should be capable of negotiating, accepting when he/she is wrong, resolving disagreements, trying new approaches and monitoring shared representations (Teasley & Roschelle, 1995) to resolve any conflicts.

### The Challenge of Attitudes in Collaborative Competency Development

In choosing to use *savoirs*, *savoir-faire* and *savoir-être*, we open ourselves to the most complex part of competency development: attitudes. According to those researchers who do address these elements, it is one that they say develops naturally over the course of activity. However, this view imposes a risk for teachers who wish to facilitate the development of collaborative competencies. If we take from Dewey, experience can be educative or mis-educative (marked by experiences which limit learning and development in a certain or desirable direction) (Dewey, 1938b). As such, there is a simultaneous need to control the experience, but to allow it to take place naturally. Many people who have engaged in collaborative activity have been disappointed by the working method, and as a result now prefer to isolate themselves to complete their work, this risk seems to make teamwork (take action to create cohesion in order to obtain a common objective) a pivotal competency.

Now that we have a better understanding of what competency is, how it is formed, and some specifics of collaboration as a competency, we would like to go on to discuss the notion of physical-digital workspace. Looping back to ideas in activity mediation, that the instruments we use impact psychological processes, which can include the development of competency, it is vital to understand the nature of the artifacts with which we are working. In our case, these occupy both a physical space (taking the form of tables, boards, tablets) and a digital space (related to the software present on these physical objects).

## *1.7 Physical-Digital Space*

The notion of “space” is complex and requires an explanation of its context in order for it to be understood. If we’re talking about planets and stars, space takes on a specific meaning linked to the universe. If we’re talking about the architectural structure of an office, space refers to the workplace and its forms, or perhaps the organization of desks in “open-space.” We can also refer to cultural spaces, activity spaces, economic sectors, such as leisure space, private space in juxtaposition to public space, etc. Space is a very fragmented notion.

While there is no science of space as such, Henri Lefebvre analyzed historical discourse about space in his book “The Production of Space,” examining notions from mathematicians to philosophers and many domains in between. He proposes the existence of three types of space: physical space, mental space and social space. Physical space refers to space in the sense of the physical sciences, that which is material. Mental space makes up logic, thought, and the abstract. Social space is the domain of the "logico-epistemological" – including imagination, projections, and symbols (Lefebvre, 1974).

Each has a role to play in this dissertation. First workspace, specifically the physical space and surfaces in or on which students work together to solve problems (screens, furniture, tools, digital media etc.). Second, in order to understand the development of competencies, we must also interest ourselves in mental space. Third, as collaboration takes place in the social space, this is also a vital focus. Specifically, our interest is how the physical spaces (combined with their digital capabilities) influence and interact with the other two on the limited level of group work.

**A Workspace Typology**

Increased interest in collaboration skills and work styles for engineers/designers has led to increased interest in CSCWD (Computer Supported Collaborative Work in Design) tools and changes to the traditional single-user workspace. Multi-user interactive tables represent one such example, with researchers across various domains attempting to understand how these tabletop environments influence user behavior.

Topics investigated by researchers include table size, Human-Computer Interfacing, device orientation, etc. (Buisine et al., 2012; Homaeian et al., 2018; Mercier et al., 2014; Ryall et al., 2004; Zagermann et al., 2016) Some have also begun integrating vertical surfaces. For example, Rogers and Lindley (Rogers & Lindley, 2004) conducted experiments to examine how the physical orientation of different work surfaces impact collaborative processes. They identified several differences in work between vertical and horizontal displays during coordination and collaboration activities. They found that having a horizontal display encouraged group members to "work around it in a socially cohesive and conducive way (Rogers et Lindley, 2004)." Contrariwise, working with a vertical display rendered the interactions more "socially awkward," often decoupling individuals working at the board from the rest of the group. Meanwhile, another study using both horizontal and vertical surfaces at the University of Technology of Compiegne found that the different surfaces facilitated different types of activity: tables were most useful for divergence and the generation of ideas, while horizontal surfaces helped in decision making processes (Jones et al., 2011).

The Tatin and Tatin-pic projects, precursors to the *Halle Numérique* platform and the Cré@tion project, in which this thesis is situated, hoped to encourage engagement in collaborative design activities by removing individual input devices in favor of shared and collective spaces (Jones et al., 2012). The conversion to such spaces was seen as a way to increase perceptive crossing (non-verbal communication linked to the perception of a subject towards other subjects and the inverse) (Lenay et al., 2007), an element which is perceived to be significantly diminished when individuals work with single-user systems (laptops, tablets, etc.).  As such, questions remain about the articulation between not only horizontal/vertical displays, but individual vs. collective workspaces.

In order to facilitate the discussion of different types of physical-digital workspaces present in this study, we have established a workspace typology (Figure 17: Physical-digital workspace typology  divided along two axes: individual/collective and public/private. This *a priori* typology has been established based on our reading of existing literature, rather than as the result of an empirical study.

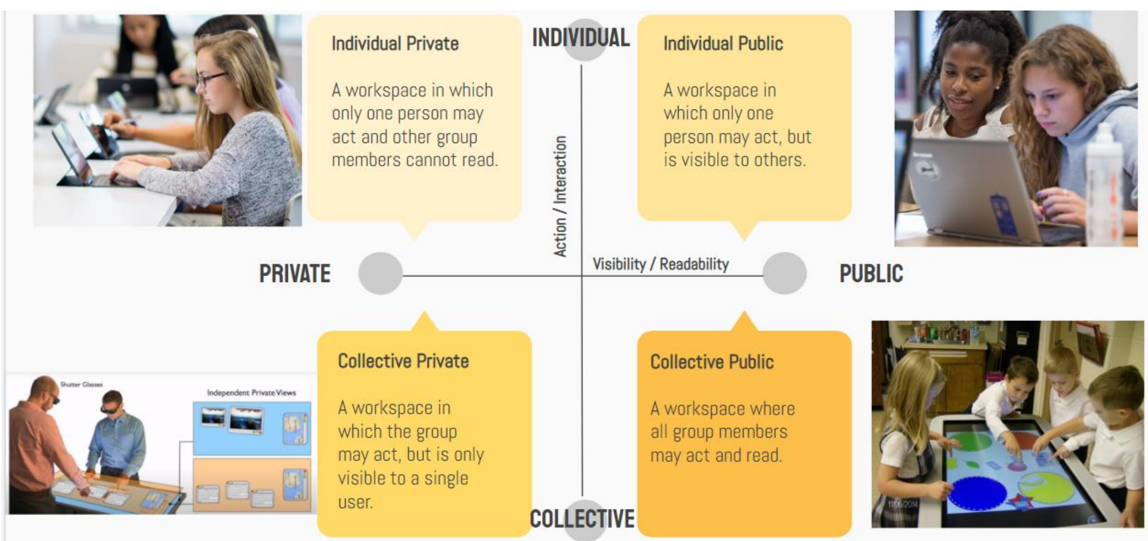



**Figure 17: Physical-digital workspace typology**

The individual/collective axis refers to the number of individuals who can interact within the space. For example, smartphones, tablets, and personal computers represent an individual activity space since only one user at a time can *interact* with the device because they do not recognize multi-user input and their size makes it inconvenient for several people to work simultaneously. Tables, on the other hand, can allow for a collective usage when equipped with multi-user software.

The public/private axis refers to the number of users who can *see* the activity (readability). Private spaces are limited to a single person, where public spaces are readable by all present actors. When placed along an axis, from one to all group members, it becomes apparent that some readability access within a workspace may be open to only part of a group (i.e. three out of five participants).

We consider these spaces to be dynamic; their identification can be based on a variety of factors, such as, sharing settings (ex.: a folder in a Google Drive shared with a sub-group, but not the entire group); a juxtaposition between a designer's intended use and the actual use of the workspace (ex.: two users contributing one finger each to zoom an image on a smartphone, while not intended or convenient, this temporarily changes the nature of the workspace); or social dynamics which may influence that use (ex.: respect for others' personal space or an individual's vs collective's perception of what a space is meant for). While we are primarily interested in physical-digital spaces, these can be material, digital, mental (such as the Joint-Problem Space (JPS) described by Teasly & Roschelle (1995)) or some combination of these.

While the other spaces can be achieved with a single instrument, the existence of a collective-private space is debatable because of the very nature of the spaces as contradictory. A collective space implies that many people can act there, while private implies that only one or a few people could see it. This would mean acting blindly in said workspace. It may instead only be practical as a specific juxtaposition of an individual private space with collective public space inside of the same tool. We could perhaps imagine it as a dashboard, where a limited number of users can view what others are doing in their own spaces or could consider those times when an individual searches his or her own personal documents while using a shared surface as such an example. The environment discussed Lissermann, Huber, Schmitz, Steimle, & Mühlhäuser (Lissermann et al., 2014) constitutes another which could be thought of in this regard - a pairing a multi-user (collective public) table top over which a private space is projected using glasses (individual private).

**The Role of Individual and Collective Workspace in Collective Activity**

Before addressing activity mediated by physical-digital tools, let's return to mental and social space and the role they play in collective activity. One example of the usage of space on such a level is the group discussion strategy Think-Pair-Share. Proposed by Spencer Kagan in 1991 (Hamdan, 2017), activities such as Think-Pair-Share can be described as a way of structuring personal and collaborative reflection, making use of private-individual mental space (think) before eventually sharing reflection with one other person (pair) and finally the entire class/larger group (share), thus transitioning from mental to social space. During the activity, teachers ask students to reflect on a question for a predetermined amount of time. Afterwards, students share those ideas with a peer, then switch roles so that their partner can share their ideas as well. While still in pairs, students discuss their ideas in order to arrive at a consensus, then share their ideas with a larger group. This method allows individual students to reflect and organize their thoughts prior to sharing (Lom, 2012).

Research on this method has demonstrated that time used for reflection, followed by discussion, opinion sharing, and feedback received from peers and teachers helps develop self-efficacy and participation. It also improves results on tests (Hamdan, 2017; Lee et al., 2018). The "think" portion of this tool is an example of individual-private space. However, students can also write their ideas on paper (material/physical) or on a computer (digital). During the sharing process, the nature of the workspace can change. We find it important to recognize this, even if it is difficult to pinpoint without externalization on the part of the subject. Those who revert from an internal monologue to an external one, in the form of narration or self-explanation, leaving the private-individual workspace, and entering into individual-public space as other participants now have "read access" to the thought construction process. Workspaces can be both part of the environment and a cognitive construct. The elements within an individual-private space are introduced into a public space via verbalization, sharing of notes, or become collective if the partner adds or modifies elements. This type of activity, in a space that is individual or private, can be linked to the division of work that is part of individual work and cooperative processes.

A few studies have taken up the banner of the role of individual space in collective activities. Gracia-Moreno, for example, studied the articulation between private and public spaces for the collaborative construction of knowledge via concept maps. Students worked together using computer software which provided a shared workspace as well as a private space, specific to the individual. Much like the results found in Think-Pair-Share research, she demonstrated that after working in a private space, students were more capable of expressing their knowledge (introducing and explaining). Additionally, using these spaces made epistemic conflict more likely during sharing phases as students had more time to develop their ideas, they were more capable of defending them (Gracia-Moreno, 2017).

## PART ONE CONCLUSION AND SUMMARY

The goal of the research project in which this thesis is embedded was to understand if, how and to what extent these techno-pedagogical devices used at UTC could be mobilized to facilitate the development of collaborative competencies. This point of departure led us to investigate the state of the art on several topics: what does the use of instruments have on psychological processes? What is meant by collaboration and how do we identify it? How can we talk about these techno-pedagogical devices, which go beyond just the digital or just the physical, occupying both spaces? The answers we found to these questions in the literature led us to believe that there is likely some impact of the instrument being used on competency development.

Sociocognitive theories of education reveal that it is through experience and engaging with others that we *learn* to engage with others and become active participants in society. Vygotsky theorizes that instruments impact our psychological processes. Rabardel demonstrates that instruments can change our interactions with each other, the objects upon which we are acting and even our own reflection or perceptions as we are transformed through our action. Wittorski and Pastré tell us that through action we can develop competency. We see clearly in these theories that through action an individual can be transformed and that there is a relationship between the artifacts and the potential to act which can, in turn, lead to competency development. But what is this link? How can we qualify it in the context of collaboration? How can we demonstrate its presence or lack thereof? This led us to pose our own question: What is the impact of physical-digital workspaces on collaborative processes, and by consequence the development of collaborative competencies? What methodological tools can we use to bring some elements of response to these questions?

In part one of this dissertation, we positioned our research within the socio-constructivist current, especially in regard to experience and interaction with others as central to learning. From there, we explored the different methods for analyzing activity in complex circumstances, especially when that activity is mediated by the use of tools. This allowed us to show that activity cannot be understood in a vacuum but must be analyzed on at least two levels: that of the context (cultural-historical) and that of the individual subject in relation to the group and the means. This double-level analysis allows us to understand the shifting nature of the individual engaged in a collective activity.

From there we discussed collaboration, specifically how the term is used, the differences between it and cooperation, and the interactions which take place within collaborative activities. We revealed three dominating paradigms of collaboration: as a method for learning, a method for working, and a philosophy of interaction (a way of being in society). These different paradigms often overlap within given contexts, making collaboration even more difficult to delimit, as it is linked not only to a method, but to an intention. Despite this, based on research from CSCL/CSCW, we define *collaboration* and *cooperation*. *Collaboration* is the co-elaboration and co-evolution of tasks, ideas and concepts in order to create a joint product. *Cooperation* refers to the negotiation and convergence of work completed separately in order to create a cohesive product. We nest them within a more complex structure called *globally collaborative work*, which refers to five modes of interaction which appear when a group is working together: individual work, communication, coordination, cooperation, and collaboration.

We also discussed competencies, what they are and how they are developed. We define competencies as an "ability to act" (*savoir-agir)* (Tardif, 2018) made up of *savoirs* (theoretical knowledge…), *savoir-faire* ("know-how", knowledge-in-action, procedural knowledge) and *savoir-être* ("know how to be", personal qualities, production of adapted actions…) (Boudreault, 2017; Hatchcuel & Weil, 1992; Pastré, 2004) which a person or group can mobilize in a given situation, based on their understanding of that situation. We go on to present our research on collaborative competencies, beginning with a bibliographic analysis before exploring collaborative competencies as an object of study, an analysis framework and then extracting elements of effective collaboration in order to describe a generalized competency framework. The proposed framework consists of five key competencies: regulation, communication & listening, teamwork, social intelligence, and constructive conflict.

Finally, we discussed the notions of space as thought of by Henri Lefebvre. We then focused on different types of workspaces, in relation to readability and interactivity. We presented a typology on two axes: individual/collective and public/private. Lastly, we discussed the role of individual or private space in collective activities, demonstrating that the presence of such space allows users to formulate their thoughts, thereby facilitating participation, sharing and the emergence of epistemic conflict.

# PART TWO: EXPERIMENTAL METHODOLOGY

## PART TWO INTRODUCTION

This part is divided into two chapters. In Chapter 2, we will discuss the appearance of tactile technology, especially tactile tables designed to facilitate collaborative group processes. Next, we'll discuss the development phases of the *Halle Numérique* platform used in this research and analyze its uses from the perspective of its designers. This will allow us to expose tensions which exist between intent and real usage during the descriptive study phase, in which we analyze real (as opposed to theoretical or those intended by designers) uses by students and teachers.

In Chapter 3, we discuss our research question and methodology. We begin by clarifying the object of our study. This includes a complex system of the student's activities, experience, reflection (construction), and competencies (those of the group and each individual member of that group). It is with this in mind that we designed our protocol, data collection methods, and coding/analysis schemas which we detail here. We have taken an intersectional approach, with both qualitative and quantitative data.

# CHAPTER 2 TACTILE TECHNOLOGY AND THE DEVELOPMENT OF THE *HALLE NUMÉRIQUE*



### *Chapter Introduction*

In this chapter, we will cover the appearance of tactile technology from the 1980s up to now, including the development of the *Halle Numérique* platform. We feel that it is important to understand why we are seeing a move towards tactile technology and especially multi-user tactile technology. We also want to point out that this thesis is embedded in a context with a long research heritage. The technology we are using in our study has been developed over the last 15 years through various research projects, largely in engineering sciences. This is the first time that the Halle Numérique platform is being looked at through the lens of educational sciences; we will discuss why and what that means at the end of the chapter.

### *2.1 Tactile Technology*

Tactile technology has seen a huge increase over the last ten years. While the technology existed as early as the 1980s, it didn't take off until 2007 when Apple introduced the iPhone (Cohen, 2007). Figure 18 shows Apple's self-reported sales from release to 2017. Their data indicates an exponential rise in the use of the iPhone since it was introduced. It is also important to note that the graph only displays figures for the iPhone, not including the iPad or touchscreen devices from other companies such as Samsung, Google, LG, Sony, etc. Beginning in 2010, with the introduction of the iPad to the market, these devices began appearing in schools. By 2013, 53% of students were using tablets several times a week[3]. Research continues to be conducted regarding their usage in the classroom.

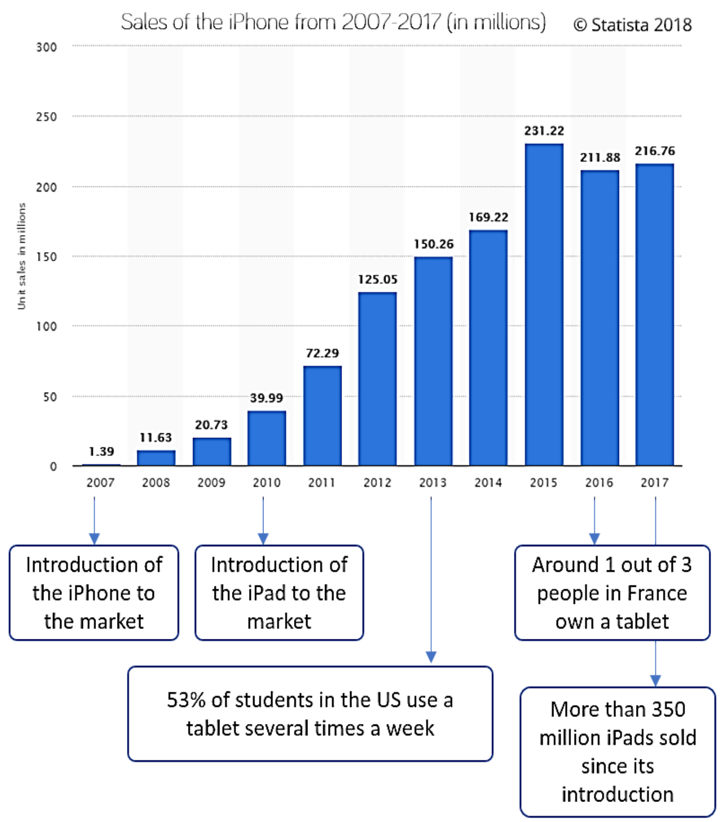



**Figure 18 : Sales of the iPhone from 2007-2017, annotated**

[3] Usage by students in the United States: https://www.statista.com/statistics/273855/full-size-tablet-usage-frequency-for-school-work-by-us-students-by-education-level/ Penetration rate in France: https://fr.statista.com/statistiques/507003/utilisateurs-tablette-penetration-france/

## Tactile Tables

Research around tactile tables began to appear in the early 2000s, with the study by Rogers & Lindley (2004), projects like TATIN (2009) and the installation of the *Halle Numérique* platform at the University of Technology of Compiegne between 2014 and 2015. Since those first experiments, a number of other research projects have also sought to understand how interactive tabletops could be used to support collaborative work and learning. Topics investigated by researchers include table size, Human-Computer Interfacing, device orientation, etc.

In the *Interact Lab* at the University of Sussex, Rogers and Lindley (2004) conducted experiments to examine how the physical orientation of different work surfaces impacted collaborative processes. They identified several differences in work between vertical and horizontal displays during coordination and collaboration activities. For example, having a horizontal display encouraged group members to "work around it in a socially cohesive and conducive way." Contrariwise, working with a vertical display rendered the interactions more "socially awkward," often decoupling individuals working at the board from the rest of the group.

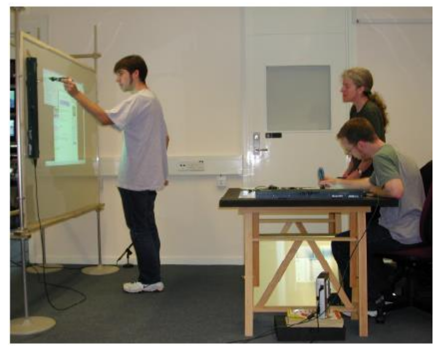


**Figure 19: Table & board setup (Rogers & Lindley, 2004)**

Ryall, Forlines, Shen and Morris (2004) explored the issue of group size and table size on interactions with shared-display groupware. In their research, they used a single problem-solving task. A poem had been broken into separate pieces and needed to be reassembled. During their research, they found that larger groups completed the task more quickly than smaller groups, likely due to the nature of the task and the amount of searching required to complete it.  The size of the table compared to the size of the group had no significant effect. Subjects' opinions, however, were impacted by the size of the table, but not the

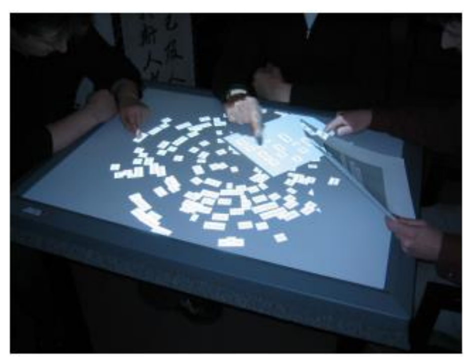


**Figure 20: Table setup (Ryall et al., 2004)**

group, with a strong preference for the larger table. The size of the group did affect how the tabletop was used as well as the emergence of certain social interactions. For example, groups of two worked closely together, sharing space and resources while groups of four were more likely to emphasize personal contributions, cast blame for problems and make use of an animator to control the resources. In terms of the tabletop, in both cases, an individual workspace was appropriated for each user, and participants were hesitant to interact in the space of another user (Ryall et al., 2004).

Buisine et al., (2012) sought to understand how tabletop systems influence collaboration, especially in terms of equity of contributions, when compared to pen-and-paper tools. They found that the table space increases collaborative behaviors and decreases social loafing. They hypothesize that this may be related to the closeness and perception related to sitting around a common workspace with common objects. The proximity created by such spaces allows for “more subtle communication channels.”

The SynergyNet project, which started in 2011 and ended in 2014, had the primary objective of creating a technology that would foster collaborative learning situations in the classroom (Mercier et al., 2014). In one section of their research, they compared a multi-touch environment to a paper environment to explore differences in group interactions. Much like other research using similar comparisons, their results indicated that ideas produced were similar, but students were more likely to combine and co-build ideas in the multi-touch environment (Mercier et al., 2015).

**Figure 21: Synergy Net project**

All of this research, and much more which is not discussed here, points towards tabletop environments being conducive to collaboration and collaborative learning. However, questions about the influence that such workspaces have on learning to collaborate have not been answered. The “why?” is not difficult to answer. As we have discussed, evaluating competency is a complex process, which does not lend itself well to empirical research. Some of the most pressing questions are those of transferability: When users collaborate using this kind of technology, to what extent do they develop knowledge which is useful when not using the technology? In what ways are the schemas formed relevant to other situations? How are users' attitudes towards collaboration impacted?

### *2.2 The Development of the Halle Numérique Platform*

In this section, we present the technology that was used during the research, which allowed for the examination of various combinations of physical-digital workspaces and the analysis of their influence on the emergence of collaboration and development of collaborative competencies. The *Halle Numérique* platform was developed over a series of research projects at the University of Technology at Compiegne. These hardware and software systems were designed to facilitate collaboration during preliminary design phases with engineering students.

The first project began in 2006, focusing on interactive whiteboard technology. However, the single-user system was deemed inadequate for collaborative sessions. Issues with shadows and single-user software presented numerous problems. It was at this point that the first interactive prototypes were put into place. This testing took place until 2008, when the first experimental table prototype was created.

This table was designed to test the multi-touch technology and facilitate collaborative discussion. At that time, researchers were focused on analyzing a single activity phase in a single session. In 2009, the Tatin research project was launched, and the decision was made to focus on horizontal surfaces, based on recent research indicating that it was more efficient for creativity.

At the same time, over 2008 and 2009, a second prototype was being designed with improved resolution and precision, to make it compatible with professional software. In 2010, the Tatin-Pic project was launched, financed by the Picardy region of France. It was around this point that researchers decided to pair the horizontal surface with a vertical surface to facilitate the different types of processes that were taking place. Horizontal surfaces were determined to be best for divergence and creativity, while vertical surfaces facilitated decision-making and convergence. The Tatin-Pic project lasted until 2013, when the start-up Ubikey, which today continues to develop the software associated with the system, was launched.

From 2014-2016, the University of Technology of Compiegne installed the *Halle Numérique* (digital hall), where this technology was made available to teachers and students. Today, UTC has five sets of the system, consisting of a large tactile table (horizontal) and board (vertical). Each of these is equipped with a software suite that allows for collaborative work - a simultaneous interaction of multiple people on the same surface.[4]

The most recent project, Cré@tion, in which this dissertation is embedded, began in 2017 and will continue until 2021. This latest project aims to understand how such tools can influence collaborative processes and the development of collaboration skills.

Future projects are also being planned, most notably a collaboration with Japanese researchers interested in facilitating collaborative work between separate sites.

**Figure 22:** ***Halle Numérique*** **Research project timeline**

[4] http://ubikey.fr/notre-histoire/ & http://www.utc.fr/tatin/TATIN/PROJECT.html

## *2.3 Platform functionalities*

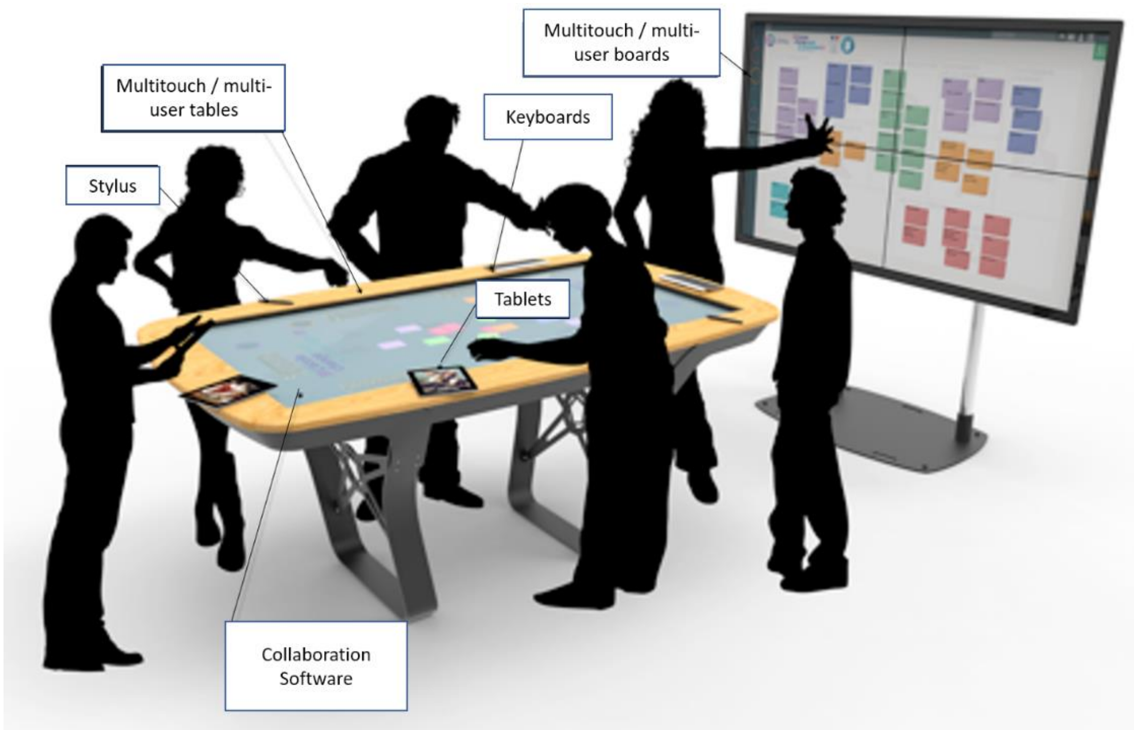



**Figure 23: *Halle Numérique* platform**

Using digital tools as a topic of research necessitates an in-depth analysis of each tool, its interface, mechanisms, assumptions, and anticipated uses in order to make sense of the limitations and the affordances offered by the proposed workspaces.

The system, as it exists today and is used in this research, consists of a multi-touch, multi-user tactile table and board setup. The tables have an UHD screen (3840x2160 pixels) at 84" (1860x1046 mm). This allows for a comfortable space for each individual user at the table, making individual reflection, research, and note-taking with a virtual keyboard (with no limitations for the amount or location of keyboards) possible within a common space.

The horizontal space (table) allows for face-to-face work, with perceptive crossing (non-verbal communication), and are used most frequently for the production of information and the proliferation and divergence of ideas (Jones et al., 2012). The board also has an UHD screen (3840x2160 pixels) at 86" (2042x1151mm). This space is designed for the sharing and organization of information produced by participants. In addition, any device with an internet connection and browser (smartphones, tablets, laptops) can connect to the session and be used for the individual production of written notes, drawings, images, etc. The table is designed to be at waist height for an adult - taller than typical tables. They are surrounded by stools which permit a fully-seated or half-standing position. They are lightweight and easy to move around.

**Functionalities common to table and board**

There are some functionalities common to both the vertical and horizontal surface. The most important is, arguably, the main menu. To open the menu, the user must press his or her finger on the work surface and hold it there for approximately two seconds. A circle appears and loads as a visual indicator that the menu is about to open. This was done in order to differentiate between a "false touch" (such as simply pointing at an item on the board), the user's desire to move an item, and the desire to open a menu. The menu itself (Figure 24) has several options: create a drawing-type post-it, create a text post-it, select multiple items, open a web browser, and use a local file search.

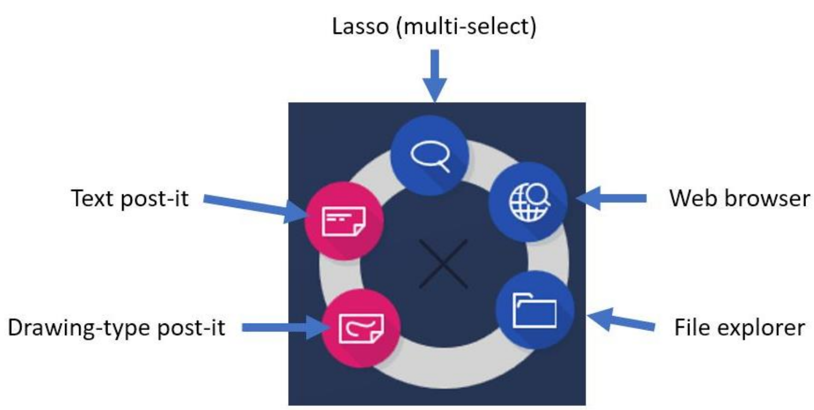



**Figure 24:** ***Halle Numérique*** **platform: System menu**

The most basic and common object is the text post-it note. The default note is yellow and rectangular, to resemble a paper post-it note. When this item is chosen, a virtual keyboard appears with the post-it note attached at the top. In addition to a text keyboard, there are several emoticon keyboards with a diverse library of icons, from traditional faces to food items. Typing on the keyboard can be difficult because of the sensitivity of the device, so users are forced to type slowly, waiting to ensure that their input was correctly recognized. Users accustomed to typing quickly on a physical keyboard can become frustrated by this. Word suggestion was put in place to facilitate the typing process, requiring only the partial entry of a word via typing.

On the post-it note itself, there are several options (Figure 25)

- Anchor: Anchor the post-it note in place to prevent movement.
- Edit text: Once the post-it note is detached from a keyboard, it becomes movable (as long as it is not anchored) and the text is unmodifiable. Tapping the post-it note to open the object's menu gives the option to modify the text and opens a new keyboard.
- Change shape: The shape defaults to rectangular, but it can be changed to a square, oval, diamond, arrow, etc.
- Change color: There are seven color options. These were intended to allow groups to create different categories of items, especially when combined with shape options.
- Add a dot: Dots are simply round circles of various colors, intended for voting or marking post-its notes. Multiple dots can be placed on a single post-it note.
- Change font size: Make the lettering larger or smaller – typically used to call attention to items (titles) or facilitate reading from further away.
- Straighten: Because all of the digital objects can be rotated, users tend to spend a lot of time trying to straighten them manually. To avoid time lost to such an activity, an automatic adjustment option is available.
- Create a link with another element: The pink button with a chain-link icon (Figure 25) allows the user to drag a line from the post-it note to another object on the same surface. That link can then be modified in terms of color, thickness, and arrow direction.
- Copy object: The object can be copied to prevent users from needing to rewrite similar phrases. It also allows for a copy of an object to be transferred between different documents.
- Delete object

These last three elements are common to all the digital objects (post-it note, drawing, and images).


**Figure 25:** ***Halle Numérique*** **platform: (left) post-it note and menu; (middle) drawing-type post-it note; (right) using the navigator to move images into the workspace**

The next type of digital object is the drawing-type post-it. The drawing post-it allows users to create free-form drawings. Once the modify button is clicked, users can choose colors and brush types to draw. When finished, it must be confirmed before the object can be moved. This alleviates the technical difficulty of trying to tell the difference between a desire to draw and the desire to move an object.

The navigation function uses a Chromium browser (an open-source browser project). Like any other navigator, it allows users to access the web, use search engines, open websites, etc. Users can also copy text from a site to create a new post-it note or export images from the browser to the table's workspace. Once in the table's workspace, the image becomes modifiable, gaining the same functionalities as the drawing-type post-it.

Lastly, the file search menu item allows users to import PDF documents into the digital workspace. Once imported, only one page at a time is displayed, with a navigation arrow to go to other pages. The document can be copied and set to different pages if the user wishes to view multiple pages at a time. It is also possible to draw directly on the document.

**Board functionalities**

Some functionalities are specific to the vertical surface (board). The capabilities of the application for this surface were designed based on the assumption that the vertical surface will be used for decision-making according to studies by Rogers & Lindley (2004) and Jones et al., (2012). When first connecting, users log in with their personal accounts (or group account, as is the case for our participating high school and middle school groups). Once connected, the software is organized by projects, inside of which is a file system. It is possible to add other participants to the project, so that all members can access work inside or outside of the class via a browser (a separate tool with its own specificities). On the main menu of the project, previously created documents and files are available. To the right there is an option to create a new document, where a variety of built-in templates are proposed. Most of these are tools related to analysis and design common in engineering as well as project management, such as the Ishikawa diagram (used to analyze cause and effect), SWOT (a strategic planning tool to help identify strengths, weaknesses, opportunities, and threats), GANTT (used for long term project planning), etc. There are also two blank templates: the white board and the flow chart.

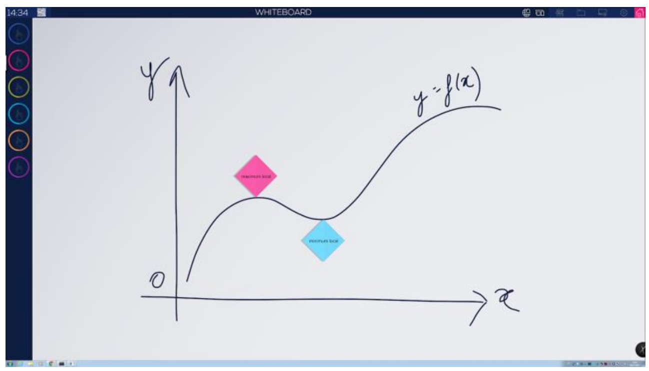



**Figure 26: *Halle Numérique* platform: whiteboard drawing**

The primary difference is the possibility to draw directly on the board using the whiteboard functionality, where any drawing must occur on a drawing-type post-it in the flowchart. In addition to these suggested templates, it is possible to import a PDF and set it as the background template.

Lastly, the board allows for work on two separate documents (templates) or a document and a navigator with a split-screen functionality.

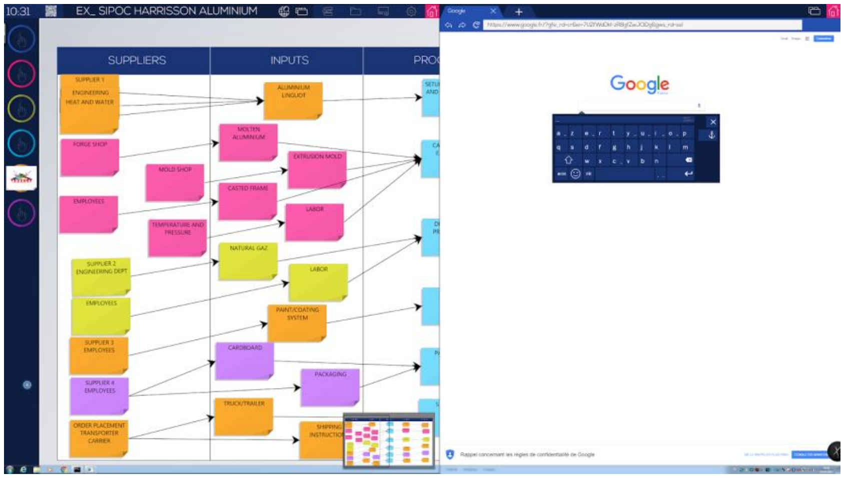



**Figure 27: *Halle Numérique* platform: split screen**

Digital objects can be transferred seamlessly between the two documents in split screen mode. A mini-map of each document appears at the bottom right, allowing users to navigate across their document when the other half of the screen is in use (Figure 27).

**Table functionalities and other devices**

There are no functionalities that are specific only to the table surface. Rather, it loses some of the functionalities that are available on the board, notably those related to the document management system. The table was designed based on the assumption that the table surface will be used for divergence, creating different viewpoints, and creativity. As such, it is a space around which users discuss ideas and on which users are expected to generate written ideas. It is typical for users to appropriate a space at the table for themselves and for other users to respect that space.

Upon launching the software, there are six portals (colored circles) positioned in the center of the table. These can be moved around and placed within reach of one or more people. These portals serve as a wormhole for digital objects to be transferred between the table and the board. They each have their own color to facilitate the movement from board to table, should someone wish to redo work on a post-it. Knowing the color allows it to be sent to a specific portal, and therefore a location/person. On the board, all portals are lined up on the left side of the screen and are not movable. When an object is in a portal, it appears in the portal on both the board and table surface until it is removed to one or the other of the work surfaces. No object can appear in both places at once for modification, only for this transfer.

While other devices can be connected to the system (smartphones, tablets, personal computers) the interface and possibilities are designed based on the assumption that these are supportive technologies, primarily for sending items into shared space. When accessing the system from such a device, the interactions are limited to: writing post-its, modifying their shape and color, selecting the destination portal, and sending images or photos. However, post-its cannot be returned to these mobile devices through the portals. Once the smartphone user sends the post-it, it will appear in the destination portal and be recoverable from both the board and table surface.

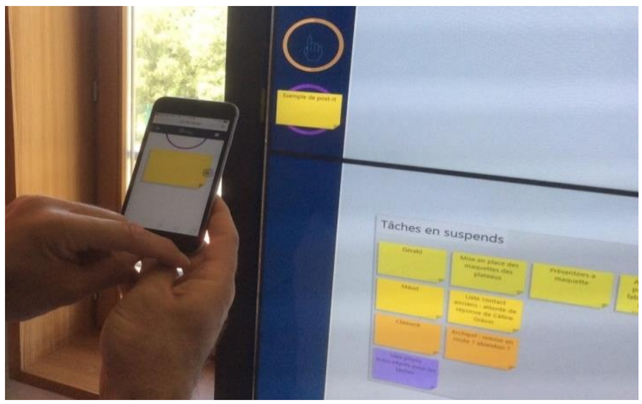



**Figure 28:** ***Halle Numérique*** **platform: post-it on smartphone**

**Limitations**

While this system is very stable and user friendly, there are a few limitations that must be considered. First off, the hardware and the software must be taken into account both separately and as a single system. The hardware used for this study was built at UTC from 2014 to 2015. As such, the hardware technology in use is no longer the best available on the market as of 2018. Large screens are now cheaper than they were at the time of development and new tactile technology has been developed. The software can work on any of these systems, as long as the hardware meets the relatively low minimum requirements. As such, the user's experience is linked both to the hardware and the software.

In the context of the *Halle Numérique* platform, smartphones and computers are often preferred for user input over the tactile keyboard on the table. This is due to the users' familiarity with their own devices and the ease of typing. This is linked to the hardware itself and may vary from system to system based on the tactile technology used. For example, three of five tables in the *Halle Numérique* use an infrared laser system, detecting interruptions in the laser grid and interpreting those interruptions as input. In 2018 and 2019, two of the systems were converted to a capacitive system, like those used on smartphones and tablets. The infrared system interprets anything as input, including clothing, hair, papers, etc., while the capacitive system is designed to ignore these in favor of human touch.

There are also some technical limitations and ergonomic considerations that have gone into the software's functionalities and designs. For example, many users try to double tap post-its in order to modify the text - a functionality which exists on smartphones. However, unlike on a smartphone, a post-it is also movable, so to differentiate between the desire to move it or the desire to edit it, the edit function must be accessed via a menu that appears after a single tap and disappears after ten seconds without additional interaction. For first-time users this is counterintuitive based on their previously developed usage schema for tactile devices. This either forces them to assimilate the new usage schema or to re-evaluate whether or not the purpose of the application of this usage schema merits that assimilation. This is the source of numerous recommendations for changes to the software to fit their pre-established usage schema.

Many recommendations received for updating the software itself are often related to a tension between what users are "used to" and what is technologically feasible. Likewise, some requests are related to hardware rather than the software itself, such as responsiveness or text entry speed. Requests related to the software are taken into account by the startup which markets it to businesses. However, some requests may not be feasible for security reasons. For example, users can become frustrated when accessing their Google Drive from the built-in browser because closing the window disconnects the user from their Google account. They are required to reconnect when launching a new browser. However, this is necessary because usernames and passwords are not stored for security reasons.

What becomes clear as we look at these limitations is that many of them go back to users' habits, or what they're accustomed to doing with their own devices. There seems to be a relatively stable class of situations around the usage of tactile screens. These have entered into tension with those related to the tactile tables and boards, requiring a renewed process of instrumentation and instrumentalization.

### *Chapter 2 Conclusion: What Role for Educational Sciences?*

Up until the end of 2017, the research projects that led to the development of this technology were heavily rooted in engineering, from IT to design. The Cré@tion project is the first to integrate educational sciences, the question is: why? If we ask, “What is the role of technology for education?” the response comes easily. Technology facilitates access to resources, allows students and teachers to change from their traditional roles, may allow for the efficient development of certain knowledge, or even serve as a source of motivation for some. Sometimes technology can become so integrated that you no longer even realize that it is present (Baron et al., 2013).

However, if we ask the same question in the inverse, “What is the role of education for technology?” the responses are much more complex. Normally, when a new technology appears in the classroom, it is because there is a wish to integrate it into the classroom, without necessarily reflecting on the constraints or problems that may appear. For example, giving tablets to a teacher does not guarantee that he or she will use them and even less that such usage will be efficacious (Villemonteix et al., 2015). This is not the result of a lack of desire, but a lack of support and understanding of the reality of teachers and their students. As such, the presence of educational sciences during phases of conception, or in this case potentially the preconception/adaption of a technology, permits us to understand the effects of these technologies on learning and identify situations where it can augment the experience of students and teachers.

Ultimately the decision was made to include educational sciences as part of this series of research projects because the devices we described were introduced to students and teachers with relatively little understanding of their impacts and limitations. Indeed, it was observed that students were struggling to work together and even resisted adopting the tools on some occasions. The Cré@tion project, as an extension of these previous projects, aims to develop a better understanding of these technologies in the context of education prior to introducing them into the classrooms in the region. This way we can evaluate considerations such as the forms of the technology, the spaces in which they are integrated, as well as the support that needs to be given for such an endeavor to have the desired effect: facilitating the development of collaborative competencies.

# CHAPTER 3 RESEARCH QUESTION AND METHODOLOGY



***Chapter Introduction***

Although we know that tools influence the nature of collective activities (Gracia-Moreno, 2017; Lenay et al., 2014; Rabardel, 1995), very little is known regarding what that means concretely for the articulation between different types of physical-digital workspaces and the impact on student activity and learning during collaborative group work. Our goal is to analyze the impact that the use of such workspaces (digital, tactile, and multi-user tabletop and board) have on how students work together and the skills they develop. As such, we ask the following question: How do physical-digital workspaces influence interactions within student work groups, and by consequence, the development of collaborative competencies?

This question gives way to two hypotheses:

H1: The characteristics of the workspace have an influence on the collaborative processes implemented by students during collective activity.

H2: The characteristics of the workspace have an influence on the competencies developed by students.

In this chapter, we investigate how our research question could be answered from a methodological perspective. What methodological tools and analysis are most useful?

***3.1 Object of Study***

How do we define the object of study in our research? What do we mean by the role of technology in the development of collaborative competencies?

Our research object relates to the expression of competency during students' productive activity as they complete collaborative group work while using specific physical-digital workspaces.

What do we mean by the expression of competency during productive activity? We find in the literature on competency that there are several popular methods for competency evaluation (general and technical) at the level of the individual. These methods are most notably linked to the evaluation of performance, or the completion of work, which is supposed to have necessitated the mobilization of the competencies in order for it to have been completed, as is the case of the portfolio (Tardif & Dubois, 2010). In addition to the well-documented limitations of this type of approach, collaboration as a competency is particularly challenging. A grade, degree, or certification is necessarily validated based on individual competencies, where collaboration is necessarily with others. How then do we use the evaluation of performance of a group to attest to the individual acquisition of competencies which are, by nature, collective? If the group is successful, must we consider that he or she who said nothing possesses a competency, one to keep quiet in favor of collective success? The fact that one person in a group uses one of the desired competencies does not mean that all of the group members have developed it, but the fact that they didn't mobilize it also does not mean that they do not master it (perhaps that the opportunity simply didn't arise or the "place" for the activation of the competency was simply occupied by another group member). There are many tensions in such an approach. How then can we understand a competency which is by nature both individual and collective? Methodologically, we have made the choice not to identify a competency as acquired, but simply as "activated" or "expressed". This idea comes from the notion that competencies are "situated", mobilized in certain classes of situations by the actors with their diverse dispositions; these competencies are being viewed as not generic or independent of their work and learning contexts. In other words, we have considered the know-how mobilized over the course of a session in order to say whether it is possible or not to develop that competency in the given situation based on the actions of an individual within the context of the group's interactions.

Figure 29 is an apt summary of our conceptual framework. Using the PAWs model from Samurçay & Rabardel (2004), we have color-coded the variables in such an ecosystem in relation to our research interests. The independent variable, represented here in gold, is the instrument being used by the group. The controlled variables, represented in blue, include the situation (elements related to the specific task, the templates or activity sheets used, and instructions given, etc.) as well as the social groups (external knowledge and techniques), in this case mediated by the teacher or provided supports (such as the course workbook). Finally, our dependent variable, represented in white, is a rather more complex system of the student's activities, experience, reflection (construction), and competencies, along with those of the group and each individual member of that group. It is with this in mind that we designed our protocol, data collection methods, and coding/analysis schemas.

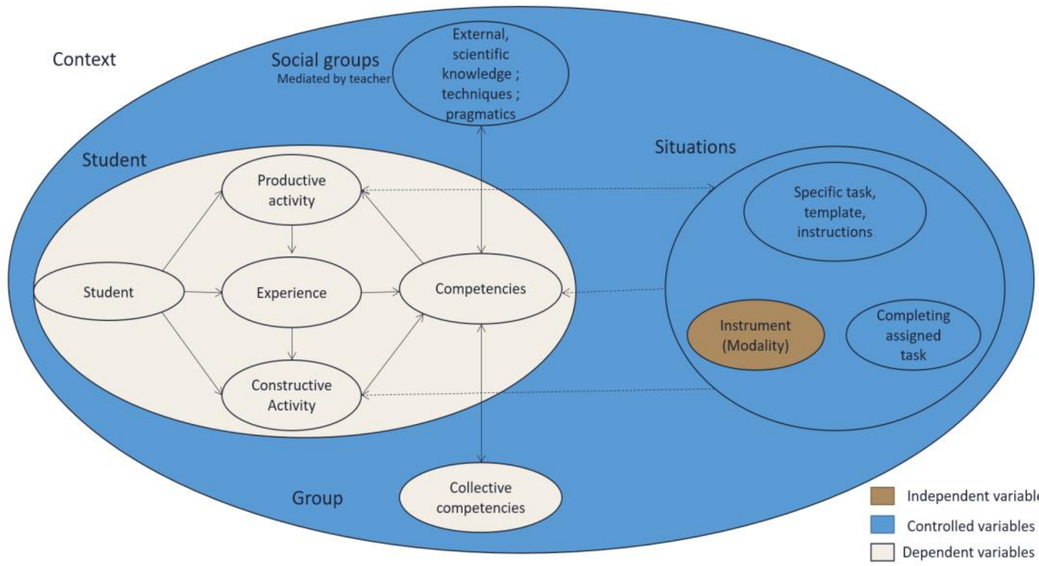



**Figure 29: Identification of experimental variables using the PAWs model**

There are a number of other objects present in this research space that we will not focus on in our present dissertation. For example, our research object does not include an in-depth look at all potential workspaces and configurations which are possible, or even all of those possible while using only the *Halle Numérique* platform. That is to say, the modalities of physical-digital space we look at are not exhaustive. As you will see in the next section, we have chosen three modalities and compared them to a non-instrumented session. When using the terms "technology" or "instrumented" versus "non-instrumented," non-instrumented is referring specifically to not using the *Halle Numérique* platform, not a total lack of any artifacts or tools. Additionally, it is important to note that our research is not interested in a specific age group, though we do note that this can also be a contributing factor in the development of competencies due to a maturity of experience and constructive activity. However, for practical reasons, we will discuss groups from two populations who participated in various parts of our research: high school students and university engineering students.

### *3.2 Methodological Choices: An Intersectional Approach*

#### A Mixed Method Approach

Firstly, we would like to explain our choice to use a Design Research Methodology Approach, using qualitative and quantitative data.

In order to respond to our research question about the influence of physical-digital workspaces on the development of collaborative competencies, we identified three secondary questions which heavily influenced our methodology:

- What kinds of interactions occur during group work?
- How do we monitor the development of collaborative competencies?
- How do we characterize activity mediation during group work?

When designing our research protocol, we faced numerous challenges, most notably, the ecosystem within which the study takes place. While it would have been possible to create purely experimental sessions outside of the traditional classroom infrastructure, we wanted to keep that ecosystem in place, preferring a true-to-life scenario which would allow us to capture and take into account the tensions which exist in a real teaching environment during collaborative group work.

We felt that using quantitative data would give us a more objective view of the impact these tools have on collaboration. However, understanding that such methods are not necessarily sufficient to make sense of the numbers generated, a mixed method approach was adopted, using observations to better understand the context, conditions, preferences, and reasoning behind actions and interactions occurring during group work.

#### Observing Collaborative Competency Development

In this section, we would like to address the question of how to observe the development of a competency that necessarily occurs over time in a space with collective activity.

It is generally agreed upon that observing the development of competency directly is not possible, so how then can we determine whether or not a student is developing collaborative competencies? We define competency as an ability to act, first and foremost. This ability to act is built upon theoretical knowledge, procedural knowledge, and personal qualities, but ultimately competency is evaluated based on whether a person can act in a given situation in a way that is determined to be acceptable. Who determines whether the action is acceptable depends on that situation? In the context of school, it is often a teacher whose determination matters the most, though peers will form their own assessments. In a work scenario, it is often a combination of the hierarchical superior and peers. As Wittorski's five developmental paths suggest (1997), competency is also developed over time through logical action, iterations of activity and reflection, retrospective reflection, reflection prior to activity, or controlled transmission and production.

A study which aims to understand the development of collaborative competencies must take into account what students are doing, the quality of those interactions, and their change over time. So, if we are trying to understand an ability to act that develops over time, upon reflection, we consider it logical that we can observe the actions undertaken over the course of many group sessions and the impact that those actions have on the collaboration. Nevertheless, there are very practical limitations to observing such a process, including limited time. Collaborative competencies are being constantly revisited and revised as they are put into action. The development has also likely been in construction for a long time in high school and college-aged students. As such, it seems a stretch to believe that a single semester would be enough to determine if the competency is acquired or even if major changes have occurred. However, while we believe that validating the competency as acquired seems out of reach, we can consider if actions linked to the competency appear during the observed sessions.

### *3.3 Research Protocol*

Following a Design Research Methodology approach, our results came from three research phases: A research clarification phase, an empirical analysis phase (Descriptive Study, Figure 30), and an experimental phase (Prescriptive Study). Finally, these results were subject to an empirical analysis from which we have drawn our conclusions (Blessing & Chakrabarti, 2009). In this section, we will describe our approach to the Descriptive and Prescriptive study.

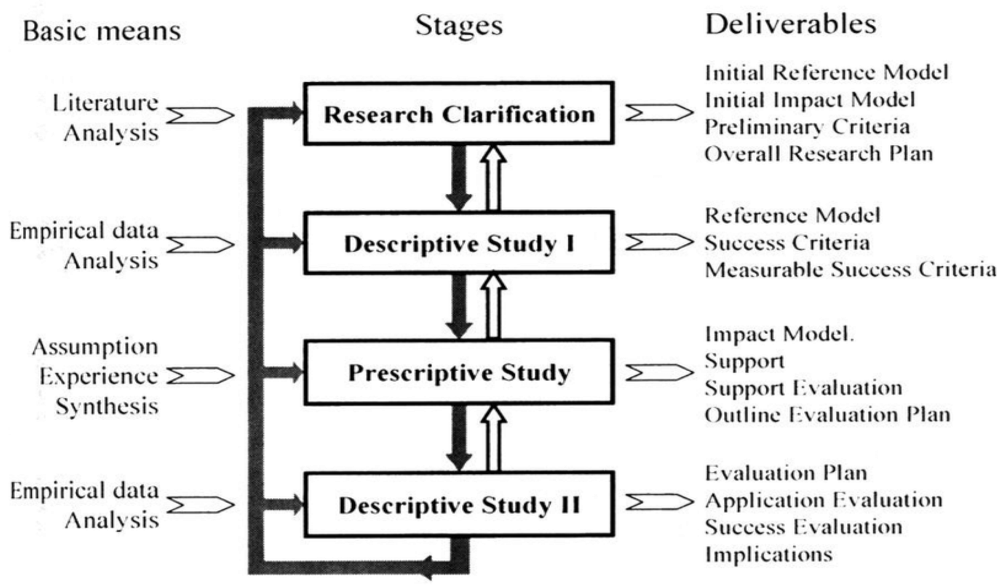



**Figure 30: Design Research Methodology (Blessing & Chakrabarti, 2009)**

### Descriptive Study

The descriptive study had two primary objectives: (1) helping us develop an understanding of the technology being used and how students and teachers use it for classwork and (2) developing and validating a reference model for collaborative interactions based on our literature review and observations.

The descriptive study took place over the Cré@tion project's first year, from November 2017 to June 2018. During this time, two separate sample populations were observed. The first consisted of 30 students from a French technical high school (P1) and the second of 29 university engineering students (P2) participating in two different courses.

This section has been separated into two parts, based on the student groups, in order to describe the context of each. Afterwards, we will detail the data collection methods, which were common to both.

It is important to note that this descriptive study phase is not an attempt to respond to a specific research question, but rather an exploratory study. Our aim was to investigate collaborative activities using the *Halle Numérique* platform. In general, it meant questioning the role of the artifact in the students' collaboration as well as the teachers' supporting activity. This phase gave us the opportunity to better understand real uses of the existing tool and to develop and validate a model for analyzing collaboration in future research.

***Descriptive Study P1 (High School Students)***

For the first data collection phase, contact was made with a local technical high school requesting teachers to volunteer to develop an interdisciplinary project for their students. During the project, they would use the *Halle Numérique* platform for planning in a project-based learning experience. A group of three teachers from different domains (Engineering Sciences, History and Literature) came forward with the idea to create a pop-up museum about 20$^{th}$ century wars. In this way, the project integrated elements of history, writing and design; each teacher was able to fit the project to her curriculum. The teachers chose a class of approximately 30 students whose parents consented to their participation.

**Study Preparation and activities**

There were two meetings between researchers and teachers to plan the student work sessions which would take place in the *Halle Numérique*. The project's workflow after these initial meetings is detailed in Figure 31.

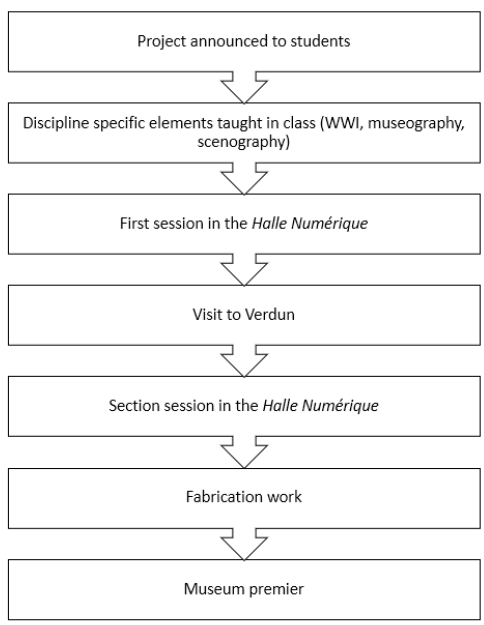



**Figure 31: Descriptive Study project workflow with high school students**

Two sessions of 3 hours each were arranged. The first session in the *Halle Numérique* was designated as a period for students to work in groups to generate ideas and choose a subject for their pop-up museum. The second session was designated as a coordination phase, where students would identify tasks to complete, assign them, and create a timeline for completion. After this, students would work in the classroom to build the elements they had agreed upon and make their pop-up museum a reality.

For the first session, teachers and researchers worked together to design a canvas (work template) that was integrated into the background of the board workspace, with the goal of guiding the students' reflection (Figure 32). The template consisted of five boxes with the following labels:

1. Theme of the room = message for the public, concept
    a. What conflict(s)?
    b. What aspects of war/peace?
    c. What links between situations?
2. Identification of different possible productions based on theme
3. Effects (sound, light, path, hands-on)
4. Target audience (constraints and expectations)
5. Available documents and materials

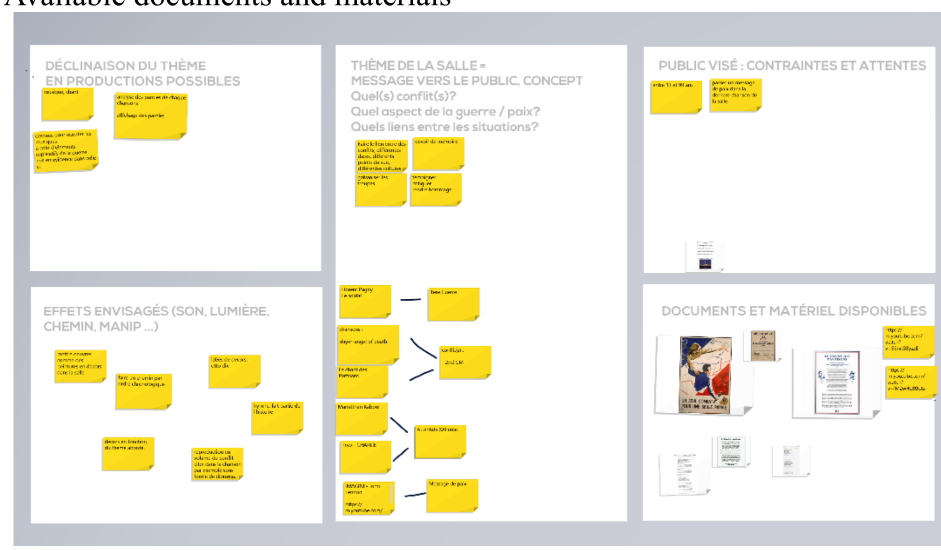



**Figure 32: Session 1 template - Group 4's production – War through music**

It was recommended that students start with their target public before moving on to other sections, but students were free to go back and forth among the five boxes.

After the first session, the literature teacher assigned a collaborative writing task to students. They worked in groups of two to three to write a short report about their experience (See annex: Annex 5: High schooler reports after first session (original French)).

The second session did not have a designated template, but students were shown what their work might look like beforehand through a series of examples, accompanied by recommendations for the amount of time to spend on each phase. The following scenario was recommended:

1. Summarize work already completed, including decisions made during the previous work session. (five to ten minutes)
2. Complete the 3 tools: (1) Task map, (2) GANTT, (3) SCRUM, dedicating one hour, 45 minutes and 30 minutes to the respective tools.

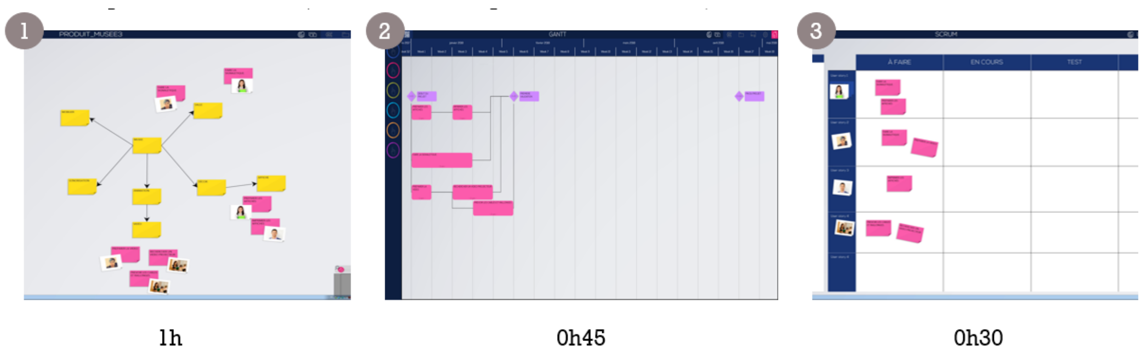



**Figure 33: Pop-up museum: Session 2 scenario recommendation**

3. Summarize work completed during the session and how the group will proceed during the next class session. (five to ten minutes)

Researchers requested that teachers intervene in student activities as they saw fit, as they would under normal circumstances.

A final session, which took place in the classroom and without instruments, was also observed. In this session, students were asked to create technical drawings for the elements which the group would need to construct in order to make their museum a reality. This final session allowed us to collect data about student work habits in a more "traditional" environment where they had access to paper, pencils, and rulers, rather than the *Halle Numérique* technology. This session allowed us to establish a point for comparison.

**Group makeup**

While previous work has shown that students are more likely to contribute if group size remains at two to four students (Johnson & Johnson, 2002), larger groups were used for several reasons: first, there were practical limitations related to the size of real classes versus the number of equipped cubicles available; second, collaborative work outside of the classroom (such as in the workplace) is likely to happen in larger teams, so we considered five to six to be an appropriate number.

| Group code | Females | Males |
|---|---|---|
| DSP1G1 | 0 | 6 |
| DSP1G2 | 0 | 6 |
| DSP1G3 | 4 | 2 |
| DSP1G4 | 0 | 6 |
| DSP1G5 | 1 | 5 |

**Table 9: Descriptive Study, Population 1 group makeup**

The student group consisted of 30 high schoolers, divided into five groups of six students each. Teachers allowed students to select their own groups, leading to some disparities related to gender distribution. Woolley et al.'s (2010) research has indicated that a heterogeneous group, especially one which includes females, has higher rates of collective intelligence, which seem to be mostly associated with increased turn taking that is likely to occur with increased emotional intelligence within the group. The researchers perceived this to be more present in the female participants than in the male, likely due to socialization. We did not request a specific mixing, allowing teachers to choose how groups would be assembled. According to teachers, students self-selected based on pre-existing relationships, friends choosing to work with friends. They described one group (group DSP1G4 – Descriptive Study Population 1 Group 4) as consisting of "everyone else," i.e. those who did not have pre-established relationships.

***Descriptive Study P2 (engineering students)***

For the second Descriptive Study population sample, we worked with professors at UTC within the context of two classes, TD DI05 (Value Analysis) and TD GE37 (Initiation to Project Management). The classes themselves were two-part, one section dedicated to in-class lectures and the second part dedicated to group work on case studies, followed by a project. We observed class work sessions from two professors in TD DI05 and one from TD GE37.

**Study Preparation and Activities**

Unlike with P1, the university professors already had standardized course material and case studies which they had used in previous semesters using the *Halle Numérique* platform. Indeed, a good deal of design efforts had gone into the *Halle Numérique* with the intention of using it to teach these courses, amongst others. As such, no special preparations were made, apart from explaining the study to the professors. Once they agreed to participate, students were informed, with the option of opting out of the study. Teachers were asked to conduct their classes as they would normally, with no requirements or restrictions related to our presence.

For TD DI05, data was collected from four case studies and project work. The case studies are as follows:

A. Revisiting the sack of flour –Identify and analyze two situations from the lifecycle of a sack of flour and propose alternative solutions to its current functions.
B. Causal analysis of an ice scraper - Analyze a situation in which an ice scraper is used, from causes to results, and propose potential alternative solutions based on these.
C. The case of the school bag – (Design to cost) Analyze a client request to reduce the weight of student school bags, or alleviate the need to carry them, without using digital solutions. For this activity, students needed to determine which analysis tools to use to best respond to the brief.
D. Recruitment resumé and cover letter – Examine a request from a recruiter who is unsatisfied with the traditional resumé/cover-letter pairing. They were given a list of questions, sometimes providing a specific analysis tool while other questions required students to choose which tool to use.

For TD GE37, data was collected from three case studies and project work. The case studies are as follows:

A. Case 1: A medical supply company has had issues reported regarding premature aging of plastic parts on the catheters that they supply. Based on research within the company, a way to repair this has been proposed. According to the provided information about the company and its goals, the group must complete a project clarification canvas and perform a risk analysis.
B. Case 2: Based on predetermined tasks, complete the preliminary planning tools for the project described in case 1 (GANTT, PERT)
C. Case 3: Based on provided price points, determine economic feasibility, return on investment (ROI), and financing for the project.

For both courses, student projects were typically provided by real companies, with real projects. The focus of the students' work varied by class, in that TD DI05 focused on design using the tools presented in class and used during case studies, while TD GE37 focused on project management tools and procedures that the groups put into place to respond to the briefs. As a result, the focus of the final product varied from group to group, with advancement happening on different aspects at different rates.

Non-instrumented sessions were also observed, with students using their own tool sets in a room equipped with whiteboards and a non-tactile television screen to which they could connect a single laptop computer.

**Group makeup**

Teachers asked students to form groups themselves based on their course of study, with the goal of creating a heterogeneous group based on their discipline/knowledge profile. The majority of classes consisted of male students, so some groups had no females. In each class, two groups were observed (Groups 2 and 4). The groups consisted of four to six students as follows:

| Group code | Class | Females | Males |
|---|---|---|---|
| DSP2G2a | TD DI05 | 1 | 3 |
| DSP2G4a | TD DI05 | 2 | 3 |
| DSP2G2b | TD DI05 | 2 | 3 |
| DSP2G4b | TD DI05 | 0 | 5 |
| DSP2G2c | TD GE37 | 2 | 4 |
| DSP2G4c | TD GE37 | 0 | 4 |

**Table 10: Descriptive Study, Population 2 group makeup**

Some minor changes to group makeup were made when students switched from case studies to project work. Based on students' interest in a given project, they were allowed to change groups. However, group makeup remained stable in the observed groups.

***Data Collection and Analysis***

Video and audio recordings of DSP1/2G2[5] and DSP1/2G4 were collected systematically for all participating groups during each session. These groups were also observed directly by a researcher occasionally (due to rotating between groups across different sessions.) Three groups from both student populations were not recorded. This decision was made for two reasons: ethical and technical. Since both studies used real classes, we did not want to make participation in the research obligatory. Some students did not wish to be recorded at all, while others did not wish for their images to be shared. Parents of students in P1 signed a release to allow for recording of students, but as they are minors, their images cannot be shared. As such, most of the images used in this research have been obscured to protect the identities of participants. Additionally, some resource

[5] Descriptive Study Populations 1 and 2, Group 2 (DSP1/2G2)

limitations, including cameras and space to ensure audio was clear were limited, so multiple cameras were used to film groups two and four to ensure proper coverage prior to the installation of more robust observation systems.

These robust recording systems consisted of four cameras and a microphone positioned at various locations around the cubicles in which students were working (Figure 34). These cameras and microphone were fed to a separate room inside of the *Halle Numérique*.

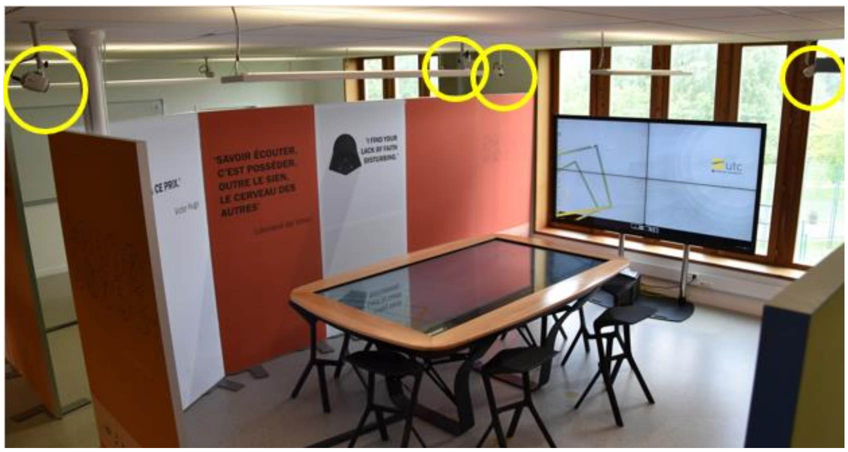


**Figure 34: Recording equipment - camera locations**

The audio and video were captured on several devices and displayed on a monitor that could be used to change between groups, as the sessions occurred simultaneously (Figure 35). This system incorporated a Yamaha MG06X (outlined in yellow) for mixing sound, a Blackmagic Multiview4 (outlined in red) to combine the video streams from the four cameras, and an Extron SMP 111 streaming multimedia processor (highlighted in purple) for saving the final videos.


**Figure 35: Video and audio capture system**

This system combined the audio and video streams into a single display, showing the group from the front right, front left, back, and straight down (Figure 36).

**Figure 36: View from cameras**

Regarding our observations, an analysis matrix was created with the various parts of the activity to which we wanted to pay special attention as part of the research clarification process. The observations were left very broad, as no detailed research question had yet been defined, apart from a general research goal of understanding collaborative learning instrumented by the *Halle Numérique* platform. The observation form consisted of eight parts:

- **Participants** (students, teachers, researchers, and others). Observers tracked who was in the cubicle at any given time as well as their interactions, if any, with the student work group.

- **Workspace** (physical and digital elements of the space and room organization)
- **Artifacts/tools -** appropriation, usage, and impacts (physical elements, work methods, tools, and models)
- **Time (sequence of events)** While students were given templates to complete their work, how they completed their work was up to them. Recommendations were given; for example, "brainstorm and write down all your ideas, then share them and make decisions." Students were not required to follow these recommendations. As such, initially observers recorded the recommended activity and compared it to the actual activity, both in terms of time, process, and expected behaviors.
- **Activities** (Teacher) Based on a typology of guidance activities from Bocchi (2010), four types of teacher interventions were coded: (1) those seeking predictions (hypothesized result of the activity), (2) procedural (showing or telling how to do something), (3) encouraging adaptations (open questions to advance hypothesis), (4) challenging student assumptions (questions to advance conceptualization).
- **Activities** (Student) This section initially consisted of determining whether groups were working collaboratively or cooperatively, in the sense of the terms defined by Dillenbourg, Baker, Baudrit, etc.… After work with DSP1, this was expanded to include communication (especially as presentations and the introduction of new ideas), coordination (planning of the activity, dividing tasks, etc.), and regulation (reflection about procedures, behaviors, or attempts to motivate others) during observations of DSP2.

For student activities, we referred to **actions** (language acts, gestures, movements). Language acts were noted based on a combination of Soller (2001), Zumbach et al.(2005), and Sizmur (1996) analysis models.

### Prescriptive Study

The prescriptive study took place from September 2018 to June 2019 at UTC in the *Haut de France* region of France, using two instances of a single university course (TD DI05) offered in the Fall of 2019 and the Spring of 2019. Students self-selected for the course but were given the option to opt out of the research. Across both semesters, a total of 45 students were observed, while there were a total of 75 students participating in the course. All 75 students responded to a questionnaire.

In order to understand how different physical-digital work surfaces impact collaboration, research was conducted on three different modalities but with varied work surfaces. Figure 37 depicts the three modalities. The first consists of the multi-user, multi-touch table (individual public space (Tucker et al., 2019, 2018)) and board system as described above (collective public space). The second consists of single-user tablets (individual private space) and the multi-user, multi-touch board. The third modality is the multi-user, multi-touch board alone. The digital tables for modalities two and three were deactivated and covered with sheets of wood to allow participants access to a standard table. Participants were asked not to use personal devices or computers during their work session, but these items were not confiscated.

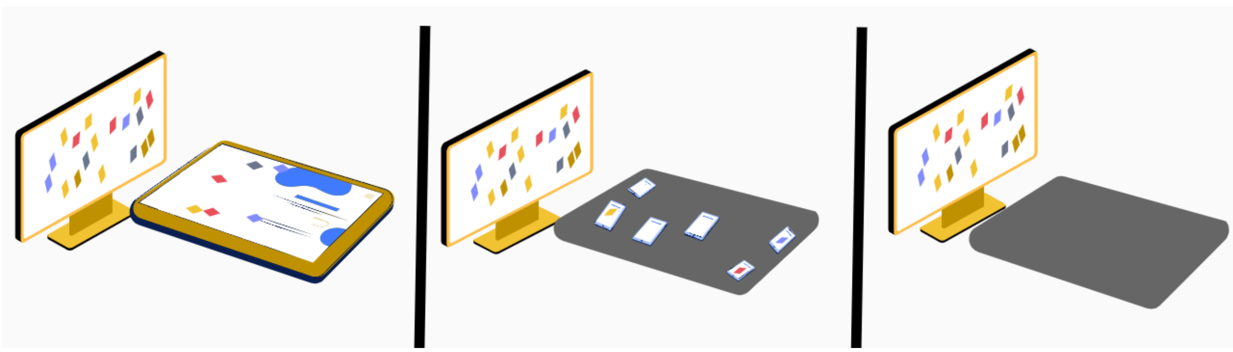


**Figure 37: Experimental Workspace Modalities (1. Table/Board - left; 2. Tablets/Board – middle; 3. Board only – right)**

| Group Code | Semester | Session | Modality | Total Members | Male | Female |
|---|---|---|---|---|---|---|
| PSP1F18T4M1 | Fall 2018 | N/a | Table/Board | 5 | 1 | 4 |
| PSP1F18T5M2 | Fall 2018 | N/a | Tablets / Board | 5 | 3 | 2 |
| PSP1F18T3M3 | Fall 2018 | N/a | Board only | 5 | 4 | 1 |
| PSP1S19T4S1M1 | Spring 2019 | 1 | Table/Board | 5 | 4 | 1 |
| PSP1S19T5S1M2 | Spring 2019 | 1 | Tablets / Board | 5 | 3 | 2 |
| PSP1S19T3S1M3 | Spring 2019 | 1 | Board only | 5 | 3 | 2 |
| PSP1S19T4S2M1 | Spring 2019 | 2 | Table/Board | 5 | 3 | 2 |
| PSP1S19T5S2M2 | Spring 2019 | 2 | Tablets / Board | 5 | 2 | 3 |
| PSP1S19T3S2M3 | Spring 2019 | 2 | Board only | 5 | 3 | 2 |

**Table 11: Group codes for Prescriptive Study**

Students divided themselves into groups based on their course of studies, with the aim of creating diverse groups based on this factor. We have created a code for each group, shown in the table above. These codes will be used from here to refer to a given group. The code is broken down as follows:

- PS – Prescriptive Study (versus DS for Descriptive Study)
- P# – Population number – In this case P1 refers to university students. Other

groups are not discussed further in this dissertation in order to focus our analysis.

- F18 or S19 – This refers to the semester during which the group was observed – Fall 2018 or Spring 2019.
- T# – This is an internal code, relating to the cubicle in which the group worked: Table 3, Table 4, Table 5, etc.
- S# – This refers to the session number. In the Fall 2018, only one session was observed (consisting of one student group per modality), but in Spring 2019, two were observed (two groups per modality). They are identified as S1 or S2.
- M# – Modality number. M1 refers to the table and board modality; M2 refers to the tablets and board modality; M3 refers to the board only modality as described in Figure 37.

During the sessions, data was collected from four case studies. The case studies are as follows:

A. Revisiting the sack of flour – Identify and analyze two situations from the lifecycle of a sack of flour and propose alternative solutions to its current functions.
B. Causal analysis of an ice scraper – Analyze a situation in which an ice scraper is used, from causes to results, and propose potential alternative solutions bsed on these.
C. The case of the school bag – (Design to cost) Analyze a client request to reduce the weight of student school bags or alleviate the need to carry them, without using digital solutions. For this activity, students needed to determine which analysis tools to use to best respond to the brief.
D. Recruitment resumé and cover letter – Examine a request from a recruiter who is unsatisfied with the traditional resumé–cover letter pairing. They were given a list of questions, sometimes providing a specific analysis tool, while other questions required students to choose which tool to use.

Each of these sessions lasted approximately two hours, with around one hour and ten minutes being fully dedicated to group work. About 55 hours of student work were recorded and coded. At the end of each case, students were required to share their final production with their professor for evaluation and feedback. The rest of the time was spent in setup, breakdown, and moving between rooms following the teacher's initial briefing and to go to the debriefing.

Prior to the experiment, professors were asked not to intervene while the groups were in discussions that were collaborative or cooperative in nature, unless students elicited their help. The difference between the two was explained and the professors were given key identifiers, such as epistemic conflict, co-elaboration, and co-building versus reading case material, writing in their notebooks, reading, or planning.

*Student Training Protocol*

Students received a 10-minute training session between the briefing with their professor and when they began to work with their assigned modalities. The training session, which occurred at the start of the second session, was delivered by researchers or student workers, following a script adapted to the modality being used. Students were asked to follow along and perform actions at the same time as the trainer demonstrated the functionalities. Students were shown:

- How to create a post-it note
- How to change the form and color of a post-it note
- How to create a drawing note
- How to open a web browser to conduct an online search
- How to search for an image and copy it to the workspace
- How to select multiple objects to copy or delete
- How to transfer elements between workspaces (table to board and tablet to board if applicable)
- How to organize post-its and create links between them
- How to split the board screen into two separate canvases

**Figure 38: Training Sessions: Table/Board (Left); Tablets/Board (Right)**

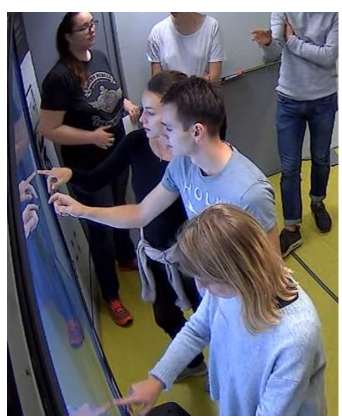


**Figure 39: Training Sessions: Board**

The creation functions were initially shown either on the table or tablets, as applicable, then the board-specific functionalities were demonstrated. For the board-only groups (Modality 3) the functionalities were demonstrated only on the board.

***Data Collection and Analysis***

Video and audio recordings were collected systematically for all participating groups during each session. These groups were also observed directly by a researcher over the course of the study, rotating between groups across different sessions. (I.e. a group may have been directly observed in Session A but not in Session B). Two groups from each class were not recorded. This decision was made for ethical reasons. Since both studies used real classes, we did not want to make participation in the research obligatory. Some students did not wish to be recorded at all, while others did not wish for their images to be shared. As such, only volunteers were used for the three recorded modalities in each class session.

Students were given a questionnaire before and after the recorded work sessions. The questionnaire was divided into two sections. The first part consisted of nine multiple choice questions focused on collaborative competencies, while the second part focused on general information about the student's preferences when working in a group, such as frequency of collaborative group work, number of students, division of work, and partner preferences (See

Annex 6: Questionnaire).

**Modes of Interaction Coding**

The videos of group work were coded based on the CIAO (Collaborative Interaction Analysis mOdel), described in Part 3, Chapter 4. CIAO is the operationalized form of *globally collaborative work,* consisting of five modes of interaction: individual work, communication, coordination, cooperation, and collaboration. In order to identify when students enter into one of these modes of interaction, we have proposed some potential interaction chains based on Sizmur's discourse moves. For example, introducing a new idea or asking a question in an effort to get new information is considered to be communication. Challenging an idea is coded as cooperation, etc.

The videos were coded in 30 second segments and annotated based on the modes of interaction which appeared within that time frame. For example, one 30 second period could have individual work, communication, and cooperation. Videos were coded blindly by two separate coders based on CIAO. To determine whether or not the difference in coding was acceptable, we looked at agreement between the two coders using Cohen's kappa. This is a measurement specifically designed to assess agreement between two raters and give a measure of reliability. This was calculated, after controlling for coding errors, based on each mode of interaction. I.e. did both coders agree that a specific 30 second section included collaboration? Did both coders also agree that the next 30 second segment did not? The results for each mode of interaction are as follows:

- Collaboration: 0.97 – near perfect alignment
- Cooperation: 0.97 – near perfect alignment
- Coordination: 0.64 – substantial agreement
- Communication: 0.62 – substantial agreement
- Individual Work: 0.45 – fair agreement

Upon further examination and a discussion between coders, after the coding was completed blindly, it was determined that the most errors were relative to the method itself (using increments of 30 seconds) rather than the model. One coder would code an event in one 30 second block, and the other in the next if the event crossed over into the following 30 second coding block. Once adjusted, the alignment between the coders for

Collaboration, Cooperation, Coordination, and Communication were considered acceptable. The initial decision to use 30 second time frames was an effort to keep segments (chains) together, but this proved not to be the best way to approach this issue. In the future, continuous coding using tools such as Anvil, etc. would be more appropriate.

We were surprised that the coding for individual work revealed the most difficulty, while the coders agreed verbally in a co-coding session, which was arranged to help pinpoint the source of the difference. The amount of activity in a given section of video often meant that the individual work went unnoticed or was easily missed. Rather than true disagreement, the low Cohen's kappa rating correlates with the challenge of observing several individuals and catching each action that one could consider to be individual work, despite rewatching the video segments.

**Collaborative Competency & Engagement Coding**

Collaborative competencies were analyzed similarly, in that two coders blindly coded the videos based on the $CO^2$ framework described in Part 4, Chapter 6. We consider this framework to have more subjective elements, which we consider acceptable in this first iteration as competency is defined socially and evaluated by individuals based on their own understanding of a given situation. However, the framework does attempt to establish some basis for comparison. Each coder gave every individual participant in each group session a "grade" from -2 to 2 based on the impact of his/her actions on the collaboration. A "grade" was attributed every 25 minutes and at the end of the session. These grades were averaged to give an overall competency activation score for each session. To illustrate: students A, B, C, D, and E all participated in four sessions related to their class. During session one, the coder gave students, A, B, C, D, and E a grade for the first 25 minutes of session one. A new grade was given at 50 minutes (taking only into account interactions in the 25 to 50-minute time frame). Finally, a third grade was given to all of the students at the end of the session (usually around the 75-minute mark, which accounted for interactions from 50 to 75 minutes). These three grades from session one were averaged for Student A, giving him a final "competency activation" score for session one. The same score was calculated for the other students across the other sessions as well.

This method was used in an attempt to get a more accurate understanding of competencies activated during the session, rather than relying on one overarching "grade" for the entire session for each individual. It also permitted us to get a better look at the time frames during which certain skills were more likely to be activated. I.e. Regulation skills may be used more frequently at the beginning of a session, etc. For more details regarding the coding methodology, please see Part 4, Chapter 6.

### *Chapter 3 Conclusion*

We would like to briefly address some of the limitations that arose during and after the research. The research protocols that were put into place relied heavily on observation and post-session video/audio analysis. We can immediately criticize this with the general agreement in the literature that competency development cannot be observed. While we attempted to take this into account with our analysis tools, we ultimately still struggled with this. Our protocol attempted to access this by viewing it through the lens of action and experience in the moment. In hindsight, we believe complementary interviews with student participants would have facilitated our understanding and ability to answer our research questions more fully. Nonetheless, our research protocol has enabled us to capture some interesting results regarding collaborative processes and the potential for competency development.

## PART TWO CONCLUSION AND SUMMARY

In this part of our dissertation, we described the research heritage in which this thesis is embedded and described briefly why educational sciences have a role to play here. New technologies are often introduced into classrooms with vague goals, little support, and a lack of understanding of their impact. This led the engineering researchers who were rolling this technology out at UTC to ask about its impact on learning to collaborate. Inviting researchers in educational sciences into a joint project to better understand how the *Halle Numérique* technology has led to an interesting question about the articulation between collaborative workspaces and collaborative competency. Asking the question: How do physical-digital workspaces influence interactions within student work groups, and by consequence, the development of collaborative competencies?

In order to be able to answer this question, some choices needed to be made regarding how to understand, qualify, and quantify interactions and competencies. Leaning on the notion that competency is situational (Pastré, 2004; Wittorski, 1997), we have chosen very specific situations. Using the People at Work model (Samurçay & Rabardel, 2004) as a point of departure, we designed a study in which we control the task, templates, instructions, criteria for completion, and external knowledge mediated by the teacher. We then decided to vary the artifact being used across the work groups while we observed group and individual productive activity. By varying the artifact and proposing different forms of physical-digital workspaces, we can get a look at how they might influence productive activity within the group.

The biggest challenge for us was assessing competency development. Rather than attempting to address whether or not a competency is acquired or is being developed, we chose to look at whether or not the opportunity exists based on the types of activities in which individuals and their group engages. We felt that this might give us the possibility of determining whether development *could* happen even though time was not sufficient to determine that it *did* happen, which we have termed "competency activation." Ultimately for both collaboration processes and competency activation, we felt that applying quantitative tools would give us a more objective look at the possibility that the artifact is having an impact on the group. However, we've also employed ethnographic observational methods to ensure that this numerical data is put into context. It is important to identify tensions and attempt to understand the layer related to engagement in activity. We especially mobilized Rabardel's instrumented activity theories (1995) as a lens through which to understand the creation and stabilization of certain classes of situations and the functions of each kind of workspace. We also mobilize the People at Work model (Samurçay & Rabardel, 2004) in an effort to get at the relationship between the productive activity that we are observing and the psychological subject's internal process to construct or modify a competency.

In Chapter 2, we discussed the appearance of tactile technology, especially tactile tables designed to facilitate collaborative group processes. This research heritage points to tabletop devices positively influencing shared talk time and co-building of ideas during group work. Next, we discussed the development phases of the *Halle Numérique* platform. While the initial projects began with vertical boards, numerous issues, and research around the time of the initial projects influenced a turn towards tabletop environments and eventually a shift towards a combined system. We went on to present the functionalities of the software environment and its possible simultaneous usage by a group of people, largely from the perspective of its designers. This will allow us to reveal tensions which exist between intent and real usage during the descriptive study phase, in which we analyze real uses by students and teachers. It also allows us to set up the hardware and software in our experimental environment.

In Chapter 3, we detailed the object of our study, we explained our methodological choices, and we detailed our research design and protocol. Our research focused on investigating how tools impact competency development by looking at the productive activity of the group and individuals within it. We ask how physical-digital workspaces influence interactions within student work groups, and by consequence, the development of collaborative competencies? We developed two hypotheses from this research question: the characteristics of the workspace have an influence on (H1) the collaborative processes implemented by students and (H2) the competencies developed by students. To test these hypotheses, we use a mixed method approach, mobilizing both quantitative and qualitative data regarding collaboration processes and competencies. In our protocol, we set up experimental research within the context of real university courses. We described the three physical-digital workspace modalities to be tested, which consist of a table and board (individual-public space and collective-public space), tablets and board (individual-private space and collective-public space), and board only (collective-public space). We observed 45 engineering students enrolled in a value analysis course. They were divided into nine groups (three groups for each of the three modalities) and participated in four work sessions of 1.5 hours each, leading to about 55 hours of video. These videos were then analyzed to look at how groups worked together and the processes that they mobilized as well as how individuals and groups activated collaborative competencies, mobilizing the two frameworks we present in the next sections.

# PART THREE: THE INFLUENCE OF PHYSICAL-DIGITAL WORKSPACES ON COLLABORATION

## PART THREE INTRODUCTION

In this section we will address in Chapter 4 our research question: How do physical-digital workspaces influence interactions within student work groups? To bring some elements of response to this question, we begin by defining the interactions and processes we look at within the context of *globally collaborative work* before presenting CIAO, the Collaborative Interaction Analysis mOdel. This model uses language acts as well as some physical actions taken by participants to identify the *globally collaborative work interactions* being mobilized.

In Chapter 5, we look at the results of applying CIAO to analyze student groups working with different forms of physical-digital workspaces: table-board, tablets-board and board only. Additionally, we apply Rabardel's (1995) schema functions to describe how students are using the tools and how those usages vary from modality to modality.

# CHAPTER 4 COLLABORATIVE INTERACTION ANALYSIS FRAMEWORK



### *Chapter Introduction*

During our descriptive study phase, we found that the delineations between cooperation and collaboration did not accurately represent what we were seeing in student group work, leading us to propose the idea that work can be *globally collaborative.* Groups often integrate several different modes of interaction to decide upon and achieve their goals. With this proposition came the need to be able to pinpoint those different modes of interaction. What are they, and how do we know they are happening? For a detailed description of *globally collaborative work*, please see the 1.5 *Globally Collaborative Work* section of Chapter 1.

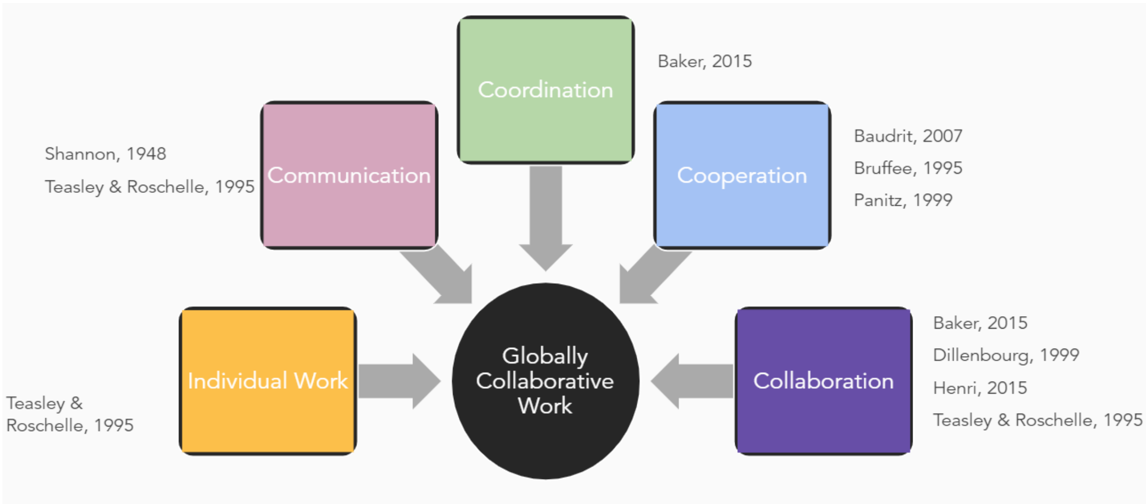



**Figure 40: Globally Collaborative Work (Tucker et al., 2018)**

In this chapter we take each of the five modes of interaction which we propose make up *globally collaborative work* (Figure 40) and describe how we have identified them using verbal and non-verbal indicators. We have termed the analysis model discussed here CIAO (Collaborative Interaction Analysis mOdel). In our chapter discussion, we will wrap up with a description of how we mobilized CIAO and describe other potential uses for it.

### *4.1 CIAO: An Analysis Framework*

In order to better understand *globally collaborative work*, we chose to examine its expression through communication: verbal and written. (Sizmur, 1996; Soller, 2001; Zumbach et al., 2005). Individual work and communication serve as the base from which cooperation and collaboration are built. As such, it is difficult to discuss each separately because they build upon each other, making it necessary to identify a "theme" or an "idea" as the unit of analysis and then follow its handling over time. In order to identify and differentiate these modes of interaction, the context and sequence must be taken into account (i.e. idea > elaboration > challenge > negotiation, etc...) While Sizmur's categories are sufficient to describe language acts in collaborative activity, we felt that they did not capture the processes well enough, but they could serve as a base when chained together into their full context.

The example used below occurred after students had divided tasks and agreed to work independently to find music to use in their museum.

| Message | Speaker | Category | Mode of interaction |
|---|---|---|---|
| Because in fact, the music that we chose… I have an idea. You take the music that you chose, you look at the theme of war that's in it, and next to it, you talk about that war. | **DSP1G4SA** | Introducing idea | **Communication:** Introducing a new idea **Cooperation**: attempt to make the individual work being completed coherent with the group's goal |
| Ah, yeah, but we can only talk about one war… | **DSP1G4SF** | Challenging idea | **Cooperation:** the task had not been understood in the same manner. Student DSP1G4SF attempts to re-establish this shared vision **Communication:** A question is asked to which a simple answer is provided, without further elaboration. This introduces new supporting/clarifying information for the argument. |
| (goes to the board and indicates a square on the template) Hey, we can work on multiple conflicts. | **DSP1G4SC** | Supporting idea | |
| (Speaking at the same time as DSP1G4SC) No, not necessarily. Songs... *Chant des partisans*, it's a revolutionary song. You have the other one what you found…? (points to DSP1G4SE) | **DSP1G4SA** | Elaborating on idea Question (Query Loop (QL) starts) | |
| Ah yes, we can… | **DSP1G4SF** | Hedging | |
| *Manhattan Kaboul* | **DSP1G4SE** | Answer (QL ends) | |
| There's *Manhattan et Kaboul*, which is about the 2001 attacks. So, you see, they're different periods. They're not at all the same. | **DSP1G4SA** | Integrating ideas | |
| They asked us to work on $20^{th}$ and $20^{st}$ century wars. | **DSP1G4SF** | Retracting challenge | **Cooperation:** Resolution and re-establishment of shared vision. |
| Well there you go. | **DSP1G4SA** | Supporting idea | |
| Then it's fine. | **DSP1G4SF** | Supporting idea | |

**Figure 41: Example of coding using Sizmur's discourse moves and context, integrating modes of interaction**

However, Sizmur's discourse moves limit us to just that: discourse. As students are using a specific tool which allows other types of communication and the embodied nature of the individual in a co-located group activity, we feel it is necessary to examine non-verbal elements as well and find a way to integrate them into the coding scheme for it to be coherent and complete, leading us to develop a coding scheme called CIAO (Collaborative Interaction Analysis mOdel).

### *4.2 CIAO: Verbal Starting Points*

Let us look at some examples of these different types of starting points.

As described in the work of (Teasley & Roschelle, 1995), narration "enable[s] students to monitor each other's interpretations" in order to ensure that the group is in agreement. The narration gives the opportunity for other group members to interrupt and signal a divergence. When narration occurs, but no response is given, we have considered this to be individual work. As it is being constructed and carried out by the individual and no acknowledgement occurs, we consider that the narration serves a reflective role. When a response (usually verbal) is given by any of the group's members, it is coded as communication, as the narration has been confirmed as received by a group member and constitutes the transference of an idea from the individual into the group's joint-problem space. Narration can develop into collaboration if group members begin adding elements, thus co-building the ideas. However, if a challenge is issued because one or more group members do not agree, the participants enter into a phase of cooperation as they attempt to repair their shared understanding and goals. Figure 42 depicts one such possible flow. Items in pink refer to communication, yellow to individual work, blue to cooperation, and purple to collaboration.

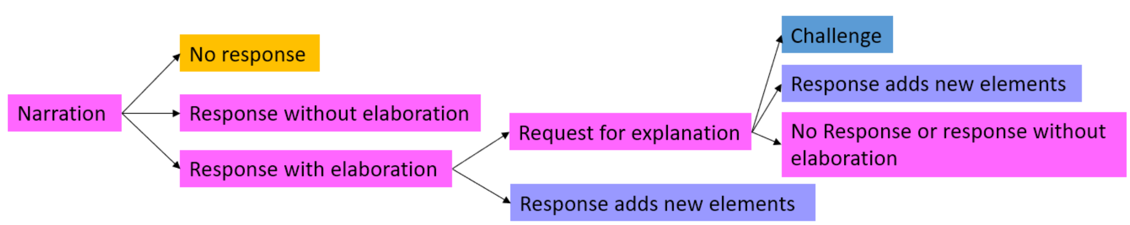



**Figure 42: Narration Starting Point**

The basic use of communication is to introduce new ideas into the group. When a new idea is introduced, even if no response is given, it is an instance of communication. When responses are given, it follows the same path to cooperation or collaboration as narration. If the idea is challenged, the group will begin to negotiate to either fit the new idea into their existing work or ultimately reject it. If the idea is accepted without modifications, it is simply communication. Finally, if the idea is not only accepted, but leads other group members to build upon the idea, it becomes collaboration.

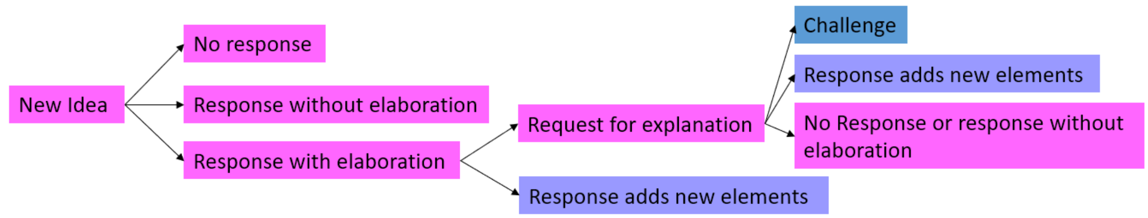



**Figure 43: New Idea Starting Point**

Communication also occurs when a student makes a request for information and an answer is provided, as shown in Table 12.

| | |
|---|---|
| **Ex. 1** | **Student 1:** The object must permit the user to contain the flour *(Introduction of new idea)*<br>**Student 2:** Ok *(Response without elaboration)* |
| **Ex. 2** | **Student 4:** I don't know which phrase to use to go down … *(Request for information)*<br>**Student 1:** "So", I think (*Response without elaboration)* |

**Table 12: Examples of verbal communication**

In example 1 of the above table, a student introduces a new idea, and receives an affirmative response, accepting without challenging or elaborating. This particular idea does not travel any further, simply integrating it as-is into the collective work. Participants may also return to ideas that have already been settled, calling them back into question or adding new elements to them. Table 13 shows such an example, where one student challenges a previously reached understanding about what it means to improve the packaging of a sack of flour.

| |
|---|
| **Student 1:** I think that…it's just about the functions, not the solutions. *(Calling a previous idea into question)*<br>**Student 2:** To improve the packaging *(elaboration)*<br>**Student 3**: I think that one is good *(defending previous idea)*<br>**Student 1:** Well, to improve the packaging. It's about adding functions *(reiterate challenge)*<br>**Student 3:** and in fact, increasing the functions is improving the packaging *(clarification)*<br>**Student 1:** Exactly<br>**Student 3:** (Cont.) but we can still leave it [unclear], we can put it in red *(negotiation)*<br>**Student 1:** Yes (*acceptance)*<br>**Student 4:** Yes, I agree *(acceptance)*<br>**Student 5:** To me, it's written in the instructions… the instructions just say to… *(challenge to agreement)*<br>**Student 1:** the packaging, the value of the packaging<br>**Student 5:** Yes, exactly but<br>**Student 1:** How do you increase the value of the packaging? That's the… *(challenge)*<br>**Student 5:** How do you increase the value? You increase the functions (*accord*)<br>**Student 1:** Yes, exactly, that's it<br>**Student 5**: I agree, but to me increasing the functions is implicit. Here it says, "I want it to be better" and that's explicit. So, for me, that's the FT 1 and the FT2 is implicitly that you have to increase the functions or reduce the cost. Do you see what I mean? (*Defense and request for support*)<br>**Student 1:** but<br>**Student 5:** It's just implicit or explicit that makes… *(clarification)*<br>**Student 1:** You mean that improving the packaging ….? *(Request for clarification)*<br>**Student 4:** Then it's implicit<br>**Student 5:** No, no, no<br>**Student 2:** So, in fact, increasing the functions and reducing the cost, it's both *(clarification)*<br>**Student 5:** To me, changing the packaging is explicit *(clarification)*<br>**Student 2:** Actually, I agree *(acceptance)*<br>**Student 1:** Yeah, it's true. it's not…<br>**Student 2:** So, who wants it to go below? [raises hand] *(mediation)*<br>**Student 5:** below what?<br>[Student 4 raises hand.]<br>**Student 1:** no, I see what you meant<br>[Student 3 puts post-it below.] *(document proposition)*<br>**Student 1**: Yes! That's it. *(acceptance)*<br>**Student 2:** Yeah, that works! *(support)*<br>**Student 1:** I admit it does *(support)* |

**Table 13: Example of Cooperation**

In this excerpt from sample population 2 of the descriptive study, we see different forms of communication playing a role in the resolution of the conflict: verbal communication (making up most of the transcript), non-verbal communication (voting with hands to signal agreement or disagreement), and communication mediated by the tool (the movement of the post-it note to a lower position answered a question raised by student five and demonstrated the idea more clearly for other group members).

The different modes of interaction flow into each other, making it necessary to use an idea as the base for the coded chain. In Table 14, we show an example of a challenge to an existing idea in the form of a question transitioning quickly to collaboration and then back to cooperation.

| | |
|---|---|
| **Cooperation** | **Student 1:** It might be annoying, but could we replace "drive" with um…? *(Challenge to existing idea)* |
| **Collaboration** | **Student 2:** to go somewhere? *(elaboration)*<br>**Student 1:** Yeah, something like that *(acceptance)*<br>**Student 3:** Because, actually, she doesn't want to drive *(elaboration)*<br>**Student 1:** Yes, exactly *(acceptance)*<br>**Student 3:** Yeah, you're right, you're right *(acceptance)*<br>**Student 2:** Yeah but where do we put drive then? *(Query)*<br>**Student 3:** Bah... just afterwards *(Response)*<br>**Student 2:** to go somewhere? *(elaboration)*<br>**Student 4:** Yeah, there maybe… *(incomplete utterance)*<br>**Student 3:** So, you put… *(incomplete utterance)* |
| **Cooperation** | **Student 2:** For me it's this one, to go somewhere else [indicates another post-it on the board] *(Challenge to idea)*<br>**Student 3:** But you could put it between the two *(Negotiation)*<br>**Student 2:** In terms of abstraction, it's really lower *(Negotiation)*<br>**Student 1:** Bah, no because going to work is the final thing… she wants to be there *(Defense of Idea)*<br>**Student 2:** Yes *(Acceptance)*<br>**Student 1:** She doesn't want to go somewhere else **(***Defense of Idea cont.)*<br>**Student 4:** But you could but go somewhere else between the two *(Negotiation)*<br>**Student 3:** Yeah, I admit you could *(Acceptance)*<br>**Student 2:** So, it's… drive to go to work. That works for me. *(Acceptance – conclusion of accord)* |

**Table 14: Example of Collaboration with transition to Cooperation**

Table 15 represents one example of coordination. As this group entered the cubicle, they began immediately by deciding how they wanted to work, basing the structure on a previous work session.

| | |
|---|---|
| **Coordination** | **Student 1:** So, we do it the same way as last time? *(recommending a method of work)*<br>**Student 2:** Yeah (*acceptance)*<br>**Student 3:** Yeah, it wasn't bad *(acceptance)*<br>**Student 1:** We write lots of ideas (*acceptance)*<br>**Student 2**: Lots of ideas, yeah… we start with the objectives? It's easier. *(Acceptance and elaboration)*<br>**Student 4:** Oh yeah? I would have… *(challenge)*<br>**Student 2:** Well...<br>**Student 1:** Anyway, why don't we start where we want to? *(negotiation)*<br>**Student 3:** Yeah, that's it…<br>**Student 2:** Yeah... in class he said it's easier... than the causes *(negotiation)*<br>**Student 3:** We each write out our ideas?<br>**Student 2:** Yeah, that's fine. *(acceptance)* |

**Table 15: Example of Coordination**

For our purposes, this entire exchange is coded as coordination, regardless of challenges and negotiation happening because they all relate to the structure and organization of the task, rather than being specific to the task itself. This differentiation was important in the context of our research as we moved into the Prescriptive Study, since students in the university engineering course often needed to debate which tool they would use (and therefore the form of the work itself) as part of the core activity. This aspect of the coding scheme needed to be dealt with more precisely. As such, the decision was made to include debates about the nature of the tools to be used as cooperation/collaboration. As such, coordination and cooperation often flow into each other when the merits of the method to be used are being discussed. In the above example, the nature of the tool is not discussed to such an extent as to merit it being coded as cooperation. That is to say there is no significant chain as described by (Zumbach et al., 2005) or (Sizmur, 1996).

To summarize, these verbal starting points can begin as narration, introduction of new ideas (in the form of questions, statements, reading from a text, etc.), or even as coordination, which complexifies to negotiate the nature of the tool to be used.

### *4.3 CIAO: Non-verbal Starting Points*

Non-verbal starting points are much more limited but require attention. Since students are in a space using tools to further their collaboration, it is necessary to pick up on non-verbal starting points as well. Ideas can be communicated directly through the tool, rather than verbally. Figure 44 demonstrates a student working individually (writing on a post-it note), who then transfers the idea to the board via the portal located in the center of the table.

**Figure 44: Writing a post-it (Individual Work) Transferring a post-it into collective space (Mediated Communication)**

This action would be coded as individual work, followed by communication. We consider the act of transferring the note from her individual space into collective space to represent an effort to communicate a message. It should be noted that these items can be treated by the group as they appear or they can be treated later, remaining in the portal for a time.

**Figure 45: Student reorganizes notes on the board without discussion**

Another non-verbal starting point is the act of reorganizing items on the board when it is not accompanied by a group decision for the reorganization to occur. The individual reorganizes the collective workspace without input from other group members. In Figure 45 we see a student working on his own in the collective space, reorganizing the items on the board, while the other students work on other tasks individually. This action is coded as individual work, as the activity is not discussed with the others and may be part of the reflection process for the student making the changes. When this occurs, we typically see it followed either by a phase of communication (in which the individual explains the changes he or she has made), or by a phase of cooperation or collaboration, the former being more prevalent as the group seeks to understand the changes that have been made.

### *4.4 CIAO: Other Coding Elements*

Though not strictly part of the *globally collaborative work* model, there were a few other items that we wanted to be able to track and identify. These included: setup phases, teacher interventions, technical issues, and time spent off topic.

Setup phases were coded for practical reasons related to syncing video coding between coders and with the capture software working behind the scenes in later phases of our research. As videos did not necessarily start when students were working and could include time during which students were arriving into the individual boxes, by tracking setup time, we could better target the time during which real work occurred in a video segment.

We needed a way to code the teacher's intervention in the group processes, in order to account for that time, and explore the impacts of those interventions in a later part of the research. As such, teacher intervention appears in our coding model but is merely used to identify the time when a teacher is interacting with the group.

Technical issues were tracked to help us better understand how downtimes related to the tool impacted group work and dynamics. Technical issues were coded when there was a technical event or bug that took up the group's time (such as software crashes or the software not performing as expected) or when a student had difficulty finding or performing a function (such as creating links between items). We felt that this needed to be tracked: first, as a potential disrupter to the group's workflow, and second, as a means of identifying issues in order to improve the software.

Lastly, off topic items were coded to allow us to follow the group's workflow. Groups which were struggling tended to have more time spent in off topic conversations throughout the activity.

For additional examples of interaction and coding chains, please see Annex 4: Mode of interaction identification examples (French).

*Chapter 4 Conclusion: Using CIAO*

In the guise of a conclusion, we would like to discuss some potential uses for CIAO. We've identified at least two ways in which it could be used. The first is reflective of the way in which we have used it, as a means to understand the collaborative processes that have been mobilized during a work session.

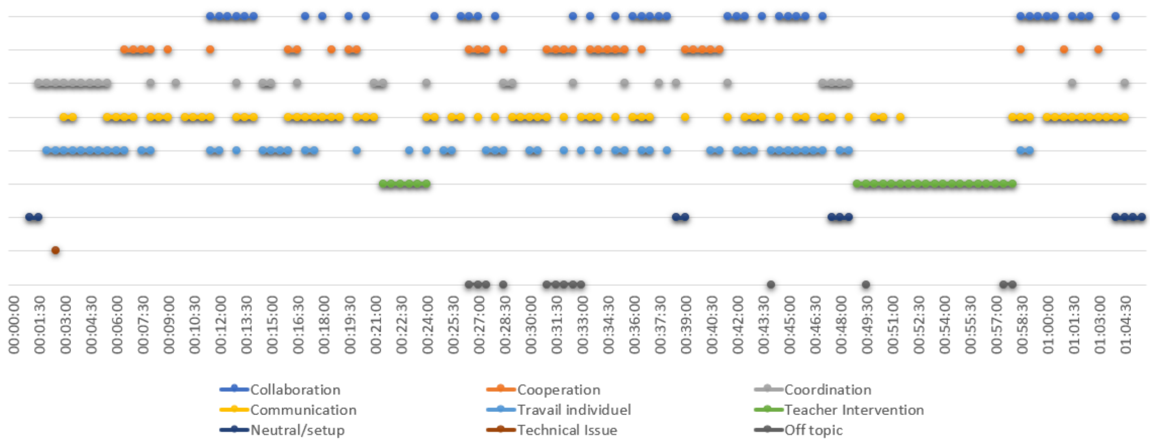



**Figure 46: Using CIAO to track a group's mode of interactions over time**

To create Figure 46, we have coded the appearance of these different modes of interaction over time. It demonstrates the appearance and movement between the different modes of interaction which can occur during a single group session. This graph was constructed by identifying which modes of interaction appear within a single 30-second time frame over the course of a work session.

This particular usage also translated into a quantitative output as we looked at how much time each group spent in each mode of interaction, as seen in Figure 47. In this figure, Percent of time is equal to more than 100% because modes of interaction can overlap. For example, Group PSP1F18T5M2 spent about 34% of their time collaborating, 34% cooperating, 12.6% coordinating, 40% communicating, and 45.6% working individually. This representation allowed us to quantify the overlap and demonstrate how collaborative processes (or modes of interaction mobilized) were impacted across different groups, activities, and physical-digital workspace modalities.

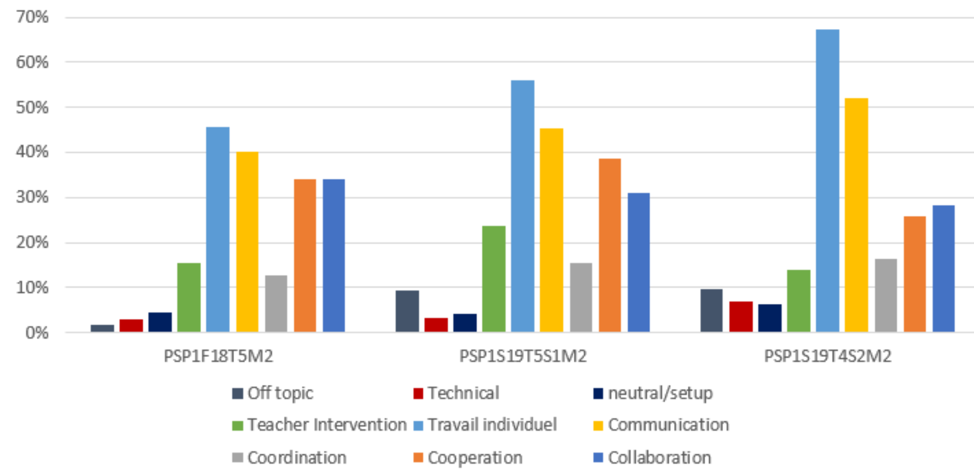



**Figure 47: Percent of time spent in each mode of interaction across three different work groups for the same activity using the tablets-table modality.**

As a second usage, though perhaps not mobilizing the granular analysis for which CIAO allows, we feel that *globally collaborative work* and CIAO have a role to play in how we design and evaluate. In terms of designing digital, physical, and physical-digital spaces: if we expect to see each of these modes of interaction appear when groups are working together, designing to facilitate that appearance and the transition between them should be taken into account during the design process. These spaces could also be designed to favor certain modes of interaction over others to potentially manipulate the focus and outcome of a work session. Likewise, in terms of designing collaboration scripts (Dillenbourg, 2002) to engage students in collaborative work, scripts could be designed to take into account each of these modes of interaction. For example, in his 2002 article, Dillenbourg describes a script consisting of four steps in which:

1. Students form groups and distribute roles amongst themselves (coordination)
2. The group receives a list of concepts and divide the work between them (coordination)
3. Each student writes their definitions (individual work)
4. Groups share their work with each other (communication) and form a grid of definitions (cooperation as they initially put them together and negotiate meaning) in order to form a final product in which all of the relationships are clear (collaboration to co-build the final product.)

We feel that considering these different modes of interaction would be especially beneficial when one of the goals of the group work is learning to collaborate.

Finally, one of the questions we encountered many times, when working with teachers, related to when they should intervene in student group work. There is a sense among the educators with whom we worked that they would break the groups' flow if they intervene at certain times. While not a principal focus of this thesis, we believe there is merit to this concern which CIAO can expose and potentially help to resolve in a classroom setting. While using the model to shed light on collaborative processes in data is certainly more interesting for researchers, there may also be some use for this tool "on the fly" in a classroom setting to identify when a teacher can intervene in a group to provide insights without breaking the workflow.

# CHAPTER 5 USAGE OF PHYSICAL-DIGITAL WORKSPACES DURING GLOBALLY COLLABORATIVE WORK



***Chapter Introduction***

In this chapter, we look at how the physical digital workspace modalities used during our prescriptive study impacted the work of students and the collaborative processes in which they engaged based on CIAO. We have classified each modality as being collaboration-heavy, cooperation-heavy, balanced or "failed" based on the amount of time each group spent in these modes of interactions. Results that are identified as collaboration-heavy demonstrate significantly higher levels of collaboration as opposed to cooperation, cooperation-heavy demonstrates high levels of cooperation over collaboration, balanced refers to the appearance of both collaboration and cooperation in equal measure and failed collaboration designates those work sessions which do not make significant progress beyond the modes of interaction used to regulate activity (individual work, communication and coordination). For a detailed analysis by session and modality, please see Annex 7: Detailed Analysis of Collaborative Processes.

Along with the results of applying the CIAO model, we will also discuss the schema which developed and stabilized over the course of the experimentations, especially focusing on the four functions of schema described by Rabardel (1995). Finally, we will discuss the feedback that each modality received from both students and teachers.

### *5.1 Table & Board Modality*

Across all activities, the table and board modality demonstrated higher levels of cooperative activity and is identified as cooperation heavy (Figure 48: Table and Board: CIAO Averages (Instrumented Sessions)). Towards the beginning of the first instrumented sessions, students typically agreed to complete a brainstorming session in which they each write down their ideas at the table (individual public space) and then pool them together on the board. In action, this translated to sending the finished post-it notes directly to the board (collective public space). Rarely, students would keep a post-it note on the table, tucked into a corner. Occasionally, another student may ask what is on a post-it note when still in the individual-collective space. As such, this space served as a means of production and a means to gauge the participation of others. It also sometimes served as a space for communication, with this function being left largely to the board.

With most of the production being done individually, at least initially, it was accompanied by a phase of communication, in which group members explained the ideas they had produced. During these phases of communication, team members would pose questions, give feedback, or challenge the idea. These interventions led to cooperative work, the negotiation, defense, and modification of the individual's work in an effort to form a coherent product. Individual activity was high during all sessions, as students spent time generating written notes to share, sometimes using the drawing features to illustrate their ideas and find images or information online. Some students also took personal notes for prolonged periods of time, increasing the individual work count substantially. This did not occur to the same extent in other groups but is likely not related to the tool but to individual study and work habits.

How to read this chart: *The above chart depicts three different groups: PSP1F18T4M1, PSP1S19T4S1M1, and PSP1S19T4S2M1. The results shown for each group are an average of the three sessions in which each of these groups used the table and board modality. If we look at PSP1F18T4M1: This group, averaged 15% time spent off topic, 3% of time on technical issues, 7% of their time setting up, 14% of the time with the teacher, 53% with at least one student working individually, 30% communicating, 22% coordinating, 32% cooperating and 16% collaborating. For more a more detailed breakdown about each group and session please see* Annex 7: Detailed Analysis of Collaborative Processes

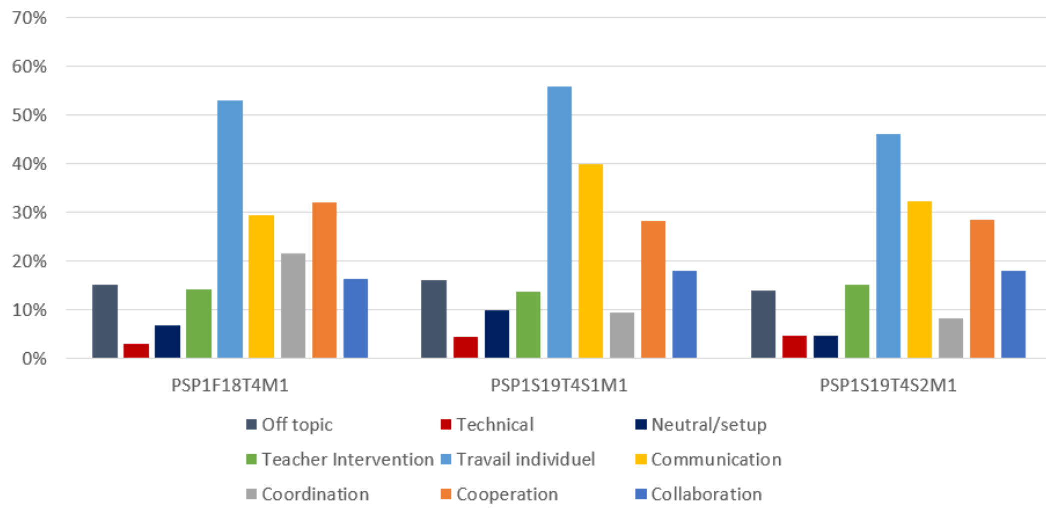



**Figure 48: Table and Board: CIAO Averages (Instrumented Sessions), % of time spent in each mode of interaction.**

We noted slightly higher levels of interpersonal conflict around this modality, likely related to the levels epistemic conflict, which remained higher due to more divergence. For example, in the ice scraper analysis, one student had organized notes on the board in a logical, but aesthetically pleasing way. When changed by someone else, the student called it ugly and withdrew to the table to take notes. For the first half of the session, she had played an active role, but after the reorganization she only commented when necessary or when asked for input. The need to integrate ideas, which had been produced individually, was an opportunity for creativity and epistemic conflict, but also generated a risk of interpersonal conflict within the group. It is important not to necessarily interpret this element as a negative aspect, especially if learning to collaborate is a primary focus. Putting students into situations where conflict can occur will allow them to activate and develop conflict-resolution skills.

Mobilizing Rabardel's schema categorizations (1995), both the table and board served each of the described functions. We will begin by focusing on the table, then the board – however these two objects have a particular articulation, so this discussion will have some overlap.

**Schema in the Table and Board Modality**

In this sub-section, we will mobilize Rabardel's notion of schema, "an active organization of lived experience which integrates the past" (Rabardel, 1995). We will pay special attention to the action schema, but our primary focus is to describe them in articulation with the four functions of schema proposed by Rabardel (1995). For him, schema can serve:

- Epistemic functions: turned toward the comprehension of the situation;
- Pragmatic functions: turned toward the transformation of the situation and the obtention of results;
- Heuristic functions: orienting and controlling the activity;
- And collaborative functions: a means of transformative action directed at another's activity.

In terms of epistemic functions, i.e. schema turned towards understanding the situation, the table allowed students the opportunity to reflect on the object of their activity, search for information and externalize their thoughts by creating post-its, drawings or using example imagery from their search.

**Figure 49: Left: student searching using a web browser; Middle: two students writing their ideas on the table with a web browser open to an image of a car; Right: Student transferring the car to the wormhole in order to send it to the board.**

In Figure 49, for example, as part of a discussion about potential changes to the windshield of cars to discourage the formation of ice, a student mobilizes a usage schema for using a web browser to find images. He searches for the image of a Formula 1 car. Then, he writes a post-it detailing the idea to use helmets rather than windshields as a potential solution. This is another example of a usage schema related to the use of post-it notes as a way to externalize thoughts or even use them as a memory tool for themselves until such a time as it becomes relevant to share it with the group.

In terms of pragmatic functions, i.e. turned towards transforming the situation and getting results, the table served as a means to produce written notes to eventually use once sent to the board, see Figure 50. While not directly transforming the situation, the table became a first step in getting results.

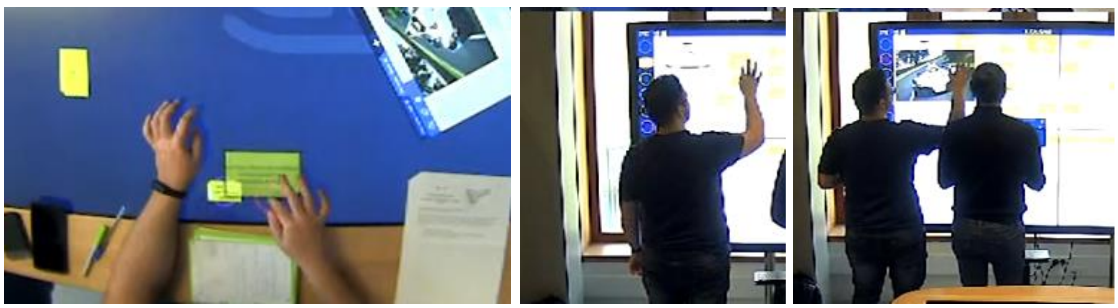


**Figure 50: Left: Student transferring his post-it note into the wormhole. Middle: Student retrieving his note from the wormhole and positioning it on the board; Right: Student adding the image of a car next to his notes.**

As the image of the car is being positioned, the following exchange occurs:

***Student A:*** *I get the impression that we're each working in our little corner.*
***Student B:*** *Well yeah, we're brainstorming.*
***Student C:*** *We're brainstorming together.*
***Student A:*** *But that's not teamwork.*
***Student C:*** *It's ok, but if you want to, we can set a time to stop but don't say it's not teamwork. We'll summarize afterwards.*

After this exchange the students continued to write their ideas and discuss aloud, choosing a time to stop this phase of individual work. However, this exchange points to an interesting tension in terms of what it means to work together but also in terms of how the workspace should be used: separately before reconvening or entirely together. Three out of four members of the group had developed a schema related to individual reflection using the table, then transferring their ideas to the board. Student A in this case was an outlier, using the board for his individual work and encouraging the group to come back together more quickly. This exchange occurred early in the experiments before the stabilization of the usage schema occurred. However, the stabilization that occurred pointed towards different schema related to roles within the group. The student serving as the group's animator would use the board for this function, while the rest of the group would use the table.

In terms of heuristic functions, turned towards orienting and controlling one's own activity, the table gave students the opportunity to reflect and externalize thoughts, with the eventual possibility of re-evaluating or re-orienting one's own activity. Just as researchers understand the importance of writing, even if the writing is in bits and pieces, likewise the table allows for the construction of intermediate ideas that develop as they are written and modified (see Figure 51).

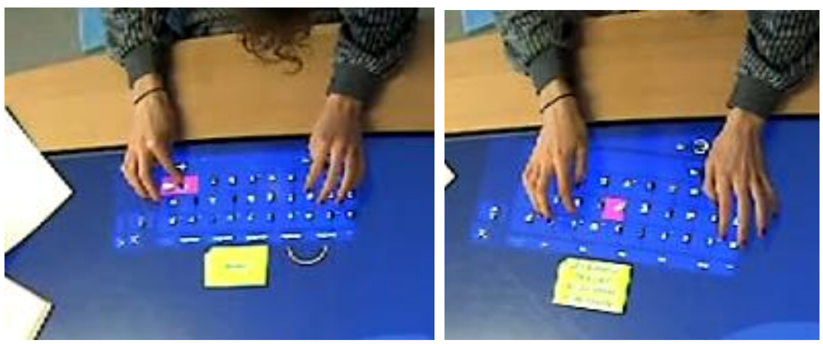


**Figure 51: Left: Student using the backspace function on the keyboard to delete most of the text she had written in her post-it note. Right: Same student rewriting the post-it note.**

Lastly, the table served a collaborative function, i.e. a means of transformative action directed at another's activity, in that it became a means to view others' ideas as they were being externalized. In this way, it became possible to interrupt the reflection process and insert one's own ideas orally. Additionally, it was possible to view others' ideas and combine them with the heuristic function of orienting one's own activity. Finally, the table was a means of producing or modifying written ideas as a collective.

For example, in the following exchange a student had written a post-it note that was now on the board. As the teacher joined the discussion, he pointed out a problem with the logic that needed to be addressed. Student C, serving as the animator, sent the post-it note from the board back to the table for modification.

***Student C:*** *I'm sending it back to you.*
***Student A:*** *Can you change that one? [indicates a post-it in a wormhole on the table]*
***Student B:*** *Yeah… [removes the post-it note from the wormhole and opens the digital*

*keyboard]*
*So, make it unusable? [Looks around the group]*
***Student C:*** *But in fact, it's to make stolen bills unusable.*
***Teacher :*** *It's in case of an infraction [points to the post-it note]*

The group, with the help of the teacher, co-corrected a post-it note that had been written by Student A.

Let's move on to the board: In terms of epistemic functions, it was used to display post-its and rearrange them as understanding changed. This occurred both individually and collectively. Students would sometimes arrange post-its on the board individually and then validate the changes collectively or not, leading to a new arrangement accomplished collectively. Additionally, teachers had designed canvas for the tools that students were mobilizing to analyze their case studies. These were organized into squares or diagrams with definitions and tips for how to use them based on information presented in class and reading. Students would choose to use these canvases to aid in understanding and working through the use case. The ability to view two canvas at the same time was frequently used to see the work the group had previously completed or different logic structures that could aid in their current reflection (See Figure 52).

**Figure 52: Using the split screen functionality of the board to view two canvases at the same time.**

In terms of pragmatic functions, the board is a place for both intermediate and finalized representations of the group's ideas. So rather than being only a place to get information, it is also a place to represent the group's changing understanding as it moves towards finalizing their ideas and solutions.

**Figure 53: Group building a model representing their ideas over time.**

In Figure 53 we see a model of the group's solution to the use case taking form. In the left-most image, the group begins building a new model of their reflection in the lower right-hand corner. We have indicated the area of interest with a red circle. In the middle image, the group has added several post-its around a central theme. Finally, on the right, they have used a color code of yellow, blue, and orange to demonstrate thematic links inside of the model.

In terms of heuristic functions, the board is used to gauge the group's progress and orient one's own activity to fill in the gaps. I.e. someone reading the board may identify missing information and attempt to complete it. It is used to orient the group's activity in much the same way; it becomes a means to evaluate the group's progress and eventually reorient the group's direction to address the perceived gaps. Very often, the teacher also mobilizes the board to this end. Additionally, the canvas provided guideposts for students. As they fill in the canvas, they will propose to move on to the next section. In Session A, the canvas used is very sparse and open, so many groups move around the different sections sporadically. Others, like the one show in Figure 54, are more structured.

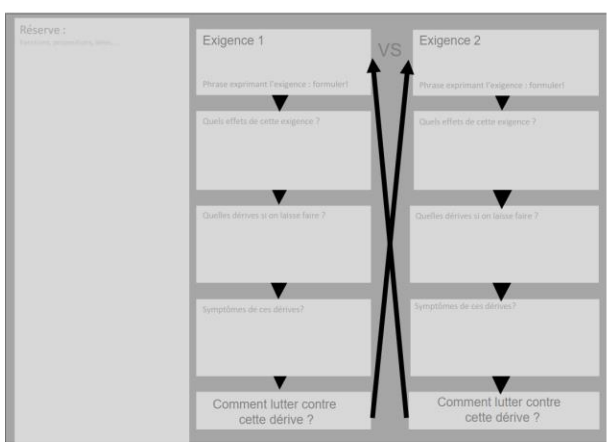



**Figure 54: Pedagogical canvas created by teachers used to analyze situations in tension**

In the following quote, one student indicates aloud that he is continuing to the next box, now that they have co-written the post-it in the previous box:

> *So, we go down? [reading from the canvas] what problem if we… bah the document is…*

This indicates that he is using the information on board not only to ascertain what he should do next, but that it is time to move on.

Finally, in terms of collaborative functions, the board is a means of keeping track of the group's progress, permitting individuals or the group to act upon it by moving, rearranging or modifying it.

It should be noted that different groups developed different schemas related to Subject-to-Other Subjects communication. For example, some groups used colors to indicate the person who produced a written note, while other used colors to indicate thematic links between ideas. When colors were used to indicate thematic links, the group was more likely to engage in epistemic conflict (Doise & Mugny, 1981) around the nature of the ideas and whether or not they fit into the agreed upon categorizations.

This dual usage made the board central to the table-board groups' progress and primary focus of the activity in the latter half of the sessions, relegating the table to a position of relative obscurity after the initial ideation phases. However, the table still had a role to play as it was used to produce written notes based on the group's discussion. This prevented blocking others' view of the board space. The central role of the board likely also relates to the students' usage schema that have been years in the making: using chalkboards, whiteboards and more recently smartboards as a central focus for communicating to a large group in a classroom setting.

The board also served as a form of reflexive mediation, allowing the individual to reflect upon and capture his/her thoughts as they were developing. This was seen as students rearranged items on the board without discussing it with others (individual work). Thus, this became both a way for the subject to help formulate and integrate others' ideas with their own and a way for "other subjects" to use the board to get a glimpse of the subject's developing understanding and potentially intervene when the subject's new arrangement ceased to match the group's shared understanding in order to repair the divergence. We see this occur in the below interaction:

*[Student C interacts with the board without speaking, Student A intervenes, moving something. Students B and E observe.]*
*[Student D picks up his workbook from the table]*

***Student D:*** *You have to write the time, because here when you say … [reads his aloud from his workbook]*
***Student A:*** *Yes, it's important I think.*
***Student D****:* *At a certain point you say it's not fast enough.*
***Student C****:* *Ok that's fine… because we have [points at a group of post-it notes on the board] she wants to go to work on time…*
***Student D****:* *Why would that be at the top?*
*[student C moves the post-it students A and B point at the board]*
***Student A****:* *No, no, no, why… or then [moves a post-it] it's right at the top, but why? Because she wants to go to work on time? Because she left too late, because she left her house too late. Why did she leave too late? Because she woke up too late…*

In this case, student C has made some changes to what the group had done, without consulting any group members. However, this prompted student D to identify a potential issue in student C's logic and request an explanation. Rather than explaining, Student C tries to readjust the board based on his interpretation of Student D's comment – that the change was being rejected. Student A readjusts it and attempts to answer the question, supporting Student C's adjustments. In this case, student C used the board to externalize his ideas and for others to realize that there had been a divergence as a result of this reorganization.

### Teacher & Student Feedback for Table and Board Modality

Evaluations by teachers determined that all three table-board groups were successful across the majority of their case study sessions. Session C seemed to pose the most difficulty, with at least two groups struggling to reach agreements and complete all parts of the activity. However, in these groups we also noted a slightly lower level of teacher intervention versus other modalities, which could have contributed to this outcome as well.

Student feedback via questionnaires indicated that while some believed that the table / board modality had merit as a way to produce ideas and make decisions, they found both surfaces to be "too slow". As a result, they felt it necessary to return to traditional tools, such as the whiteboard, in order to externalize their ideas more quickly, especially when it came to drawings.

*I don't deny that it is practical, but I think I spend too much time with my computer for notetaking already. I find that it is detrimental to my reflection; more and more I prefer old methods (board, sketching…) which are effective and stimulating.*

*I found the technology that was made available to us to be useful for everything around brainstorming. However, it's too "long" to use when you really want to draft something.*

Students also reported that the tool's usage was not always evident, meaning that information flow between the tool and user regarding its usage needs to be made clearer. Some technical issues must be confronted for this to be possible. For example, on most portable devices (tablets, smartphones, etc.) pressing with your finger in a text box will allow the text to be edited, where on the table or board you must click a pencil icon to edit the text first. Difficulty in differentiating between a desire to move an object or edit an object led designers to make this decision, which users find frustrating as it does not fit into a common usage schema seen in similar technologies.

Overall, the table and board modality lent itself to a more cooperative approach, which was consistent throughout the activities. The baseline for these groups, however, was also more cooperative, indicating that the modes of interaction used with the table and board modality follows closely with those used with paperboards/whiteboards and traditional post-it notes. However, we do not discount this tool as there does seem to be an improvement in quality of the interactions. This is backed up by previous research, which has shown that it still carries value in increasing shared talk time amongst group members, an element linked with higher collective intelligence (Jones et al., 2011), when compared with traditional tools. The around-the-table (Buisine et al., 2012) nature of this modality lends itself to this. Additionally, cooperation is a mode of interaction which we link to creativity, divergence, and epistemic conflict.

### *5.2 Tablets & Board Modality*

The individual private space afforded by the tablets allowed the students a place to reflect and write their ideas, modify them, and then send them to the board directly or delete them. While most of the production was still done orally, the access to an individual space always provided a way to act to all group members. The tablets in this modality served an epistemic function (Rabardel, 1995), allowing each student the opportunity to reflect on the object of their activity, search for information and externalize their thoughts. These externalizations in a private space, however, removed the ability of others to see what was being done, unlike in the table-board modality. In both cases, however, the interactions we saw around this were much the same. Students would ask others what they were writing as they were writing it. In the case of the individual-public table space, it was possible to simply read it directly. However, in the individual-private space, sharing the information became a choice, though we did not observe anyone declining to share when asked. It is important to note again here that these were not personal tablets but were provided for the research. In the descriptive study, where personal devices were used, sharing occurred less frequently and incoming notifications were often distracting.

As in the other two modalities, the board served as a way for students to reorganize their thoughts and put them into relationships with those of other group members. However, rather than always starting with a brainstorming phase, the three groups observed sometimes preferred not to use the individual space provided for individual reflection at all. Instead, throughout the session they worked aloud, using the tablets as a means to write down the decisions made by the group. For this modality, the added mobility in the individual space allowed all group members to move as they wished, and interact in the collective space without losing that access or needing to separate from the group to have it if everyone else remained at the board. This fluidity afforded by the tablet-board modality contributed to the groups' ability to adapt the tool to their working styles and the pedagogical scenario.

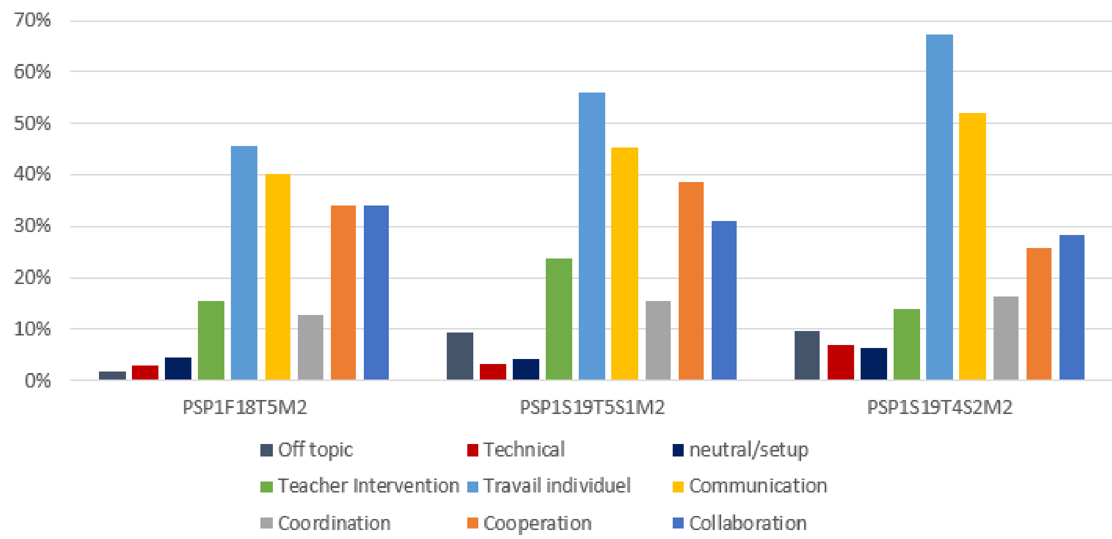



**Figure 55: Tablets and Board: CIAO Averages (Instrumented Sessions)**

While the table-board modality was clearly more cooperative, the tablet-board modality allowed for more flexibility. Overall, the groups never exceeded a 10% difference in time spent in collaboration or cooperation. Therefore, we have classified this modality as "balanced" – a more or less even mix between collaboration and cooperation is possible with this modality, with the ability to adapt it to fit one or the other readily.

### Schema for Tablets and Board Modality

In this sub-section, we will mobilize Rabardel's notion of schema, "an active organization of lived experience which integrates the past" (Rabardel, 1995). We will pay special attention to the action schema, but our primary focus is to describe them in articulation with the four functions of schema proposed by Rabardel (1995). For him, schema can serve:

- Epistemic functions: turned toward the comprehension of the situation;
- Pragmatic functions: turned toward the transformation of the situation and the obtention of results;
- Heuristic functions: orienting and controlling the activity;
- And collaborative functions: a means of transformative action directed at another's activity.

The schema which emerged for the tablets very much resembled that of the table in the table/board modality described in the previous section. In terms of epistemic functions, tablets served as a means of creating intermediate objects and externalizing one's representations. In Figure 56, we see students writing their thoughts on their tablets as part of a brainstorming phase.

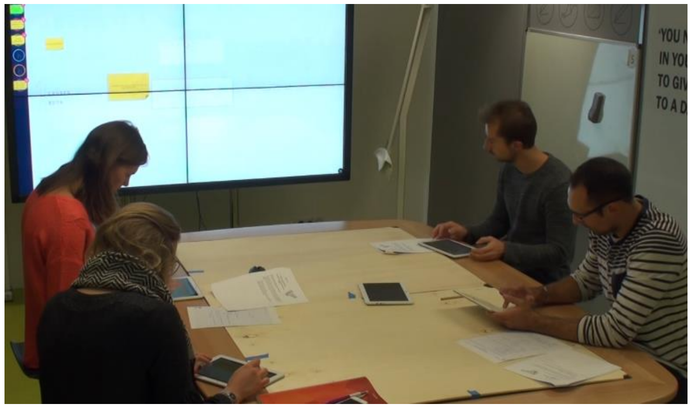


**Figure 56: Students writing on their tablets at the beginning of work session**

However, we do note some differences between the tablets and table. Notably, the table was also used to search with an internet browser and pull in images from these searches to illustrate ideas. For this modality, the board served this function despite the tablets having internet browsers and the ability to send images. It would have required switching between browser tabs and applications, which may explain why the tablets were not used for this purpose. Though not included as part of our experimental data, when our groups left the research and began their final projects as part of their class work, they used both tablets and laptops. Tablets were used to generate written ideas and laptops were used for searching and accessing informational documents (Figure 57). So, while the epistemic functions between the two individual space types we tested are similar, there are some slight differences in the usage schema mobilized to while the artifacts were in use.

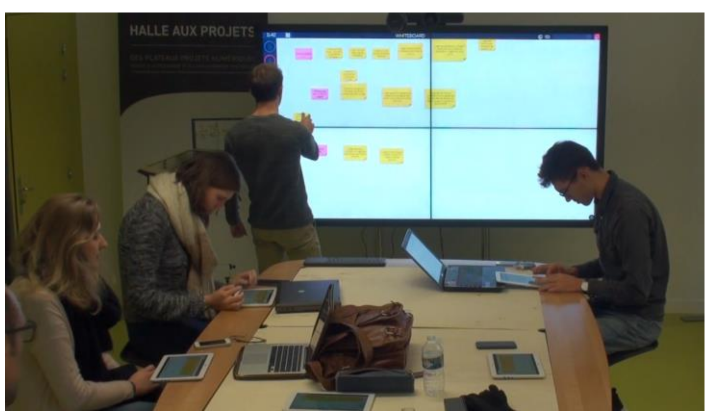



**Figure 57: Post experiment - Tablet & board group use personal laptops for finding information**

In terms of pragmatic functions, they were a means to produce written notes that would eventually be sent to the board. Like the table, the tablet served as a starting point for transforming the situation, which would ultimately occur on the board. In Figure 56, we see post-it notes arriving on the left side of the board from the tablets, as well as a few that have already been placed onto the canvas. Figure 58 and Figure 59 show how this progresses overtime. The tablets serve as the starting point to produce the ideas, which are then read, discussed, and organized to respond to the case study.

**Figure 58: Students begin to read others' ideas from the brainstorming phase**

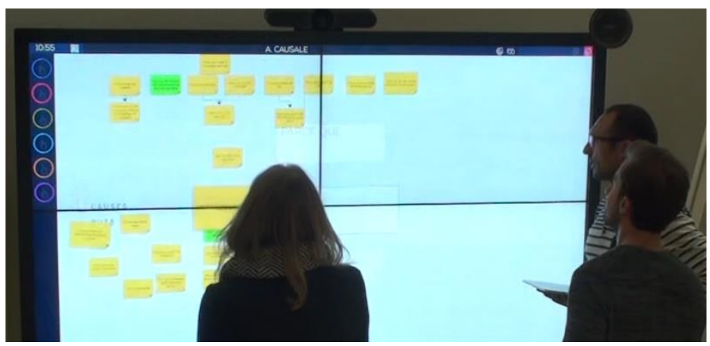


**Figure 59: Collection of ideas from the brainstorming phase are organized into a diagram**

This was typical of this modality and a very stable class of schema for groups using individual spaces, especially at the beginning of the session. As time went on during the session, as with the table, certain groups left the tablets behind in favor of the board. However, some groups and individuals took advantage of the tablet's portability to continue producing ideas individually (and collectively) in later phases.

In terms of heuristic functions, the tablets were a means of externalizing one's thoughts and building on one's reflections/representations. Students would erase their text and rewrite their ideas, but only while they had the post-it on the tablet. Once sent to the board, it could not be sent back. Any changes had to occur on the board.

Finally, in terms of collaborative functions, the role of the tablet varies from that of the table. It is sometimes a means of showing one's ideas to the others before putting it into public space. It is worth noting that this was particularly rare. Where with the table, as the work is being completed in a public space, the student does not have a choice but to allow their individual work to be seen by others. Students inserting themselves into the reflection of others was not observed in the three groups using the tablet. With the tablet, sharing with others became a conscious choice. So here again, we see tablets playing a lesser role for directly impacting collaboration during their usage, but they are a starting point that takes on this function when articulated with the board. However, we could consider the co-writing of post-it notes via the tablet transformative of another's activities. This did occur with high frequency, and indeed was often articulated with a similar usage on the board.

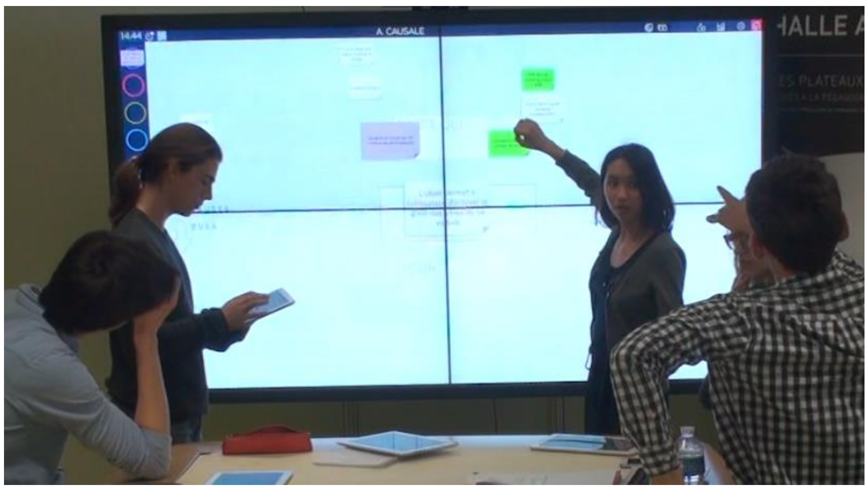



**Figure 60: Student E writing on his tablet and students A and B discuss her idea aloud**

In Figure 60 we see the start of the following exchange, in which Student E (left) writes Student B's (female, right) idea. Students A (right) and B continue to discuss it aloud. By the end of the sequence Student A is also writing an idea on his own tablet, the discussion around which leads to some changes during the writing and on the board later.

***Student E:*** *I just wanted to do, for the need to go out… if you want to put it at that level, then do "the object allows the user to remove the ice from his car because he needs to go out incessantly." I think it's missing a link, actually.*

***Student B**:* *And I have a proposition if you want. It would be to leave it up there, and there to put another one above. And there we would have another branch that explains why she takes her the car and not something else.*

*[Student E begins writing Student B's on his tablet]*

***Student A**:* *Yes, that's just what I was thinking. In fact, it would have needed a middle function that creations that junction "she needs to go somewhere incessantly in her car."*

***Student B**:* *But does that work for you? If we do a branch there and another?*
***Student A**:* *Yes, that works for me, we go up to the car and the need to go somewhere.*
***Student B**:* *Yes, but it's hierarchical all the same. Why the car, and not another option?*
*[student E removes the new post-it from the wormhole]*
***Student A**:* *In this case she needs to go out in order to go to work.*
*[Student B and Student E move post-its on the board; Student A, C and D are on their tablets]*
***Student A**:* *I'm going to put "she's fond of going out in the car" maybe… We can put safety, comfort, tradition.*
***Student C**:* *It's the sense of safety*
***Student A**:* *[continues typing on his tablet while speaking] in general when you get into a car…*
***Student D**:* *Me, the condition of security – I created it to put in the objectives actually*
***Student B:*** *[moving away from the board] ah… ah but then…*
***Student D:*** *We remove the ice from the windshield to use the car in safe conditions*
***Student A:*** *But it's not the same safety [continues writing on his tablet as the group discusses]*
***Student D:*** *No, but for me the car is not safety*
***Student C*** *Yes, it's the act of removing the ice*
***Student E:*** *[takes a post-it] So it's tradition, it's habit.*

The schema as they relate to the board in this modality resemble almost exactly that seen in the table and board modality. The exception is related to searches being performed as a group or individually (as seen in Figure 61) – attributing a new epistemic and collaborative function. Epistemic in that they allow users to find information and augment their reflection with images, and collaborative in that they allow others to watch and interpret such actions and potentially act upon them by making suggestions or inserting themselves into the others' activity. For example, this could take the form of making suggestions of which site to visit or which image to choose.


**Figure 61: Students using the board to conduct information searches**

### Teacher & Student Feedback for Tablets and Board Modality

Evaluations by teachers determined that all three tablet-board groups were successful across all their case study sessions. The work was completed satisfactorily by each group. Student feedback via questionnaires indicated a positive experience with this modality.

> *Very good support. Allowed us to study individually with the tablet before sharing our ideas afterwards on the digital board.*

> *I really liked the screen + tablet system because it allowed us to put our own ideas forward (even if shy) and then work on them together.*

> *Technology that is effective and adapted to group work because each person can express their ideas. Very intuitive system that makes working in a team easier.*

Students indicated that the tablet-board modality was very useful in allowing group members to contribute and express their own ideas. The devices themselves did not pose problems for the groups and there were no complaints regarding the device's reactivity.

### *5.3 Board Only Modality*

Across all activities, the board-only modality demonstrated higher levels of collaborative activity consistently and is identified as collaboration-heavy (Figure 62).

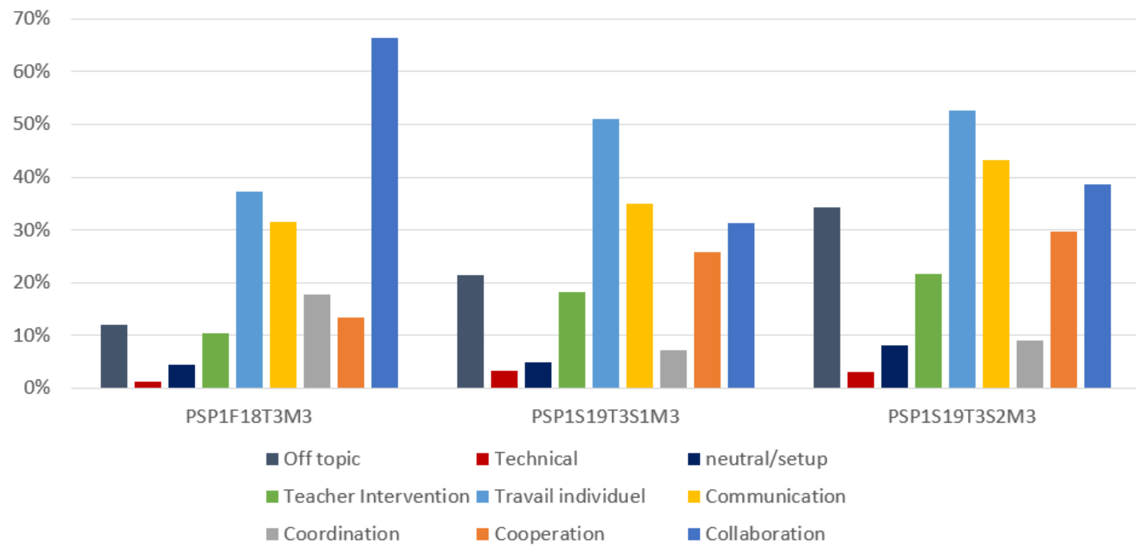



**Figure 62: Table only: CIAO Averages (Instrumented Sessions)**

At the beginning of almost every work session, student groups would try to find new ways to work together. They were often revisiting their coordination, before giving up on it. Groups working with the other two modalities tended to choose a method and stuck to it over all of their sessions.

> ***Student A*** *So, do we all concentrate on one thing?*
>
> ***Student B*** *Yeah, for me... we can do the functions there.*
>
> ***Student C*** *Can we... first we each do our own thing, then we do a phase together where we discuss case by case because the worry, generally, is that we discuss too much together, maybe and then we get off track.*
>
> *[3 students begin creating a post-it and two others look on from behind]*

In this conversation, which takes place in front of the board-only modality, we see a student realize one of the limitations of this modality: where other groups are easily able to work separately or together, their modality forces them to work together, lowering their creativity and causing them to become distracted by side-topics. Despite the recommendation made by Student C, the group continued to work together because it was impossible for two of the students to make those written contributions, since they had no access to an individual space.

### Schema for the Board-only Modality

In this sub-section, we will mobilize Rabardel's notion of schema, "an active organization of lived experience which integrates the past" (Rabardel, 1995). We will pay special attention to the action schema, but our primary focus is to describe them in articulation with the four functions of schema proposed by Rabardel (1995). For him, schema can serve:

- Epistemic functions: turned toward the comprehension of the situation;
- Pragmatic functions: turned toward the transformation of the situation and the obtention of results;
- Heuristic functions: orienting and controlling the activity;
- And collaborative functions: a means of transformative action directed at another's activity.

In terms of epistemic functions, the board became a place for the creation of intermediate objects via collective creation. Ideas were externalized orally and between one and three people recorded them. Occasionally, an individual would create an intermediate object without input from others (Figure 63).

**Figure 63: One person writing on the board-only modality**

Additionally, just as with the other two modalities, post-its were rearranged and changed as collective understanding changed. This was very rarely performed individually, as with the other two modalities as attention of most students in the work group was consistently on the board.

In terms of pragmatic functions, the board was a means to produce ideas collectively, serving as the space for both intermediate and finalized representations of the situation. For example, in Figure 64, we see students filling out the tension tool (see Figure 54). As they progress through the analysis process, they return to previously completed post-its to modify them to reflect the group's changes in thinking. This group, like others, moved from top to bottom, but returned to the top to update it as they worked.

**Figure 64: Students filling out tension tool on the board-only modality**

In terms of heuristic functions, rarely it was a place for an individual to externalize his or her thoughts but was more frequently used to gauge the group's progress and orient the group's activity to fill in the gaps.

**Figure 65: Moving a post-it on the board-only modality subject to collective reflection as it occurs**

Finally, in terms of collaborative functions, it was a means to view the group's progress, write ideas produced together and keep track of the progress. Eventually an individual could act upon this by moving and rearranging, but typically even the slightest movements would be subject to collective inquiry, as seen in Figure 65. In this case, the post-it was written towards the beginning of the session with input from the group.

Ultimately, attempts to use the board individually resulted in tensions, as others were left out of the process. This physical-digital workspace modality was a space in constant tension. At its base, we consider it to be a collective-public space, but this is consistently challenged. First, despite the large size of the board, in a group of 4, it was already too small to be truly collective. The students always approached the board in order to be “present” in the group. The majority of the work is completed with two or three students having their backs turned on the others. Additionally, the fact that students needed to be so close to the board means that they cannot easily see what others are doing in the space. So, despite considering this modality as collective-public, there are limitations to the number of people that can interact and the blocking of the space from others by people positioned in front of it.

Second, there were times when students used it as a space of individual reflection. This sometimes encroached on others’ uses as well, leading to far more time spent off topic in this modality than with the other two.

Ultimately, we expected students to use this physical-digital workspace in a way very much like they would use the whiteboard, but they didn’t. By this, we mean that in almost all student groups during “non-instrumented” sessions, a single animator was at the board and everyone else remained in their seats at the table. Instead, everyone moved around the digital board. This begs the question: why? With a traditional whiteboard, multiple students could pick up a marker and contribute, and we did see this (though rarely). There are a few potential reasons people stay away from the whiteboard, such as:

1. Fear of showing poor handwriting
2. No need to hand off a marker
3. Size and visibility of text on the digital board vs. the whiteboard
4. Usage & action schema around physical vs. digital.

A fear of showing poor handwriting seems plausible, other students hesitated to approach or pick up a marker. At least once when this did occur, the approaching student backed off immediately, holding his hands in front of him, in a gesture we interpreted as apologizing to the animator, as if it would be encroaching on their role. The need to hand off a marker seems low probability, because each group had several markers available. The size and visibility of text on the digital vs. whiteboard also seems unlikely. Students using the other two modalities would sometimes stay seated for most of the session, leaving the activity on the board to an animator. Additionally, it's possible to resize text on the digital board to make it more visible from the other side of the cubicle. Lastly, and most plausibly, is the action schema around the whiteboard versus a multi-user physical-digital workspace. Students were told that it was multi-user, so it is possible that the assumption was made that it should be used by multiple people regardless of whether or not this was the best approach. Ultimately, it would have changed very little between the instrumented and non-instrumented sessions to have a single person writing the group's ideas, but the tool afforded this, often to the detriment of the group's reflection.

**Figure 66: An example of catachresis in the board-only modality**

Lastly, we want to note one example of catachresis (Figure 66), the emergence of a new function (Rabardel, 1995), which occurred in only one group. Wormholes, the circles on the left side of the board, serve to send digital objects from the table or other devices linked to the session. Since there was no individual space or other devices in the board-only modality, the wormholes were not used. However, one group decided to use it to store extra ideas that they wanted to come back to later.

### Teacher & Student Feedback for the Board-only Modality

Finally, in the groups that used the table alone, evaluations by teachers determined that all three groups were moderately successful across all their case study sessions, but they did note that the groups tended to get stuck in their reasoning on occasion. The work was completed satisfactorily by each group. Students using the board-only modality did not see the interest in using the device, preferring their own systems. Only one student thought it might be due to a lack of mastery.

> *The technology, in the end, did not serve us much. We don't have enough digital material and we haven't had enough time.*
>
> *I didn't like working on digital boards. The software was not fluid or intuitive: we were wasting more time with these boards than with our computers.*

Indeed, the feeling of wasting time, being stuck and uncreative was mentioned during student work sessions. The presence of too much collaboration as we saw with this modality seemed to ultimately hinder the group's ability to come up with the innovative solutions they were hoping for.

### *Chapter 5 Conclusion*

Before discussing the implications of these results for our hypothesis, we would like to begin by discussing the performance of the Collaborative Interaction Analysis mOdel (CIAO) when applied to this data. While there are certainly improvements that could be made to the model or the methods used to apply it, it has allowed us to identify some differences between the modalities that we sought to test. Or at the very least to show that there is some correlation between the modality and collaborative processes.

Regarding our first hypothesis, based on both quantitative and qualitative analysis, we can confirm that the characteristics of the workspace has an influence on the collaborative processes implemented by students during collective activity, or at least that there is significant correlation. Groups using the table-board modality tended to have more cooperative interactions. They would perform individual work, reflecting on the case study before coming back together to confront their ideas. Groups using the tablets-board modality tended to be balanced between collaboration and cooperation, spending nearly equal amounts of time in each mode of interaction. Finally, the groups using the board-only modality tended to be more collaborative. They spent more time building ideas together, with lower levels of divergence.

### A Quantitative Analysis Points to Statistically Significant Differences in Modes of

### Interactions Mobilized by Student Work Groups

A one-way ANOVA and post-hoc Tukey HSD test were conducted to compare the effect of each workspace modality on collaborative processes (collaboration, cooperation, coordination, communication and individual work) and three other measures tracked for this study (time spent off topic, time dedicated to resolving technical issues and teacher intervention time). These tests are designed to determine if results may be statistically significant, i.e. unlikely to be due to chance. The p-value represents a probability of obtaining these differences if the difference doesn't really exist. A statistical significance also does not mean that the difference matters, contextualizing these results are key. The results of the statistical analysis presented here are used only as a compliment to the observational data described in the previous sections as they only represent differences in time-spent, without taking into account that while students may spend the same amount of time in a mode of interaction, does not mean that the quality of that time is equal.

The one-way ANOVA results indicate statistically significant differences between the physical-digital workspace modalities for time spent in the modes of interaction collaboration, cooperation, communication and also in time spent off topic.

In regard to collaboration: There was a significant effect of workspace modality on collaboration at the $p<.05$ for the three conditions and control condition [$F(3, 32) = 11.2$, $p= 3.5347e-05$]. The post-hoc Tukey HSD test showed a significant difference for time spent collaborating for Table-board vs. Tablets-board ($p=.04$), Table-board vs. Board-only ($p=.001$), and for Tablets-board vs. Board-only ($p=0.03$). For collaboration, the most significant difference was detected between the table-board and board-only modality, but a difference exists when comparing all physical-digital workspaces. These results suggest that levels of collaboration (as defined by CIAO) are, statistically speaking, significantly lower for the table-board modality and significantly higher for the board-only modality, while the tablets-board modality falls into a middle-range. However, when compared with traditional interventions, the board-only modality represented the most significant increase in the collaborative mode of interaction.

| **Pairs** | **Tukey HSD p-value** | **Tukey HSD inference** | **Difference Interpretation** |
|---|---|---|---|
| Table-board vs. Tablets-board | 0.0366758 | p<0.05 | **Significant** |
| Table-board vs. Board-only | 0.0010053 | p<0.01 | **Significant** |
| Tablets-board vs. Board-only | 0.0290354 | p<0.05 | **Significant** |
| Table-board vs. Traditional | 0.3554064 | p<0.05 | Insignificant |
| Tablets-board vs. Traditional | 0.0362416 | p<0.05 | **Significant** |
| Board-only vs. Traditional | 0.0038734 | p<0.01 | **Significant** |

**Table 16: Post-hoc Tukey HSD test results for Collaboration**

**How to read this table:**
*This table shows the Post-hoc Tukey HSD test result for collaboration, as defined by CIAO. The Post-hoc test is complementary to the one-way Anova, which identifies simply that a statistically significant difference exists. The Post-hoc Tukey HSD compares each of the data sets to each other in order to identify exactly where that statistically significant difference exists. The "pairs" column indicates which two modalities are being compared in a given row. The "p-value" represents a probability of obtaining these differences if the difference doesn't really exist. The inference column gives you the level at which the p-value is determined to be significant. The lower the value, the more likely the result is to be significant. Finally, the last column compares the p-value with the inference value to decide if there is a statistically significant difference in the pairs tested.*

In regard to cooperation: There was a significant effect of workspace modality on cooperation at the $p<.05$ for the three conditions [$F(3,32) = 3.64$, $p=.023$]. The post-hoc Tukey HSD test demonstrated that this difference exists between the table-board and board-only modality. These results may indicate that the tablets-board modality is similar to both the table-board and board-only modalities for cooperation, but just enough difference exists between the table-board and board-only modality to consider the effect to be meaningful. We also note a statistically significant decrease in cooperation from the traditional "non-instrumented" sessions when compared with the board-only modality.

| Pairs | Tukey HSD p-value | Tukey HSD inference | Difference Interpretation |
|---|---|---|---|
| Table-board vs. Tablets-board | 0.8999947 | p<0.05 | Insignificant |
| Table-board vs. Board-only | 0.0486069 | p<0.05 | **Significant** |
| Tablets-board vs. Board-only | 0.0627640 | p<0.05 | Insignificant |
| Table-board vs. Traditional | 0.7665281 | p<0.05 | Insignificant |
| Tablets-board vs. Traditional | 0.6880821 | p<0.05 | Insignificant |
| Board-only vs. Traditional | 0.0169798 | p<0.05 | **Significant** |

**Table 17: Post-hoc Tukey HSD test results for Cooperation**

In regard to coordination: There was no significant effect of workspace modality on coordination ant the $p<.05$ for the three conditions [$F(2,24)=0.51$, $p=.6$]. No post-hoc test was conducted.

In regards to communication: There was a significant effect of workspace modality on communication at the $p<.05$ for the three conditions [$F(2,24)=4.9$, $p=.016$] Unexpectedly, the post-hoc Tukey HSD test demonstrated that this difference exists primarily between the table-board and tablet-board modality. In terms of time spent communicating new ideas, the control and experimental modalities did not show statistically significant differences.

| Pairs | Tukey HSD p-value | Tukey HSD inference | Difference Interpretation |
|---|---|---|---|
| Table-board vs. Tablets-board | 0.0166357 | p<0.05 | **Significant** |
| Table-board vs. Board-only | 0.7555707 | p<0.05 | Insignificant |
| Tablets-board vs. Board-only | 0.0748076 | p<0.05 | Insignificant |

**Table 18: Post-hoc Tukey HSD test results for Communication**

In regard to individual work: There was no significant effect of workspace modality on time spent working individually at $p<.05$ for the three conditions [$F(2,24)=0.97$, $p=.4$]. No post-hoc test was conducted.

In addition to tracking the five modes of interaction identified in the CIAO model as part of globally collaborative work, we also tracked a few additional items. These included:

- Off-topic time: time spent discussing subjects outside of the purview of the case study, time spent on a personal device
- Teacher interventions: time spent with the teacher in the cubicle
- Technical issues: time spent resolving technical issues

No significant difference between modalities was detected for teacher interventions or technical issues. However, there was a statistically significant effect of workspace modality on off-topic time at the $p<.05$ for the three conditions [$F(3,32)=7.3$, $p=.0007$]. The post-hoc Tukey HSD test demonstrated that this difference exists primarily between the tablets-board and board-only modality. No significant difference was detected when comparing table-board and tablets-board to the traditional sessions, indicating that off-topic time using traditional, table-board and tablets-board modalities did not have statistically significant differences. However, there was a significant difference when comparing the board-only modality with the traditional sessions, suggesting that the increase in off-topic time seen in this modality is significant.

| Pairs | Tukey HSD p-value | Tukey HSD inference | Difference Interpretation |
|---|---|---|---|
| Table-board vs. Tablets-board | 0.2097767 | p<0.05 | Insignificant |
| Table-board vs. Board-only | 0.2453135 | p<0.05 | Insignificant |
| Tablets-board vs. Board-only | 0.0065097 | p<0.01 | **Significant** |

**Table 19: Post-hoc Tukey HSD test results for off-topic time**

These results indicate statistically significant differences for collaboration, cooperation, communication and time spent off-topic across the three modalities. Based on the results of our coding and analysis, we have identified each modality based on its impact on collaboration and cooperation. The table-board modality, demonstrating higher average levels of cooperation is identified as more cooperative. The board-only modality, exhibiting high levels of collaboration is considered more collaborative. Finally, the tablet/board modality, which shows nearly equal levels of cooperation and collaboration has been identified as balanced.

Statistics can help us demonstrate that a difference may be significant, but do not help us understand the nature of the differences and may not account for items that cannot be expressed quantitatively. In order to have the full picture, it is important to consider the phenomena that interest us in more detail to be able to draw valid conclusions.

## Conclusions

Based on our results and analyses, we draw two conclusions when it comes to the influence of physical-digital workspaces on collaborative processes:

1. individual space plays an important role in supporting globally collaborative work;
2. fluidity of movement between physical-digital space types is key to successful collaboration.

### *Individual Space Led to Higher Quality Collaboration*

While it is clear that the case studies and group work preferences do have an impact on how these physical-digital spaces are used, the space and its affordances do impact the ways in which the groups work together. The presence of individual space versus no individual space has the greatest impact on the groups' ways of working, creativity and engagement in the task. We see this through the differences in time spent collaborating, cooperating and communicating when the different physical-digital workspace modalities are compared.

The use of individual space gives each student the opportunity to reflect and externalize their thoughts. Gracia-Moreno (2017) noted something similar when students had access to an individual space. When students have no individual space, as in the board-only modality, they were less likely to cooperate – which means fewer challenges, negotiating and epistemic conflict (Doise & Mugny, 1981). However, groups working with individual space were more likely to take time to reflect, write their ideas and then discuss them as a group. This was demonstrated through the increased levels of cooperation in both modalities over that shown in the board-only group. Additionally, as we'll discuss in Part Four, students without recourse to an individual space were more likely to spend time discussing other topics, on their personal devices or even simply wandering around the room.

#### *Fluidity of Movement is Key to Successful Collaboration*

The groups which were judged as most successful by teachers were those working with the tablet and board modality. However, we need to take into account that this space was not only individual-private, it was also mobile. This allowed students to move from shoulder-to-shoulder to around-the-table positions quickly and easily. It was never necessary to remove oneself from the group to continue contributing. When we look back at interactions from our descriptive study, we also see this as different from laptops. Students who used laptops were more likely to stay seated, to spend more time looking at their screen and more time looking at other things online. While a laptop, by nature, is considered mobile, it is usually placed on a table and left there. So, in the context of our study it is certainly less mobile than a tablet.

## PART THREE CONCLUSION AND SUMMARY

Our primary focus in Part Three was to answer the first part of our research question: How do physical-digital workspaces influence interactions within student work groups? To us, this question was a necessary steppingstone to being able to understand how an instrument might influence the development of collaboration skills. If we could show that something changes based on the physical-digital workspace being used, then we could make the connection between those spaces, the activity (interactions), and what is learned by the student based on the actions taken. After applying CIAO as a tool to generate quantitative data points and performing a qualitative analysis around the schema used by students, we believe that there is evidence to suggest that physical-digital workspaces do influence interactions. The form that the influence takes varies from workspace to workspace based on its affordances. Collective workspace leads to more co-building. Individual and collective workspace increases cooperation. A personal and mobile individual space seems to lead to a balance between cooperation and collaboration.

In Part Three, we addressed our research question: How do physical-digital workspaces influence interactions within student work groups?

We defined collaborative interactions based on *globally collaborative work*, a way of defining and thinking about collaboration in a way that includes the various types of interactions which could occur while a group is working together (Figure 40, represented below). From this model we constructed CIAO (Collaborative Interaction Analysis mOdel).

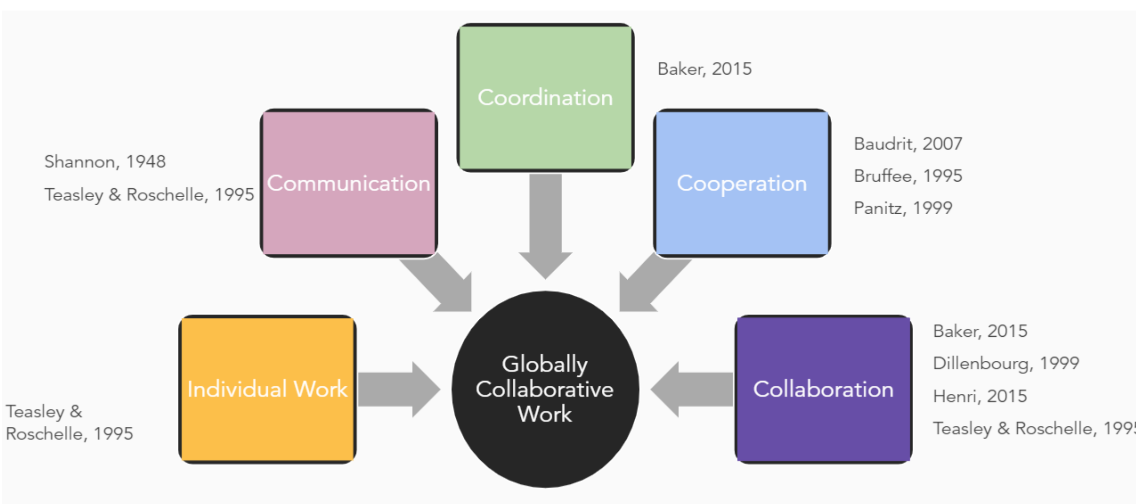



**Figure 36: Globally Collaborative Work (Tucker et al., 2018)**

CIAO allows us to use both verbal and non-verbal cues to identify these modes of interaction. We've used CIAO to analyze some 55 hours of video and audio data to collect quantitative evidence of which modes of interaction are put to use when using different physical-digital workspace modalities.

Additionally, we performed qualitative analysis applying Rabardel's (1995) schema functions to describe how students are using the tools and how those usages vary from modality to modality. Our results are two-fold:

First, we have demonstrated that CIAO can show differences in group interactions. Second, we demonstrate that groups use the physical-digital workspace modalities differently based on their affordances. Those results lead us to draw two principle conclusions: (1) the usage individual space leads to better collaboration as students are able to reflect and externalize their ideas, leading to more epistemic conflict; (2) the fluidity of movement around the space afforded by using mobile devices improved participation. Students did not need to separate themselves from the group to return to the table to write. They could bring their tablet with them and stay engaged in the group's conversation while working individually.

# PART FOUR: THE INFLUENCE OF PHYSICAL-DIGITAL WORKSPACES ON ENGAGEMENT AND COMPETENCY DEVELOPMENT

## PART FOUR INTRODUCTION

In Part Four, we address our second research question – How do physical digital workspace influence interactions within student work groups, *and by consequence, the development of collaborative competencies?* It is separated into two chapters, related to the elaboration of a framework for evaluating collaborative competency and engagement (Chapter 6) and the results from operationalizing this framework to determine how physical-digital workspaces influence student engagement in collective activity and on the activation of collaborative competencies (Chapter 7).

In Chapter 6 we will describe the evaluation protocol we used to measure student competencies and engagement in collaborative activities. We begin with an *a priori* examination of how collaborative competencies may be linked to collaborative modes of interaction described in CIAO. Then, we go on to present the $CO^2$ (COllaborative COmpetencies) framework we have developed for evaluating collaborative competency and engagement generally, explaining our reasoning behind its format, then discussing each section of the framework in depth.

In Chapter 7, we describe the results of applying the frameworks presented in Chapter 6. We first present results from a quantitative analysis before putting those numbers into context. Individual spaces, especially, seem to have a positive influence on engagement and competency activation. Additionally, they seem to have an impact on how introverted students and non-native speakers participate. Finally, we address certain tensions we see in the articulation between individual and collective competencies.

# CHAPTER 6 $CO^2$: A FRAMEWORK FOR EVALUATING COLLABORATIVE COMPETENCY AND ENGAGEMENT



***Chapter Introduction***

We have broken Chapter 6 into two sections. In the first, we present an *a priori* reflection on how collaborative competencies may be linked to the modes of interaction defined by globally collaborative work. This initial step was taken in an effort to understand how and to what extent experiences formed through student participation in and the activation of these different modes of interaction may contribute to competency development. We could have stopped at this point and related the analysis performed using CIAO to competency results with this a priori reflection. However, we did not feel that this was sufficient to come to relevant conclusions about how physical-digital workspace influences collaborative competency development. From that point, we decided to develop the $CO^2$ (COllaborative Competency) evaluation framework. This led us to face other challenges: if competency development is not observable, what can we observe? To what extent could we relate it to competency development? We attempt to answer these questions in this chapter, reaching the conclusion that while we cannot observe competency development, we can see externalized behaviors/actions and how they impact the group/group's progression. This does not directly demonstrate competency development, but it does give us a first look at whether or not certain experiences are more or less likely to occur and if students are likely to have educative (as opposed to miseducative (Dewey, 1938b) ) experiences.

## *6.1 Linking Collaborative Competencies to Modes of Interaction*

Prior to evaluating for collaborative competencies activated by the students participating in our study, we set out to do an examination of how collaboration skills relate to the different modes of interaction. Our aim was to develop a working hypothesis outlining how the two might be linked, which helped us establish the $CO^2$ framework described further in this chapter. As such, the following is a precursor step to our framework. We feel this merits an explanation in the context of understanding how modes of interactions impact competency development, and in turn help drive some elements of response to our research question. Though imperfect, this effort to connect collaborative competencies to modes of interactions is the initial step in understanding the "consequence" part of our research question. "How do physical-digital workspaces influence interactions within student work groups, and by consequence, the development of collaborative competencies?" The question itself presupposes the existence of the links that we propose here, which we then attempt to validate through observation and quantitative analysis based on the framework we explain later.

We began by defining the level of the link between the competencies and the modes of interaction in globally collaborative work, asking the question: during which mode of interaction are we likely to see the mobilization of which competency and to what extent? It is this mobilization that we refer to as "competency activation." We defined three levels of mobilization:

- **Key moments:** Low-level activation of the competency, permitting the individual to mobilize and develop basic skills associated with it.
- **Deepening ability:** Mid-level activation of the competency, permitting the individual to deepen their ability to use/mobilize the skills associated.
- **Mastery:** Advanced-level activation of the competency, permitting the individual to master the skills associated.

This is not to say that students will necessarily activate, deepen or master the competency in any one session or even in several sessions, but rather that the opportunity is likely available when engaging in that mode of interaction. This is due to how the competencies have been defined and the types of gestures and language acts used to identify each mode of interaction. Let us look at each competency.

| | Competency |
|---|---|
| **Regulation** | The know-how to manage, coordinate and evaluate his/her own work as well as that of the group. |
| **Communication & listening** | The know-how to communicate with one's colleagues in an efficient and adapted manner. |
| **Teamwork** | The know-how to create cohesion within the group in order to obtain the common objective. |
| **Social Intelligence** | The know how to recognize and respond to the emotional needs of one's peers. |
| **Constructive Conflict** | The know how to monitor, manage and resolve conflicts within the group. |

**Table 20: Competency categories and definitions**

For ease of reading, the competency is highlighted in bold and the mode of interaction appears in italics. For the **regulation** competency, the know-how to manage, coordinate and evaluate his/her own work as well as that of the group:

> During *individual work*, a student may engage in activities necessitating the integration of the group's plan with his/her own plan and objectives. They will also need to complete the agreed upon work. This is a key moment for learning how to regulate one's own activity at a basic skill level compared to the more complex interactions associated with attempting to regulate the group's activity.
>
> During *communication*, a student is expected to participate by contributing ideas and/or asking questions. This could be considered a key moment as the regulation competency includes participation. At its most basic level, this includes expressing ideas and listening to others'.
>
> During *coordination*, students can offer a plan, assist in its implementation, make adaptations of those plans or of group roles to fit the group's progress, evaluate the group's progress and they may attempt to make use of other's skills. It is here that we see the possibility of both deepening and potentially mastering the regulation competency (i.e. activating it in a situation with a high degree of complexity).
>
> During *cooperation* and *collaboration*, students may need to evaluate progress and implement the plan. However, both of these relate back to coordination, making that the most important mode of interaction for the activation of this particular competency.

For the **communication** competency, the know-how to communicate with one's colleagues in an efficient and adapted manner:

During *individual work*, a student may need to prepare individually realized work structured in an easily understandable/accessible format or even prepare writing that is destined for communication (such as writing an email). This is preparatory for the communication phase and can be a key moment of practicing communication or even "listening" as it relates to receiving written communications.

During the *communication* mode of interaction, a student may need to share and explain ideas, ask for information/clarification, give feedback, adapt to the audience, choose the most adapted communication method, and use/read nonverbal communication. However, this is an opportunity to deepen the ability. We also see similar skills necessary for *coordination*, providing the opportunity to deepen the ability. Finally, during *collaboration* and *cooperation*, the same activities can be deepened and mastered as one's ability to communicate effectively is put to the test in increasingly complex interactions, with the need to engage in active listening and ask questions to ensure clear understanding.

For **teamwork**, the know-how to create cohesion within the group in order to obtain the common objective:

During *individual work*, a student may need to complete his/her "fair share" of the work. However, this is not necessarily a key moment relative to teamwork as a competency. Likewise, *communication* may include asking others for their opinions, but does not require a high-level activation of skills associated with teamwork. However, during *coordination*, it becomes necessary to take action with others: asking for their opinions, taking turns, dividing work fairly, agreeing on objectives and potentially engaging with others socially to create a positive atmosphere. This is a first level of activation, with coordination accounting for only a small section of time, we recognize it as a key moment. The same behaviors are required during *cooperation* and *collaboration* over a sustained period that permits students to deepen and eventually master the competency. However, we often see this competency associated with being "collaborative" in the literature,

For **social intelligence**, the know how to recognize and respond to the emotional needs of one's peers:

By its nature, it is possible to consider social intelligence as a skill that would not be activated during *individual work* phases. However, it's important to note there that it may play a role as part of the reflection process or a process of understanding one's own emotional needs. As such, this could be considered a key moment as part of the process for understanding one's own needs and reactions in emotionally charged moments.

During *communication*, one may need to observe others' reactions and emotions, make sure to share talk time with others and respond to emotions as they communicate new ideas or develop their questions. We see this mode of interaction as a key moment to practice this competency. However, it is during phases of *coordination*, *cooperation* and *collaboration* that it is possible to deepen and master them, with cooperation representing the most challenging. Gauging and responding to emotional needs during negotiation and argumentation is important to prevent constructive conflict from becoming interpersonal conflict.

Finally, for **constructive conflict**, the know how to monitor, manage and resolve conflicts within the group:

During phases of *individual work*, it is necessary to prepare one's explanations and preempt any confusing elements. During *communication*, it's expected that new ideas will be discussed. *Coordination* is a key moment, given that it is a first opportunity to negotiate, resolve disagreements and try new approaches to ways of working. However, it is during *cooperation* that the most important skills should be seen: negotiating, accepting being wrong, resolving disagreements, trying new approaches, monitoring shared understanding/repairing it, offering solutions to disagreements. This is a moment to master constructive conflict skills.

Finally, during *collaboration*, we expect to see continued monitoring of shared understanding and signaling of divergence, as well as building upon other's ideas once agreements have been reached. We see this has an opportunity to deepen the competency, but not to master it as many of the key components associated with it occur during the cooperation mode of interaction by its definition.

After having identified the collaborative competencies, this reflection served as a second step upon which we constructed an analysis framework for evaluating collaborative competency and engagement which we discuss further in the next chapter.

| | Individual Work | Communication | Coordination | Cooperation | Collaboration |
|---|---|---|---|---|---|
| **Regulation** | x | x | xxx | x | x |
| **Communication & Listening** | x | xx | xx | xxx | xxx |
| **Teamwork** | o | o | x | xx | xxx |
| **Social Intelligence** | x | x | xx | xxx | xxx |
| **Constructive Conflict** | o | o | x | xxx | xx |

**Table 21: Linking Collaborative Competencies to Modes of Interaction**

How to read this chart:
o – little to no development opportunity
x – key moment
xx – deepening ability
xxx – opportunity to master

### *6.2 $CO^2$: A Framework for Collaborative Competency and Engagement*

There is a problem in setting competence standards and assessing against them, though this is the most common approach. They're usually described in terms of behaviors that should appear in a general situation. However, this conflicts with the notion that competencies are situational. As such, assessing competency based on such a framework is problematic. Westera (2001) asserts that it is likely that only incompetence could be determined because of how competencies are defined today. This is coupled with several other problems, notably that what it means to be competent is very subjective and even ephemeral – what may be considered the "right" performance by one, may not be by another. Recognizing these potential weaknesses, we have tried a slightly different approach, by looking at how a learner's behavior impacts the group's process and progression. While this does not address the possibility of changes in attitudes or social norms around collaboration as a competency, it is an attempt to refocus our evaluation on the impact of a behavior rather than the performance of the behavior itself (Table 22). As such, engagement becomes the lens through which we evaluate competency.

| Existing Competency Evaluation Models | $CO^2$ Framework for Situated Collaborative Competencies |
|---|---|
| Generic behaviors & attitudes | Situated behaviors & attitudes |
| Evaluation based on individual performance (scale 0 to 4) | Impact on group / other members (scale -2 to 2) |
| Generic competencies for wide range of scenarios | Competencies activated in a specific situation |
| Viewed through the lens outcomes | Viewed through the lens of engagement |

**Table 22: Collaborative Competency Evaluation: existing and proposed approaches**

Starting from the categories and competencies recalled in Table 20 and our initial reflection about collaborative competencies in relation to modes of interaction, we identified three key indicators related to each competency. For example, the regulation competency can be observed through participation, taking responsibility and coordinating & evaluating work. From this point, each of the three categories were broken into five levels which demonstrate the impact of the associated behavior on the group's work. Again, this is not designed to be exhaustive, merely representative of the modes of interaction we see during globally collaborative work (for example, we still do not include the organization of such work which may entail other competencies and indicators like creating and maintaining a network of actors).

Most competency frameworks work on a positive scale, such as 0 to 4, with 0 being low competency and 4 being high competency. This tendency was described by Sanojca (2018). We have taken a slightly different approach, defining a scale from -2 to 2. This has yielded a gauge-like measure describing how the actions of individuals impact the group's activity: -2 represents actions which are most detrimental to the collaboration; 0 represents actions which do not particularly help nor hinder the group's activity (neutral); finally, 2 represents those actions which are most helpful in advancing the group's activity. In order to provide a clear understanding of what we have established, we'll look at each measure in the framework more closely. Before doing so, we also feel it's necessary to address the engagement aspect of our framework, as it is the principal lens through which we have determined the indicators for this framework.

Engagement is difficult to define operationally, but "we know when we see it, and we know when it's missing. (Zyngier, 2008)" One of the complexities when we talk about engagement in educational sciences is the influence of our ideologies on what engagement means: "a continuum, ranging from relatively rational and technical approaches to those that are more constructivist, to those reflecting a critical democratic worldview (Vibert & Sheilds, 2003)." This continuum of engagement described by Vibert and Shields is very similar to that of collaboration (See Chapter 1: Paradigms of Collaboration) : between a method of working (a technical vision), a method of learning (a socio-constructivist vision), and a philosophy of interaction (a democratic vision). In their research, Vibert and Shields consider engagement very broadly, and rightly so. Engagement is embedded in much deeper contexts: social, cultural, political, pedagogical, etc. We acknowledge here that engagement itself is a complex topic, with its own diverse indicators for measurement that are often mobilized to evaluate engagement on large and small scales in the context of education. For our purpose, we base our definition of engagement on the level of an individual and that individual's impact on the group through their engagement or disengagement.

We define engagement in the spirit of Newmann, who describes it as "the investment in and effort directed toward learning, understanding or mastering the knowledge, skills, or crafts…. [the] active involvement, commitment and, concentrated attention, in contrast to superficial participation, apathy, or lack of interest (Newmann, 1992)". This definition begs another question to be asked: what is the difference between motivation and engagement? Motivation is also a complex topic, but comes back to: "why? If we are talking about intrinsic, extrinsic, individual, collective or situated motivation, the motivation always comes back to the why behind the action. What pushes the individual or group to act as they do? However, using engagement as a lens through which to understand the potential for competency development means that it is interested in the expression of that motivation in the activity, without necessarily going all the way to what motivates that action, the "why." So, why engagement and not motivation then? In the classroom, it is no doubt important for a teacher to be able to understand his/her students' motivations and the why behind their actions (their engagement or disengagement) in order to be able to evaluate his/her own pedagogical practices and promote a positive learning experience. However, the first step to such an intervention is to evaluate the level of engagement of a student in their activity in order to better target this adaptation.

Similarly, we can ask why discuss competency with engagement? If we consider competency as the ability to act in a given situation according to one's understanding of that situation, then engagement plays a role. If we expect students to learn to collaborate by acting in said situation, then disengaging or failing to act will necessarily hinder the development of those skills we are seeking to study. As such, it seemed pertinent to us to consider student engagement and look for patterns to ascertain whether or not students are engaged in the activities we are observing. Thus, it is the possibility that students could gain those skills in which we are interested presently. Indeed, one's level of engagement became a key element in developing this model, with disengagement often appearing on the lower end of the spectrum (-2) and engagement with increasing quality appearing in the rest (-1 to +2).

## Regulation

Regulation, or the know-how to manage, coordinate and evaluate his/her own work as well as that of the group, has been divided into participation, responsibility, and coordination & evaluation of work.

### *Participation*

We consider participation to be the most basic level of an individual's willingness to be an actor within the group: being present in the activity space (in the room, in the online forum, etc.) in order to have the possibility of being able to interact with other group members and the object of the group's work. As soon as the individual is present, we also consider actions that attempt to encourage the participation of others.

We recognize a tension between an individual's competency and the positive intention behind an effort to encourage the participation of others. A tool which allows individuals to be aware of the participation of others can facilitate a passage from level 0 to level 2. However, if everyone participates for the duration of the session, it may be that such effort is never necessary or the lack of participation is not easily identifiable, leaving individuals with a grade of 0.

| -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|
| Separates himself from the group or is often absent. Does not interact even if someone speaks to him/her directly. | Mostly engaged in the group but may need to be reminded to participate. | Engages in the group's activities and responds to others. | Engages in the group's activities and helps manage them. He/ she encourages the participation of others. | Engages in the group's activities and helps manage them. He/ she encourages the participation of others by making use of their skills and interests. |

**Table 23: Levels of Participation**

When we look at how the tool supports the participation measurement, there are a few things to take into account: notably, that if a student is not actively engaged, the tool may be partially to blame as it could serve as a point of distraction. On the flip side, if a student is pushed to encourage another one to participate because the tool allows him/her to realize that his/her colleague is no longer engaged, does this balance out the distracting nature of the tool?

***Responsibility***

Responsibility also plays on the notion of engagement but takes into account the reliability and quality of that participation, going back to Newmann's (1992) idea that engagement can be superficial. Taking into account the quality as well as the quantity of the actions allows us to see the individual's potential interest in the activity, or at least his or her ability to "fake it" for the benefit of the group. Within globally collaborative work, it is likely that individuals will take on roles within the group or accept to complete a portion of the work individually. It is especially during these moments that responsibility, or one's ability and willingness to add meaningfully to the group's discourse through his/her own activities becomes apparent.

| -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|
| Does not do the work that was assigned to him/her or that they accepted to do. Does not accept to do any work. | Partially completes his/her work. | Does the work that he/she agreed to without bringing new elements. | Does the work that he/she agreed to do but brings new elements while still being in line with the group's objectives. | Does the work that he/she agreed to do, while bringing in new elements that allows the group to expand its horizons. |

**Table 24: Levels of Responsibility**

***Coordination & Evaluation of Work***

Coordination and evaluation of work is an important element in task cohesion (Van den Bossche et al., 2006). Participation (and having a way to contribute) to activities linked to the advancement, coordination and planning of the group's work necessitates action towards developing and refining the group's objectives, tools and methods in an ongoing manner. Activities we may see that point to the development of this competency relate to evaluating the group's progress or work quality, offering ideas for advancing the group's work when pertinent, or even something as simple as scheduling.

| -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|
| Resists attempts to organize or structure work. | Does not openly resist coordination of work, but often does not follow the plan put in place by the group. | Accepts the group's plan but does not participate in its construction. | Gives ideas and assists in the coordination of the group's activity. | Evaluates the group's progress and helps structure the group's work. |

**Table 25: Levels of Coordination & Evaluation of work**

## Communication & Listening

Communication & Listening, or the know-how to communicate with one's colleagues in an efficient and adapted manner, has been divided into communication, listening and reactions & feedback.

### *Communication*

To observe communication, we found it necessary to go back to the idea of presence: if one is not present (even if that presence is through virtual means), it is not possible to communicate, but higher levels of communication are oriented towards the quality of that communication. At its highest level, we consider one's capacity to adapt to have the most positive impact on the group. One's ability to propose or use alternative methods of communication implies some *savoir* about different kinds of communication models and technologies, even if the individual is unable to articulate what those are; some *savoir-faire* related to one's ability to choose the correct tool and adapt to their audience; and finally points to attentiveness (*savoir-être)* to one's partners.

| -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|
| Absent; Wonders around; is not present for communication. | Doesn't express his/herself well. Attempts to explain ideas, but they remain unclear. May become frustrated as a result. | Expresses his/herself well and gives supporting details. | Expresses his/herself concisely with sufficient detail so that he/she is understood. | Expresses his/herself concisely and uses alternative methods of communication to facilitate the understanding. |

**Table 26: Levels of Communication**

***Listening***

In its simplest form, communication consists of the sending and receiving of messages via a channel (Shannon, 1948). Thus, listening or receiving communications plays an important role in collaboration. However, we do not only refer to oral channels for this competency. By using a tool that allows written communication, drawing, reading and writing must also play a role here, even as we use the term “listens” to describe all three in Table 27. One’s capacity to listen to others, but also to make attempts to better capture or understand what they are trying to express is key to this indicator.

| -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|
| Does not pay attention to group activities or attempts to communicate. | Does not seem to listen to others all of the time. Seems distracted. | Listens to others, turns toward them to show attention. Reads what others have written/drawn/found during searching. | Listens to others and asks questions to ensure understanding. | Listens to others, asks questions. If communication is unclear, they will propose alternative communication methods to facilitate. |

**Table 27: Levels of Listening**

***Reactions & Feedback***

Defining communication as the sending and receiving of messages seems an oversimplification, so we have found it necessary to consider the continuity of discourse. The category Reactions & Feedback attempts to integrate not only the quantity, but also the quality of responses when engaged in discourse with group other members.

| -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|
| Does not engage in discourse, even if his/her opinion is asked. | Does not give developed responses. May be frustrated when his/her ideas are not understood or when an explanation is requested. | Feedback is often simple (yes/no) with little detail. | Developed responses to both verbal and non-verbal communication. | Developed responses that attempts to integrate multiple perspectives. |

**Table 28: Levels of Reactions & Feedback**

These reactions are a major part of what allows the group to enter into epistemic conflict and collaboration (Tucker et al., 2019). It builds on the two previous indicators, moving on from the simple act of communicating an idea or making attempts to understand it, to being able to effectively respond to others’ communication and at the highest point, the capacity of uniting ideas from different group members to build collaboration as defined in globally collaborative work (See Chapter 4).

## Teamwork

This competency is especially interested in notions of group cohesion. Festinger (1950) describes cohesion as the result of all the forces acting on group members in order to force the group to stay together. Van den Bossche et al., (2006) identify two types of cohesion: social cohesion and task cohesion. Social cohesion concerns the nature and quality of emotional links in the group, while task cohesion refers to the dedication between team members to accomplish an objective that requires the group's effort. Both elements come in to play for this competency. Teamwork, the know-how to create cohesion within the group in order to obtain the common objective, includes balanced/fair work, group objectives and social cohesion.

### *Balanced/Fair Work*

Balanced and fair work comes from the ideas of justice related to the quantity of work performed by the team's members, but also the roles and opportunity left to other participants to engage with the work, i.e. avoiding domination of the group's time and roles. Balanced and fair work requires engagement from each member of the team, or the ability to adapt fairly when not all group members are contributing equally.

| -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|
| Does not engage in the work or works on tasks alone before coordinating with others. Unreliable, may be resistant. | Agrees to do work when asked. Will sometimes take on roles. May dominate the group (does not share). | Agrees to work on his/her tasks. Uptakes tasks that are most interesting to him/her. | Makes efforts to divide work equally amongst group members. Takes on roles but leaves space for others to contribute. | Willing to adapt and take on needed roles (interchangeability) according to the group's needs. Divides the work equally and does his/her part of the work. |

**Table 29: Levels of Balanced/Fair Work**

The behaviors expressed in Table 29 are often associated with notions of being reliable and "collaborative" that we see in the literature (See Chapter 1: Collaborative Competencies).

### *Group Objectives*

Group objectives refers to task cohesion (Van den Bossche et al., 2006). In order to accomplish the group’s goal, it is necessary to align on the group’s objectives periodically. This Group Objectives skill considers those actions made by individuals to define and work towards group objectives, including asking others for their opinion and integrating perspectives and needs of each group member.

| -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|
| Pursues his/her own interests and objectives. | Struggles to reconcile the group’s objectives with their own objectives. | Agrees to the group’s objectives but does not contribute to them. | Contributes to the definition of the group’s objectives. | Contributes to the definition of the group’s objectives while trying to balance between the needs of all members. |

**Table 30: Levels of Group Objectives**

***Social Cohesion***

Finally, social cohesion takes into account the ability of an individual to engage in activities related to social cohesion (Van den Bossche et al., 2006), such as the utilization of humor during appropriate moments (that do not disturb the group’s focus and advancement).

Research in group dynamics (Carless & De Paola, 2000; Van den Bossche et al., 2006) shows us that social cohesion is not as important as task cohesion for efficacious collaboration. However, there is a clear and understandable preference to work in a group with a friendly atmosphere. As such, this part of our competency framework includes elements related to social cohesion and activities that favor it.

We define humor as: amusing communications which produce positive cognitions and emotions in an individual or group (E. J. Romero & Cruthirds, 2006). According to Romero & Pescosolido, the usage of humor in a group creates a positive ambiance, associated with positive emotions. This can lead to increased psychological safety, acceptance of group objectives and better social and task cohesion (E. Romero & Pescosolido, 2008). This particular measure overlaps in some ways with the social intelligence competency, but we’ve included it as part of teamwork due to the contribution it can have to creating cohesion within the group.

| -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|
| Refuses to engage in team-building activities. Actively attempts to distract the group. | Pursues social conversations to the detriment of the group's collaborative work. | Participates in team building activities but does not initiate them. | Suggests team-building activities and engages in them at appropriate moments. | Encourages and suggests social interactions which favor team building. Able to refocus the group when they are off topic. |

**Table 31: Levels of Social Cohesion**

## Social Intelligence

Social intelligence, the know how to recognize and respond to the emotional needs of one's peers, is divided into interpersonal conflict resolution, emotional needs and shared talk time.

### *Interpersonal Conflict Resolution*

We use the term interpersonal conflict here to refer specifically to relationship conflicts, which we differentiate from task conflicts (addressed in the constructive conflict competency). We note that interpersonal conflict can arise from constructive (task) conflict (Beheshtifar & Zare, 2013). Interpersonal conflict resolution refers to the role an individual plays when interpersonal conflict arises in a group. This ranges from being the cause of the conflict to demonstrating the ability to resolve it and return the group to work. This particular measure looks at that ability to resolve conflict when it occurs, with the most positive impact being those who are able to resolve these conflicts, as opposed to using avoidance strategies which could have a negative long-term impact on the group.

| -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|
| Is the source of interpersonal conflicts in the group. | Ignores interpersonal conflicts and does not attempt to resolve them. | Attempts to resolve conflicts, but with difficulty. | Attempts to resolve interpersonal conflicts and succeeds in bringing the group back to work. | Encourages diverse viewpoints and resolves conflicts within the group. |

**Table 32: Levels of Interpersonal Conflict Resolution**

***Emotional Needs Responsiveness***

Emotional needs responsiveness concerns an individual's ability to recognize and respond to the emotions of others. This measure is at the heart of social intelligence, or the capacity of the individual to perceive, understand and respect the emotions and viewpoints of others (Bender et al., 2012). We can turn to a classic of psychology to understand why this particular skill is important. Maslow tells us that a sense of belongingness and a fulfilled sense of esteem are important psychological needs (1943). The ability to create that sense of belonging and contribute to fulfilling those psychological needs will ultimately have a positive impact on collaboration as group members feel encouraged and empowered to contribute and engage. We can see this in actions that recognize members for their contributions or attempts to recognize and respond to emotions others express without negatively impacting the individual in question (for example, embarrassing others for their emotions)

| -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|
| Does not recognize the emotions of others or exacerbates the situation. | Recognizes others' emotions but does not respond to them. May not see the emotions as valid. | Recognizes others' emotions, but the response is very brief, not addressing the root or attempting to adapt to them. | Recognizes others' emotions and attempts to respond to them. Recognizes good ideas and encourages others. | Recognizes others' emotions. Thanks others for contributing. Makes attempts to encourage individuals as well as the group. |

**Table 33: Levels of Emotional Needs Responsiveness**

***Shared Talk Time***

Finally, shared talk time refers to an individual's capacity to equally share airtime with the group in an effort to allow others to participate and contribute. This has been linked to collective intelligence (Woolley et al., 2010b). Sharing talk time allows each individual to express his/her ideas and opinions which could lead to better buy-in from all group members if they feel that they have been heard. However, it is common that some individuals cut people off in order to express their own ideas. This action can lead to resentment and frustration on the part of those being interrupted. For example, in 2008, we saw the first usage of terms like "mansplaining" and "manterruption" referring to such interruptions coming from men, which are now heavily used and debated in gender politics and online forums (Koc-Michalska et al., 2019). This measure attempts to account for participant's problematic vs. correct behavior (defined as equal talk-time amongst group members) when it comes to such interruptions, as well as strategies that may be proposed to ensure talk time is shared fairly across the group.

| -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|
| Cut others off when speaking several times. | Cut others off occasionally, but even if he/she realizes it they will continue talking | Cuts others off, but realizes/ apologizes and lets the person finish | Does not cut others off, shares discussion time | Does not cut others off, shares discussion time, proposes a strategy to divide talk-time equally among group members. |

**Table 34: Levels of Shared Talk Time**

## Constructive Conflict

Constructive conflict, the capacity to take action to monitor, manage and resolve conflicts within the group while taking into account the needs of all members, has been divided into maintaining shared notions, ability to debate and open-mindedness.

### *Maintaining Shared Notions*

Maintaining shared notions refers to the capacity to recognize and resolve epistemic divergence within the group. This entails establishing common ground, accumulating more understanding on said common ground and continued contribution to it (Clark & Schaefer, 1989; Teasley & Roschelle, 1995). When it comes to impacting globally collaborative work, this ranges from not engaging or making an effort to maintain shared notions within the group to effectively integrating one's own and others' ideas into the group's joint problem-space (Teasley & Roschelle, 1995), successfully repairing divergence and reestablishing common ground.

| -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|
| Doesn't pay attention to what others are doing; does not realize when differences occur; continues working on his/her own ideas | Notices divergence but does not make efforts to resolve the conflict. | Proposes solutions to ensure maintenance of shared notions from time to time. | Enters constructive dialogue with others and can accept being wrong. | Integrates others' opinions into his/her solutions; guides the constructive dialogue in the group; Successfully repairs divergence |

**Table 35: Levels of Maintaining shared notions**

***Debate***

Debate is closely linked to maintaining shared notions. This covers the student's ability to engage in arguments that are clear and supported by examples, stems to the ability to support others who may be struggling to construct their arguments. Where maintaining shared notions refers more broadly to repairing divergence, the debate measure examines how they get there in more detail. It is also closely linked to the communication measures, taking them a step further to take into account more complex exchanges that can occur during cooperative interactions, as defined by globally collaborative work. Debate requires individuals to consider multiple viewpoints, arrive at a judgement and support that opinion (Kennedy, 2009).

| -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|
| Does not contribute to debate | Arguments are unclear, poorly constructed and undetailed. Arguments may be counterproductive. | Reasoning is clear and developed but struggles to respond to other's challenges. | Clear, detailed arguments. Debates without issue. | Clear arguments supported by examples. Helps / supports others defend their ideas. |

**Table 36: Levels of debate**

***Open-mindedness***

Finally, the last element of the constructive conflict competency that we include relates to open-mindedness, or the willingness to try new things. At its most basic, this means allowing others to express their opinions and ideas, even when they do not align with yours. This is not to say that poor ideas should be incorporated for the sake of others' feelings, but rather the recognition that an individual is willing to engage with ideas he/she may not agree with and develop reasonable arguments against them once they are fully expressed if they still do not agree. In this way, it is linked to one's ability to listen to others and enter into debates, doing so once an idea has been expressed. It also entails a willingness to try new approaches and seek out the opinions of their group members.

| -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|
| Attempts to impose his/her opinions. Judges others' suggestions quickly and in such a way that it may cause interpersonal conflict. | Is resistant to new ideas/approaches; Rarely asks for others' opinion. Judges ideas quickly. | Accepts others' opinions but does not ask for them. Generally open to new approaches. | Asks for others' opinions; does not judge others' ideas before they are completely expressed. | Asks for other's opinions. Does not judge others' ideas but asks questions to understand them in order to better integrate or provide feedback. |

**Table 37: Levels of open-mindedness**

### *Chapter 6 Conclusion: Limitations*

Before moving on to results we collected after applying this framework to our data, we'd like to address the limitations of this framework directly. The framework itself is the result of an a priori reflection regarding collaborative competency combined with observations from real group work with several different student populations (including engineering students, high school students, and middle school students – both normal and high risk). Despite this, it is important to note here that we recognize that this framework is neither exhaustive nor perfect. Moving forward, we hope that it can be used to build a better understanding of collaborative competency, providing some elements of response relating to how we might define what it means to be competent in collaboration concretely.

There are certain limitations which are intrinsic to our approach of using activities and actions at the heart of our analysis. For example, it requires a situation or context which encourages certain types of actions. There are other factors that we are not able to access, such as motivation or interest. While this framework could serve as a first step to gauging motivation, it is not enough to access or understand it because it is difficult to access thoughts, reflections and emotions that are undoubtedly playing a role in an individual's activity. Additionally, the tools, work environment, etc. could be a confounding factor. In our case, this was exactly what we wanted to see, but it could be less applicable in other scenarios due to this.

Applying the framework to real scenarios is subjective. We have not fully defined what the "ideal" or "worst case" can look like in our grid. Definitions of competency include the notion of situation and context for a very important reason and attempting to account for all possibilities is simply not feasible (or at least not in the context of this project). Indeed, we recognize the existence of scenarios that do not fit seamlessly into the lines that we have defined because of this multiplicity of situations, but also because people can always surprise you. In parallel, the evaluator may have his/her own ideas about what constitutes "right" behavior, which can also influence the results. For our study, we used two coders who evaluated blindly in an effort to ease this, but the element of subjectivity is still at play despite those efforts. We feel that this framework could be further developed through additional reflection and observation, or at least adapted to a situation in question. We could thus think of the framework as flexible, rather than exhaustive.

# CHAPTER 7 THE IMPACT OF PHYSICAL-DIGITAL WORKSPACES ON STUDENT ENGAGEMENT IN COLLABORATION AND COLLABORATIVE COMPETENCY DEVELOPMENT



***Chapter Introduction***

In this chapter we apply the $CO^2$ framework to our data. We begin with the quantitative results that the framework allows us to collect by using the -2 to 2 rating system. Using this quantitative data allows us to get a first glimpse at how our physical-digital workspaces may be impacting student engagement and competency activation. As with the CIAO model, while we believe that this may give some interesting insights, it is not enough to conduct only a quantitative analysis. From there, we go on to discuss indicators for engagement that we observed and the actions which led us to conclude that physical-digital workspaces which do not have an individual space lead to lower levels of engagement, competency activation, and potentially miseducative experiences.

## *7.1 Quantitative Results: Engagement & Competency Activation*

Using the framework presented in the previous chapter, we have taken the average score of each of the 45 participating students (15 per physical-digital workspace modality) from the three instrumented work sessions in order to attribute a “grade” to each modality as it relates to student engagement. The results are between -2 and 2. -2 represents a negative impact on engagement and 2 represents a positive impact. 0 is neutral. As with the CIAO results, these results were coded blindly by two coders, and an average was taken from the two resulting scores for each individual. In the table below, the resulting stores for all 15 students across each of the three sessions have been averaged to attribute the score to the physical-digital workspace modality.

| Category | Table - Board | Tablets-Board | Board-only |
|---|---|---|---|
| *Participation* | 0.03 | 0.14 | -0.18 |
| *Responsibility* | 0.70 | 0.94 | 0.52 |
| *Coordination & Evaluation of work* | 0.57 | 0.81 | 0.45 |
| *Communication* | 0.86 | 0.74 | 0.27 |
| *Listening* | 0.59 | 0.71 | 0.38 |
| *Reactions & Feedback* | 0.96 | 1.14 | 0.85 |
| *Balanced/Fair work* | 0.75 | 0.91 | 0.40 |
| *Group objectives* | 0.41 | 0.66 | 0.36 |
| *Social cohesion* | 0.36 | 0.52 | 0.10 |
| *Interpersonal conflict* | -0.15 | 0.03 | 0.00 |
| *Emotional needs responsiveness* | 0.00 | 0.21 | 0.10 |
| *Shared talk time* | 0.72 | 0.70 | -0.15 |
| *Maintaining shared notions* | 0.68 | 0.96 | 0.73 |
| *Debate* | 0.80 | 1.17 | 0.88 |
| *Open-mindedness* | 0.33 | 0.59 | 0.19 |
| **Average** | **0.50** | **0.682** | **0.326** |

**Figure 67: Collaborative Competency Grade per Modality**

A first element emerges from this: quantitatively, there is a statistically significant relationship between the experimental methods and the students' engagement in the collaboration, as measured by the exploratory grid detailed in Chapter 6.

A one-way ANOVA was applied to evaluate the impact of the physical-digital workspace modalities on the scores received by each group in each session. A statistically significant result was identified at $p<.05$ [$F=(2,41)=4.1$, $p=.02$] The difference between the table-board and tablets-board is considered insignificant. However, the results from comparing the board only modality versus the table-board or tablets-board were statistically significant.

Therefore, what stands out is that engagement and quality of interactions (as measured by our grid) are stronger when the learners have an individual workspace associated with a collective workspace, either in the form of a tablet or embedded in the public space that constitutes the tactile table. As we will discuss in our qualitative analysis, this is consistent with our observations.

There is a slight difference between the table-board and tablets-board, where the usage of an individual-private workspace seems to slightly surpass the use of an individual-public workspace. As noted in the previous chapter, this may be due to the mobility provided by the tablets, which offers a fluidity of movement within the workspace. The effect for the board-only modality remains neutral but does present some potential concerns around participation, communication, sharing talk time, as well as a much higher level of off-topic conversations.

The fact that a correlation is statistically measurable constitutes a first result in itself for the modalities used as well as a *post-hoc* corroboration of the validity of our the framework for the concept of collaborative competency activation, since some patterns were able to be captured by this tool, imperfect as it may be.

### *7.2 The Impact of Individual Space on Student Engagement*

As we saw in Chapter 5, individual space is a central element for the success of collaboration. This finding is related largely to students being able to develop ideas and contribute in an alternative way, i.e. through writing. When students had access to an individual space, as with the table-board and tablets-board modalities, the space became a way for each individual to easily communicate and contribute. This meant that contributions could be made not only orally, but through written means, which facilitated a quick exchange of information. This was not possible with the board only modality, where most of the discussion happened orally.

Individual space also favored nonverbal communication and individual reflection, permitting each person the opportunity to intervene without needing to speak up, effectively removing issues related to limited air-time and production blocking (Hymes & Olson, 1992).

One interesting element with the table related to the capability of each individual to see what others in the group were doing and to have another perspective on any of the items in the individual space, as we see in the following exchange:

**Student 1:** What are you putting, visibility? [several students have started writing post-its on the table at the same time] You’re writing visibility? [to Student 2]
**Student 2:** Yes
**Student 1:** And you, what’re you writing? [to Student 3]
**Student 3:** [Laughs] Driving her car
**Student 1:** [Reading the post-it on the table] In a safe manner? She wants

to use her car safely.

**Student 3** Legally

**Student 1:** And safely…

In this exchange, Student 1 is reading what others are writing and using it as an opportunity to collaborate or build upon the ideas of his peers. The introduction of the notion of driving safely prompts Student 3 to also put forth the idea of driving legally, enhancing the original post-it from “driving her car” to “driving her car safely and legally”. This reinforces notions of engagement through social stimulation that is commonly referenced in research on brainstorming (Dugosh et al., 2000; Nijstad et al., 2002).

The fact that the tablets are individual-private, does not prevent students from sharing them. Students can put themselves next to one another, allowing a tablet to temporarily become an individual-public space. As such, the tablet allows students to transition between physical-digital spaces easily. It’s also important to note here that these were not personal tablets, but those provided for the study. This may also have an impact here.


**Figure 68: Student showing his tablet to others**

This usage is only slightly different from that of the table, giving some choice to the student to either share or not share what he/she is writing. The major difference is when there is no individual space, so students either do not engage in externalizing individual work through writing or encroach on the group’s space to do so.

The board-only modality was a source of constant tension between individual and collective usage. Ultimately, this tension led some students to simply disengage (Figure 69) or have difficulty intervening, even though they seemed to want to participate (Figure 70).

**Figure 69: Students around the board, disengagement**

**Figure 70: Students around the board, student on the right trying to participate**

Groups which had non-native speakers (like the student on the far right in Figure 70) saw increased participation and engagement when an individual space, complemented with a collective space, was available. For example, in one group using the table/board modality, during the non-instrumented session, the group elected to use the whiteboard only (despite having post-its available). The non-native speaker contributed rarely and had difficulty breaking into the conversation when she made motions that signaled a desire to contribute (leaning in, pointing at the board, trying to speak up or make eye contact with a speaker/animator). However, during sessions using the table and board, a student in a similar situation contributed in writing and saw her ideas integrated into the group's final concept maps.

### *7.3 Collaborative Competency Activation*

The results we have collected following coding for collaborative competency activation by impact (according to the framework described in Chapter 6) do not permit us to determine if a competency is developed or not developed. We do not feel that three sessions over the course of three weeks is enough time to determine whether an individual's competency level has advanced. This is not to say that no development occurred, but the study time is too short to see a marked change with the methods we employed. We will discuss this further in Chapter 8. Development of competencies was not our primary interest, but rather we sought to identify whether or not there was an opportunity to use collaborative competencies as seen through students using them with positive impact, in action or not. Our results in this section are discussed through this lens, considering both individuals and groups.

**The Lack of Individual Space and Competency Activation**

To address the impact of individual space on competency activation, let us first look at what it means to not have an individual space. Students using the board-only modality were the only ones that showed a statistically significant difference between the non-instrumented session and the instrumented session when it came to competency activation. We saw drops in multiple measures, especially those related to participation, communication, listening, and social discussions. Within the three groups using the board-only modality, these drops occurred in three out of four individuals[6], three out of five individuals, and three out of five individuals when they began using the board only modality. The strength of these differences varied from person to person, but a statistical comparison across the different sessions revealed significant differences in the rating.

It is not surprising that students in this group had lower levels of activation when we look at their engagement. Students using the board-only modality were more likely to look at their phones, walk around the room, etc. than in other groups. Additionally, when this disengagement occurred, it was often not noticed or was even ignored by their peers. When similar activities occurred in the table-board group (which happened on a few occasions in different groups), other students acted to refocus the group on the work at hand. This may be related to the group's positioning in the room: those using the table-board tended to stay around the table, making it easier to notice and engage in actions to refocus the group. Those working with the board-only modality often had their backs turned to the person who was no longer engaged, as seen in Figure 71: Student on his phone

---

[6] This group had 5 individuals, but one of these was absent during the baseline section. As such, she is not included in this count.

while other group members continue working So, while the opportunity to encourage others to participate was available, students did not act upon it perhaps because they did not see it.

**Figure 71: Student on his phone while other group members continue working**

We also see a drop in clarity of communication and listening, as students tried to explain their ideas aloud to the group. Members in these groups often expressed frustration that no one was listening to them or that they had already said something, but they were ignored. Frequently, ideas expressed aloud went unaddressed by others. There was also an increase in off-topic talk. While this off-topic talk made for a more convivial atmosphere, the groups stayed off-topic for long periods. This ultimately hindered the work, leading to lower scores in the social category.

Finally, when we looked at shared-talk time in terms of interruptions, we saw that individuals using the board-only modality were more likely to cut off their peers' comments to make their own. For example, in the following exchange we see Student C interrupt Student A, who is then interrupted by Student B, and so forth:

> ***Student A:*** *after we could digitize it, but we can -*
> ***Student C****: yes, maybe we can digitize something else -*
> ***Student B****: Yes, no but that, I propose that -*
> ***Student D****: There aren't any solutions of -*
> ***Student B****: that doesn't work for me… we have to ask the question*

Following this exchange, rather than continuing to work as a group, Students A and C break off to continue the discussion more quietly over their case study printout. Student B turns back to the board.

Members of these groups also spoke more loudly to be heard by other group members, which led to complaints from groups in neighboring cubicles. Students seemed to develop strategies to be heard, like talking more loudly and interrupting others. In the following exchange, we see students being cut off and talking over each other until the professor comes by to shush them.

> *Students A, B and C are typing on the board. Students D and E are behind them at the table.*
>
> ***Student C:*** *Let's go, kids. Because… because?*
> ***Student E:*** *Because… I don't know… uh a lack of visibility -*
> ***Student B:*** *[cutting off student E] Because she -*
> ***Student A:*** *[loudly, cutting off Student B] because she has to go to work*
> ***Student B*** *Yeah but why do you*
> ***Student A*** *[loudly] Wait!*
> ***Student D*** *Because she's late*
> ***Student A*** *Late for what?*
> ***Student D*** *For -*
> ***Student A*** *[loudly, cutting off student D] Wait wait wait! To go to work. Is it a because or a for? To go to work. She scrapes the ice to go to work.*
> ***Student C*** *[loudly, cutting off student A] but he said -*
> ***Student A*** *[continues over Student C] but she has to scrape the ice because she has to go to work*
> ***Professor*** *Shhhh*
> ***Student A*** *[more quietly] you see?*

While such interactions would occasionally occur in groups using other modalities, it was not nearly as constant as we saw in groups without recourse to an individual space. These strategies have a negative impact on collaborative processes and could be considered "mis-educative" (Dewey, 1938a) in that they may lead students to continue to use them in future collaboration or to mistrust collaboration as a valid working/learning method because such strategies need to be employed to be heard.

### The Positive Impact of Individual Space for Introverted Students and Non-Native Speakers

The availability of individual space for the Table-Board and Tablets-Board modality had a positive increase on the activation of competencies related to regulation, communication, teamwork, and constructive conflict, especially for introverted students. Introverted students are identified as those with a low rate of participation, such as low levels of communication or engagement in discussions. Each group had at least one, if not two, individuals that we identified as introverted in the non-instrumented session. In some cases, the changes were not necessarily impressive, but students who previously did not speak at all wrote a few post-it notes and expressed themselves verbally on multiple occasions. For others, the change was more marked as they took on more responsibility, encouraged others to refocus, and contributed verbally and non-verbally more often. Some of this could be attributed to an increased sense of psychological safety that could come with repeated exposure to the same group, but it also falls in line with results from other researchers who have shown that individual space allowed for students to develop

**Figure 72: Left - Non-native speaker separated from group ; Right - Non-native speaker integrated into the group, writing a post-it note on the table**

arguments that they were then better able to defend (Gracia-Moreno, 2017).

Two of our groups had non-native French speakers. One of these used the board modality, while the other used the table-board modality (Figure 72). The one using the board expressed herself less often and was often separated from the group. However, when we compare with the student using the table-board modality, we saw an increase in the number of contributions that she made from the non-instrumented session to the instrumented sessions, as she took advantage of post-it notes to communicate her ideas. She read what others were writing as the conversation unfolded, which may have enabled her to follow it more easily. Finally, the around-the-table positioning of the table-board modality likely made it easier for other group members to gauge whether or not she was following along or wanted to make a comment. These cues were often given by the non-native speaking student but missed in the board-only group.

### Complementarity and Tension Between Collective and Individual Competencies

In the PAW model, Samurçay & Rabardel (2004) propose a reciprocal link between individual and collective competencies, positioning these collective competencies as resources for the management of the collective dimensions of productive and constructive activity. The two different levels of competency feed into each other's construction and evolution. Investigating this part of our conceptual framework was done through observations, but also by employing questionnaires.

The questionnaire was implemented to allow us to see how students say they would respond when given certain scenarios that we felt would be unlikely to emerge in the group work they were completing, such as responding to others' emotional needs. At the same time, it allowed us to see how those competencies that did emerge might compare to actual activity. Thus, we have identified some tensions between hypothetical and actual activity, giving us some information about the connection that exists between individual and collective competencies as we see them in the PAW model.

In several cases, we found that the articulation between them can be in tension or complementary. For example, about 70% of students said that if one of their colleagues was not working, they would talk to them and ask them to contribute. In reality, even when students disengaged, we saw few occasions where they were encouraged by their peers to return to work. This reveals a layered problem: If one person does encourage them, the other group members do not need to do so. In this case, we could interpret the skills as being complementary. I.e. one student possesses it and that is enough; other students may potentially learn to perform this action by watching it be done as proposed by Social Cognitive Theorists (Bandura, 1999). However, if no one tries to encourage those disengaged students to help complete the activity, but 70% of respondents say that they would, do they have the theoretical knowledge of what they should do but not the operational knowledge of how to exercise it concretely? Or was there a choice made, and if so, what was it? This brings up one of the limitations of our research methodology, where interviews could have been useful for gaining insights into these choices.

While it was possible to see a certain reciprocity between individual and collective competence with the methods we chose, getting to the heart of what is happening in this part of our conceptual framework necessitates more. A post-hoc investigation into an individual's choices and motivations for performing or not performing an action to ascertain whether or not the competency was activated in a way that simply cannot be observed. For example, they considered asking the student to participate but made some evaluation that it would not be necessary or could do more harm than good for the group's dynamic. Did all group members make that determination? Was the event not noticed, therefore being an oversight rather than an indication of the group's collective competency to keep all its members on task?

In other regards there was relatively little tension, for example, when it comes to task planning. When asked how they would approach an assignment that has a lot of different elements, 65% said that they would propose a method to complete all of the tasks, 17% said that they would start the first task right away, and 18% said that they would start on the part that they find to be the most interesting. When we look at how individuals activated the competencies in our framework, only two to three students participated in the construction of a plan at the beginning of a session. Usually one additional group member would also engage in this later, as the group needed to refocus/recoordinate their approach. Some students (one per group, on average) never participated in this process, letting the other students control the group's direction.

A number of questions remain to be investigated around the articulation of individual to group competency in collaborative activity. The question arises as to whether or not it is sufficient to see others perform the activity, or if for a student to be considered competent in collaboration they must be capable of activating the competency themselves. Do we consider that they are competent in another regard, i.e. staying silent in favor of group cohesion?

### *Chapter 7 Conclusion*

After applying this framework to our observations, we have concluded that the characteristics of the physical-digital workspaces do have an influence on the competencies developed by students. While more data over a longer period of time would be necessary to confirm the development of the competencies, we can say that there is an impact on student engagement and the frequency and level of activation of certain competencies when comparing the three physical-digital workspace modalities. Similar to what we saw with our results from analyzing modes of interactions, those modalities, which paired individual space with collective space, had consistently higher levels of engagement and competency activation than those which only used collective space. As we design or choose physical-digital workspaces for our students, if collaborating and learning to collaborate is of interest, those workspaces which incorporate an individual space and combine it with a collective space may lead to better collaboration in some instances and the possibility to develop collaborative competencies.

With that said, we feel that our approach has left us with other open questions that merit investigation in a future research project: How do we take into account tensions between individual and collective competency in the context of group work? This is an especially difficult question as schools and universities have started adopting a competency-based approach to program design. How do we evaluate an individual for a collective competency?

**PART FOUR CONCLUSION AND SUMMARY**

Our primary focus in this section was to understand if and to what extent physical-digital workspaces could influence the development of collaborative competencies. Since observing competency development directly is difficult, we elected to take a new approach because of the goal of our research: to understand how physical-digital workspaces might facilitate learning to collaborate. As such, verifying competency development wasn't necessarily the goal. We needed to see if it is possible, which can be observed in-part if competency development occurs in part through experience. In order for this experience to be gained, a student would need to be engaged in the activity. This is the lens through which we investigated how physical-digital workspaces might influence competency development. While not all of the collaborative competencies showed significant differences between modalities, it quickly became clear that disengaged students activated competencies at a lower frequency and quality than engaged students. Having access to an individual space encouraged such engagement. We feel that this must be considered when implementing collaborative learning technologies in the classroom.

In this section, we have discussed how collaborative competencies are linked to the modes of interaction proposed in globally collaborative work. We identified key moments when skills could be activated at a basic level, as well as moments when students may be able to deepen and master collaboration skills. We also proposed the $CO^2$ framework for rating student actions during collaboration, based on whether their actions have a positive or negative influence on the collaboration, with indicators related to each collaborative competency. After presenting these frameworks, we talked about results from applying them. We found that physical-digital workspace has an impact on student engagement, with the availability of an individual space alongside a collective-public space being the most beneficial. Having an individual-private space which is mobile slightly overtakes the use of an individual-public space that is stationary, as it allows for greater flexibility in the group's movement around the space without pushing some group members into the background.

We note that these individual spaces also play a role in regard to competency activation, with students being more likely to activate competencies related to regulation, communication, and constructive conflict. The physical-digital workspace seemed to have little effect on the activation of certain competencies related to social intelligence, at least for the modalities we studied.

# CONCLUSIONS



In our conclusion, we begin by proposing a synthesis of our work and discuss our methodological approach and limitations. Finally, we conclude by focusing on our major contributions. Notably, we consider that we have contributed three elements through our work:

- globally collaborative work and the accompanying analysis model (CIAO);
- a typology of physical-digital workspaces;
- a framework for evaluating and understanding engagement and collaborative competency activation.

***Research Overview***

Embedded in a research project interested in understanding how a techno-pedagogical device impacts how students learn to collaborate and develop competencies related to collaboration, this dissertation uses notions of collaboration coming from essentially cognitivist theories, in terms of their social dimensions and from progressive education, where experience is at the heart of teaching and learning. Following in the Marxist tradition of dialectical materialism, Vygotsky, Leontiev, Engeström, and Rabardel (amongst many others) tell us that the tools we use necessarily change the way an individual or group acts on an object. Likewise, introducing new technical devices to facilitate collaboration or learning to collaborate should influence the users' actions, but how and to what extent? How do we evaluate and measure that change?

To answer these questions, we went backwards to ask: what is collaboration? We identified three primary paradigms: collaboration as a method of learning, collaboration as a philosophy of interaction and collaboration as a method of working. Each of these may interact in different contexts, leading to complex and polysemic definitions related to the situation and goal of the collaboration itself. Additionally, collaboration is often put into tension with cooperation. Sometimes they are separated entirely (Baudrit, 2007a), while others say one is needed for the other (Baker, 2015; Bruffee, 1995). We define **collaboration** as the co-elaboration and co-evolution of tasks, ideas and concepts in order to create a joint product. **Cooperation** refers to the negotiation and re-convergence of work completed separately in order to create a cohesive product. In either case, how can we identify if they are occurring when observing students working? Most researchers working in CSCL use discourse analysis techniques to identify collaboration, looking at the language actions and reactions of group members. Often, non-verbal actions are also integrated into this, such as writing or searching for information.

Beyond the question of what is collaboration and how do we identify it, we find the question "what does it mean to be competent in collaboration, to know how to collaborate?" Competency itself is a complex topic, with the majority of the literature coming from linguists, didacticians and work psychologists interested in professional development and training in the workplace. From an operationalist perspective, we have defined competencies as an ability to act (Tardif, 2018) made up of savior (theoretical knowledge…), savoir-faire (knowledge-in-action, procedural knowledge…) and savoir-être (personal qualities, production of adapted actions…) (Boudreault, 2017; Hatchuel & Weil, 1992; Pastré, 2004) which a person or group can mobilize to act in a given situation, based on their understanding of that situation (Wittorski, 1997). Based on a literature review of collaborative competencies, we identified five key competencies: regulation, communication & listening, teamwork, social intelligence, and constructive conflict.

Finally, we turned towards the technology itself to ask what features might influence how activity is performed. We developed an *a priori* typology for classifying those technologies that are not only digital but have a physical component to help with our investigation of the influence of those technologies on learning to collaborate. This physical-digital typology is based on two axes: individual/collective (referring to the possibility to interact with the device) and public/private (referring to the possibility to read/view information within the device).

Tactile technology, like those mobilized in our research, began appearing in 2006, and shortly thereafter, multi-user technology became central to investigations in CSCLD research, with interest in device orientation, user experience, table size, etc. Our study used such technology developed at the University of Technology at Compiegne, France, referred to as the *Halle Numérique* platform. This platform consists of multiuser tactile tables and boards with functionalities allowing the use of personal devices, such as tablets, smartphones, or laptops.

Using the Design Research Methodology, we clarified our research question and gained a better understanding of the technology and its uses by observing course work with university students and an interdisciplinary project with students from a technical high school in the region. We then developed our primary research question: How do physical-digital workspaces influence interactions within student work groups, and by consequence, the development of collaborative competencies? This question gave way to two hypotheses:

> H1: The characteristics of the workspace will have an influence on the collaborative processes implemented by students during collective activity.
>
> H2: The characteristics of the workspace have an influence on the competencies developed by students.

In order to bring some elements of response to them, we put into place a research protocol that compared three variations of physical-digital workspaces using the *Halle Numérique* platform: (1) table and board; (2) tablets and board; (3) board only. We observed engineering students working on case studies. We collected and coded 55 hours of video and audio data, first looking at collaborative processes and then competencies. This data was coded blindly by two separate coders using the framework we developed.

Based on our descriptive study, we proposed the idea of *globally collaborative work* (Tucker et al., 2018). We argue that cooperation and collaboration are both present when groups work together to some extent, along with phases of individual work, communication, and coordination. Based on this, we developed CIAO, an analysis model to identify the modes of interaction which appear during globally collaborative work. While we do not expect to end the collaboration versus cooperation debate, this combined definition, wherein both play an important role in *globally collaborative work*, may help to redefine how we think about them, relating more to the role that each one plays. That is to say that they are not necessarily in tension but serve complementary purposes when a group undertakes the development of a product (be it knowledge, an idea or physical object) together.

In answer to the first part of our question and hypothesis, relating to the influence of physical-digital spaces on collaborative processes, we found that those groups using the table (individual-public space) and board (collective public space) tended to spend more time cooperating, i.e. in phases of epistemic conflict and negotiation. On the other hand, those groups which only had the board spent more time collaborating and co-building, to the detriment of creativity and epistemic conflict. Finally, those groups using tablets (individual-private space) and board reached a balance between cooperation and collaboration during their work. We can interpret and apply these results in a few ways. For example, when designing physical-digital workspaces to support globally collaborative work, different types of workspaces could be used at various points to influence the group's activity. I.e. if we wish to focus on epistemic conflict, using an individual space is most useful. When we want to build agreement, the use of a collective-public space could be considered to facilitate this.

So, how then does this impact of physical-digital workspaces on collaborative interactions influence the development of collaborative competencies? We began by relating the collaborative competencies we had identified to each mode of interaction, before developing a framework for evaluation that gauged how an individual's actions would impact collaboration (negatively, not at all, or positively). This necessitated using engagement as a key indicator, for if one is not engaged or participating, learning through experience cannot occur. As such, it could be used both as a measure of engagement and, by consequence, for measuring collaborative competency. We consider the resulting framework to be flexible, as it relies on basic competencies identified through a literature review across multiple domains as well as using observations of students from middle school through university. We've taken this approach for a few reasons: the nature of competence as situational implies that it is subject to change. Rather than challenging this and positioning competence as invariant (as Chomsky has done (Chomsky, 1971)), we have attempted to embrace the ephemeral nature of competence. As such, we feel that our proposed framework could be modified, where necessary, to include additional elements specific to the situation and expectations of the evaluator. Whether or not this is practical for application in the field is another question.

After applying this framework to our observations, we have concluded that the characteristics of the physical-digital workspaces do have an influence on the competencies developed by students. While more data over a longer period of time would be necessary to confirm the development of the competencies, we can say that there is an impact on student engagement, the impact and frequency of the activation of certain competencies when comparing the three physical-digital workspace modalities. Again, those modalities which paired individual space with collective space had consistently higher levels of engagement and competency activation than those which only used collective space. As we design or choose physical-digital workspaces for our students, if collaborating and learning to collaborate is of interest, those workspaces which incorporate an individual space and combine it with a collective space may lead to better collaboration in some instances and the possibility to develop collaborative competencies. An additional element was identified that should also be considered: mobility. The individual-private spaces of the tablet allowed for a better fluidity of movement around the space and easier transitions between the different modes of interaction.

***Methodology and Research Limitations***

Over the course of our research, a few methodological obstacles presented themselves.

Firstly, there was a tension between the desire to understand how the techno-pedagogical tools we were studying could be used specifically in pre-university education environments, however access to those students was limited due to the nature of the technology we were studying. While we did incorporate some findings using middle and high school students into CIAO and our competency/engagement framework, we did not feel the data collected was sufficient or structured enough (due to different types of projects) to address our questions satisfactorily in the context of a PhD dissertation. As such, we used data collected in parallel with university students as the primary of this thesis. Between these different populations, we have a much larger corpus of data than was discussed in this dissertation, but not all of which are complete due to confinement after the spread of the SARS-CoV-2 across the world, which led to the closing of schools in France. So, while this dissertation uses some 55 hours of recorded work, the ability to generalize to answer the project's question may be reduced because of the focus on a single age-group. We elected to focus on the data from university students because in the context of a dissertation, it is not necessarily considered problematic, as we can better focus the study.

Secondly, we experienced technical issues with our recording equipment that led to data loss on two occasions. The first directly impacted the results presented here, with a video file that was lost for one work session of a group using the table/board modality. Additionally, maintenance on the recording system in the Fall 2019 semester, which would have contributed an additional 36 hours of data, led to the loss of some 12 hours of recording. As such, we decided not to use the data from that semester because it was incomplete. After this occurred, we worked to install automatic data back-ups to avoid such data loss in the future. Additionally, collected data is stored in two locations. However, there is still the possibility for human error, as we again experienced in the Fall of 2019, when a student worker turned off the recording equipment before the data had fully saved on the system. For this, the system is now locked with only researchers having access to it. We attempted to add the additional 36 hours back in the Spring of 2020, but due to university closing from confinement, only part of this data was able to be collected. As such, it is also not included.

Thirdly, we experienced some issues due to absences in some of the groups. Using real students, taking real courses meant real conflicts that couldn't be rescheduled to have the full group present. However, the absences themselves did not seem to have a large impact on most groups, except for the board-only groups, who found themselves with more space than in previous sessions. This did impact engagement levels in those sessions, contributing a result related to access to the space rather than proving to be a true limitation.

Finally, we feel that we are missing an important element: students' reflections about their own experience and competency development. In future research, we believe incorporating post-experiment interviews, if not both pre- and post-interviews, would be more beneficial than using a questionnaire alone. Including this in future research would provide more context to the results we have collected and allow students to clarify their working methods and interpret their own actions. We feel that this could go a long way into better understanding the articulation of competencies on an individual and group level.

### *Contributions*

**How can we account for the presence of both collaboration and cooperation in collective work?**

There is a consensus in the literature today that the primary difference between cooperation and collaboration is found in the division of labor between participants (Baker, 2015; Baudrit, 2007a; Dillenbourg, 1999). However, not all group work is either cooperative or collaborative and indeed, some cooperative situations require some collaboration (Baker, 2015). During our descriptive study, we sought to understand what processes are put into place during group work by reviewing the literature and through observation. As this occurred, we noticed that Baker's observation of collaboration and cooperation occurring in the same work session was accurate, but that the definitions available to us did not necessarily account for it. So, one of the initial questions we sought to answer is: how can we rethink the articulation between collaboration, cooperation, and other forms of interactions in such a way that it reflects what we see during collective work and learning scenarios? Are these two group processes necessarily in tension? This question required us to consider how collaboration has been historically defined by researchers in CSCL, but also how it has been articulated with other types of interactions. Indeed, if it is as we have observed and as Baker suggests, that cooperation requires at least some collaboration, then separating them may not be the best approach. They should be understood together.

In definitions of cooperation, we typically see a focus on division of labor. We considered that perhaps, we were looking at the wrong part of cooperative interactions. When labor is divided and students work alone, they are no longer cooperating or collaborating - they are working individually. So, what is it about the process that requires any sort of "working" or "operating" together as the term "co - operate" suggests? Rather than putting the emphasis on the separation and individual part of the work, perhaps the emphasis should be placed on the what follows: coming back together and what must occur to achieve alignment within the group, not only as a matter of coordination but to repair any divergence in understanding or goals that occurred during this individual work. When looked at in this way, it sheds new light on what it means to have a collaborative interaction.

If cooperation describes understanding that is built from divergence, then perhaps collaboration could be used to describe what is built from convergence.

*Globally Collaborative Work* as a model for understanding collaborative interactions uses this idea to articulate the processes that may be present when people work and learn together. Collaboration, cooperation, coordination, communication, and individual work each serve a different and complementary purpose when people seek to work or learn together. The *Collaborative Interaction Analysis mOdel* (CIAO), is a tool to aid in the identification of *globally collaborative work* processes by demonstrating potential action/interaction chains, while not being exhaustive (Tucker et al., 2019, 2018).

We still find at least one of the problems identified by Baker (2015) that our model does not overcome: the definitions we typically use to define these interactions rely primarily on the linguistic plane. Despite using some forms of activity and communication that rely on action rather than words, these do not extend to the cooperation-collaboration layers. Even those found in communication and coordination still make use of language and symbols (like color-coding). It is possible, however, that additional actions, gestures, and behaviors could be identified within interaction chains to expand the identifications used in CIAO to perhaps be relevant to other scientific domains. Indeed, this is a topic for research that is already underway in partnership with UTC and Chibia University in Japan. Using CIAO and globally collaborative work, we have begun exploring how "atomic actions" or visual, rather than verbal, indicators could be used to support non co-located collaborative work sessions with the help of real-time video analysis leveraging machine-learning (Gidel et al., 2020).

**How can we describe the articulation between physical and digital space?**

As we mentioned in Chapter 1: Space is a complex notion that requires an explanation to be understood. It can refer to physical spaces, concepts, architecture, the heavens, etc. Lefebvre (1974) proposed three types of space: physical, mental, and social. However, at the time of his writing, the notion that space can be digital was in its infancy. While we see our research touching on each of Lefebvre's three levels, there is a very specific play between physical spaces and digital spaces that we believe needs to be articulated. Digital spaces, at least today, require some sort of physical tool to access – be it a table, computer, smartphone, etc. There is some sort of physical interface, but this physical interface can take different forms that can be governed by physical or social rules. Likewise, within a digital space, one's abilities can be restricted or directed by certain rules, typically related to one's ability to access (view) or edit (act upon) what is contained in this digital space.

The physical-digital workspace typology seeks to articulate the form that the spaces we are using, which have both a physical and digital component, may take and understand how they fit together. The typology we propose relies on the users' abilities to act/interact and read/view content. This typology largely sufficed for our purposes; however, we feel that it may be relevant to also talk about other physical affordances alongside of it, such as device mobility or orientation. Indeed, the results we have had regarding the use of an individual space is convergent with some researchers, while divergent with others. For example, Gracia-Moreno (2017) concluded that individual-private space (on a laptop) was useful for allowing students to develop their thoughts, leading to better epistemic conflict when work transitioned to a collective-public space. However, Haué & Dillenbourg (2009) indicate that laptops (individual-private or individual-public) impacted the group's cognitive load, led to less coordination and ultimately served as a distraction. Our study did not include laptops in the empirical research phase but did in the discovery phase. From our observations, we think that perhaps what is at issue here is the availability versus lack of a collective-public space to view the group's progress. However, we think it could be worth considering that there could be a combination of factors at play, including: the ability to transition between viewpoints by mobilizing different types of physical-digital workspaces (individual to collective), the orientation (blocking one's view of others, a laptop's design means that the screen sits in line of site), and the relative mobility of the individual space (laptops typically remain in the same place, in front of the user/owner).

**How do we evaluate an artifact's potential for positively influencing competency development?**

One of the major questions that we wrestled with throughout this research is how do we evaluate an artifact's potential for positively (or negatively) influencing collaborative competency development? This brought with it a myriad of other questions relating to the nature of competencies, their development, transferability, measurement, etc. We feel that while we have settled on some answers, we mostly find ourselves with more questions. In CSCL literature, little interest has been paid to understanding the development of students' ability to work together – focusing more on how tools or certain scenarios can be used to support efficacious collaboration. However, it is through the experience gained from using these tools that we might see changes to how students collaborate, not only when using a tool, but when not using it or when choosing how to go about collaborating in the future.

When diving into the literature about competency, we find that most competencies are evaluated individually. There are many ways that this has been addressed in the past: through written assessments, self-assessments, portfolios, performance assessments, etc. When we talk about collaboration as a competency, this is one that necessarily is articulated with other individuals. So, is it important to measure individuals for a collective competency? Why or why not? How could we go about evaluating individuals for a collective competency? What methodology and tools would we need? We felt that a good starting point would be to establish a rubric that identifies if and to what extent students are engaging in certain types of behaviors, but then how those behaviors impact the group's collaboration: from being disengaged to engaging in good quality interactions. This led to the development of our $CO^2$ Framework. While this framework needs additional tuning, it is a basis from which we can work to measure individual and group engagement, as well as the quality of collaborative competency activation in context.

However, we still see an issue when it comes to looking at an individual in the context of a group. Perhaps we are not only looking at the effects of distributed cognition (Hutchins, 2000), but distributed competency. This would imply that evaluating an individual is not useful, but rather that what is useful is understanding how that individual articulates his/her ability with that of the group by sharing the competency load. However, this would likely mean bringing one's previous experience with other groups to bear on the current group, making the individual's competency in knowing how to navigate collaboration important. So perhaps the next question we should ask is about transferability – across both groups and tools: How do students take the competencies that they have developed through productive activity, experience, and constructive activity then apply them to new collaborative work/learning situations? If students used certain types of physical-digital workspaces, are they more likely to have higher quality engagement when faced with new situations? Will a positive collaborative experience relative to a tool's affordances influence student's preferences for certain types of workspaces?

While we still see numerous problems with competency and how to assess it in our approach, we do feel that it is an interesting one that merits further consideration. Rather than focusing on development or proving whether or not a student possesses a competency, for us it was more interesting to try to understand whether behaviors related to the competency were "activated" or put into place by students or not. We believe that this was a valid approach in our case because we were not necessarily interested in competency development, but rather its potential for development.

Westera (2001) states that competence is only an "unclear label" and "does not increase our knowledge and understanding of the world." However, we feel that rejecting it or relegating it to colloquial language is not helpful either. We are working with a complex construct related to human thought and activity that has emerged to describe *something*. Whether or not we use the term competence to get to that *something* is debatable but attempting to transform competence/competencies into something immutable and constant in the tradition of Chomsky may be an oversimplification. Westera even goes on to say that the determinants of human ability, rather than competence, are *possessing* (knowledge), *feeling* (attitudes), and *doing* (skills) – the very composing elements we have used to define competence in the francophone tradition in terms of *savoir, savoir-être,* and *savoir-faire.*

## BIBLIOGRAPHY


Baker, M. (2015). Collaboration in Collaborative Learning. *Interaction Studies*, *16*(3), 451–473. https://doi.org/10.1075/is.16.3.05bak

Bandura, A. (1999). Social Cognitive Theory: An Agentic Perspective. *Asian Journal of Social Psychology*, *2*, 21–41. https://www.uky.edu/~eushe2/Bandura/Bandura1999AJSP.pdf

Baron, G.-L., Bruillard, É., & Barrère, A. (2013). École et dispositifs technologiques : Points de vue croisés. *Carrefours de l'éducation*, *36*, 117–129. https://doi.org/10.3917/cdle.036.0117

Barron, B., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, A., Zech, L., Bransford, J. D., & Vanderbilt, T. C. and T. G. at. (1998). Doing with Understanding: Lessons from Research on Problem- and Project-Based Learning. *The Journal of the Learning Sciences*, *7*(3/4), 271–311. https://www.jstor.org/stable/1466789

Baudrit, A. (2007a). Apprentissage coopératif/Apprentissage collaboratif : D'un comparatisme conventionnel à un comparatisme critique. *Les Sciences de l'éducation - Pour l'Ère nouvelle*, *40*(1), 115–136. https://doi.org/10.3917/lsdle.401.0115

Baudrit, A. (2007b). *Les bases scientifiques de l'apprentissage collaboratif* (p. 22). https://www.cairn.info/l-apprentissage-collaboratif--9782804153175-page-13.htm

Beheshtifar, M., & Zare, E. (2013). Interpersonal Conflict: A Substantial Factor to Organizational Failure. *International Journal of Academic Research in Business and Social Sciences*, *3*(5), 400–407.

Bender, L., Walia, G., Kambhampaty, K., Nygard, K. E., & Nygard, T. E. (2012). *Social* *sensitivity and classroom team projects: An empirical investigation*. 403. https://doi.org/10.1145/2157136.2157258

Blessing, L. T. M., & Chakrabarti, A. (2009). *DRM, a Design Research Methodology*. Springer London. https://doi.org/10.1007/978-1-84882-587-1

Blumenfeld, P. C., Krajcik, J. S., Marx, R. W., & Soloway, E. (1994). Lessons Learned: How Collaboration Helped Middle Grade Science Teachers Learn Project-Based Instruction. *The Elementary School Journal*, *94*(5), 539–551. https://www.jstor.org/stable/1001841?seq=1

Bocchi, P. C. (2010). *Les formes de régulation de l'activité des élèves*. AREF 2010, Université de Genève. https://plone.unige.ch/aref2010/symposiums-longs/coordinateurs-en-m/personnalisation-et-individualisation-des-parcours-des-eleves-2-lorganisation-du-travail-scolaire-et-les-pratiques-pedagogiques-au-croisement-de-temporalites-et-de-spatialites-diversifiees/Les%20formes%20de%20regulation.pdf/view

Boudreault, H. (2017). *Interpréter et représenter les savoir-être professionnels pour pouvoir concevoir des environnements didactiques pour les faire développer*. 8. https://rpdp2017.sciencesconf.org/data/3106_BOUDREAULTHenri.pdf

Bourmaud, G. (2006). *Les systèmes d'instruments : Méthodes d'analyse et perspectives de conception* [Phdthesis, Université Paris VIII Vincennes-Saint Denis]. https://tel.archives-ouvertes.fr/tel-00109046/document

Bruffee, K. A. (1995). Sharing Our Toys: Cooperative Learning versus Collaborative Learning. *Change*, *27*(1), 12–18. https://www.tandfonline.com/doi/abs/10.1080/00091383.1995.9937722

Buchs, C., & Butera, F. (2004). Socio-cognitive conflict and the role of student interaction in learning. *New Review of Social Psychology*, *3*, 80–87. https://archive-ouverte.unige.ch/unige:27550

Buisine, S., Besacier, G., Aoussat, A., & Vernier, F. (2012). How do interactive tabletop systems influence collaboration? *Computers in Human Behavior*, *28*(1), 49–59. https://doi.org/10.1016/j.chb.2011.08.010

Carless, S. A., & De Paola, C. (2000). The Measurement of Cohesion in Work Teams. *Small Group Research*, *31*(1), 71–88. https://doi.org/10.1177/104649640003100104

Chi, M. T. H., & Wylie, R. (2014). The ICAP Framework: Linking Cognitive Engagement to Active Learning Outcomes. *Educational Psychologist*, *49*(4), 219–243. https://doi.org/10.1080/00461520.2014.965823

Chomsky, N. (1971). *Chomsky: Selected Readings / ed. by J.P.B. Allen and Paul Van Buren*. Oxford University Press.

Clark, H. H., & Schaefer, E. F. (1989). Contributing to Discourse. *Cognitive Science*, *13*(2), 259–294. https://doi.org/10.1207/s15516709cog1302_7

Cohen, P. (2007, January 9). *Macworld Expo Keynote Live Update: Introducing the iPhone*. Macworld. https://www.macworld.com/article/1054764/macworld-expo/liveupdate.html

Cousinet, R. (2011). *Une méthode de travail libre par groupes*. Fabert.

Dahl, R. A. (1973). *Polyarchy: Participation and Opposition*. Yale University Press.

Dewey, J. (1938a). *Experience & Education*. https://ia800208.us.archive.org/11/items/ExperienceAndEducation/dewey2.pdf

Dewey, J. (1938b). *Experience and education* (1. ed). Simon & Schuster.

Dillenbourg, P. (1999). What do you mean by collaborative learning? In *Collaborative-learning: Cognitive and Computational Approaches.* (pp. 1–19). Oxford: Elsevier. https://telearn.archives-ouvertes.fr/hal-00190240

Dillenbourg, P. (2002). Over-scripting CSCL: The risks of blending collaborative learning with instructional design. In Kirschner (Ed.), *Three worlds of CSCL. Can we support CSCL?* (pp. 61–91). Open Universiteit Nederland.

Doise, W., & Mugny, G. (1981). *Le développement social de l'intelligence*. InterEditions. http://gallica.bnf.fr/ark:/12148/bpt6k3333555r

Dugosh, K. L., Paulus, P. B., Roland, E. J., & Yang, H.-C. (2000). Cognitive stimulation in brainstorming. *Journal of Personality and Social Psychology*, *79*(5), 722–735. Scopus. https://doi.org/10.1037/0022-3514.79.5.722

Edmonson, A. (1999). Psychological Safety and Learning Behavior in Work Teams. *Administrative Science Quarterly*, *44*(2), 350–383. http://web.mit.edu/curhan/www/docs/Articles/15341_Readings/Group_Performance/Edmondson%20Psychological%20safety.pdf

Engel, D., Woolley, A. W., Jing, L. X., Chabris, C. F., & Malone, T. W. (2014). Reading the Mind in the Eyes or Reading between the Lines? Theory of Mind Predicts Collective Intelligence Equally Well Online and Face-To-Face. *PLOS ONE*, *9*(12), e115212. https://doi.org/10.1371/journal.pone.0115212

Engestrom, Y. (2014). *Learning by Expanding: An Activity-Theoretical Approach to Developmental Research* (2nd ed.). Cambridge University Press. https://doi.org/10.1017/CBO9781139814744

Engeström, Y., & Sannino, A. (2013). La volition et l'agentivité transformatrice : Perspective théorique de l'activité. *Revue Internationale Du CRIRES : Innover Dans La Tradition de Vygotsky, 1*(1), 4–19. http://lchc.ucsd.edu/MCA/Mail/xmcamail.2013_06.dir/pdfXaDiE2vzyz.pdf

ESCO. (2018). *ESCO - European Commission*. https://ec.europa.eu/esco/portal/home?resetLanguage=true&newLanguage=en

Freinet, C. (1964). Les invariants pedagogiques. *Bibliothèque de l'Ecole Moderne*, *25*. https://www.icem-pedagogie-freinet.org/les-invariants-pedagogiques

Gareis, R. (1989). 'Management by projects': The management approach for the future. *International Journal of Project Management*, *7*(4), 243–249. https://doi.org/10.1016/0263-7863(89)90013-6

Gidel, T., Tucker, A., Fujita, S., Moulin, C., Sugawara, K., Suganuma, T., Kaeri, Y., & Shiratori, N. (2020). Interaction Model and Respect of Rules to Enhance Collaborative Brainstorming Results. *Advances in Science, Technology and Engineering Systems Journal*, *5*(2), 484–493. https://doi.org/10.25046/aj050262

Gidel, T., & Zonghero, W. (2006). *Management de projet. 1, 1,*. Hermes Science : Lavoisier.

Google Developers. (2014). *Google I/O 2014 - The design sprint: From Google Ventures to Google*. https://www.youtube.com/watch?v=aWQUSiOZ0x8

Gracia-Moreno, C. (2017). *Role d'un espace de travail numérique privé dans une activité d'édition collaborative de cartes conceptuelles, cas d'étude en lycée* [UNIVERSITE DE POITIERS]. http://nuxeo.edel.univ-poitiers.fr/nuxeo/site/esupversions/5698f297-dabb-436f-8f27-5a77900193a3

Hamdan, R. K. A. (2017). The Effect of (Think – Pair – Share) Strategy on the Achievement of Third Grade Student in Sciences in the Educational District of Irbid. *Journal of Education and Practice*, *8*(9), 88–95. https://files.eric.ed.gov/fulltext/EJ1139082.pdf

Hatchuel, A., & Weil, B. (1992). *L'expert et le système : Gestion des savoirs et métamorphose des acteurs dans l'entreprise industrielle, suivi de quatre histoires de systèmes-experts*. Economica.

Haué, J.-B., & Dillenbourg, P. (2009). Do Fewer Laptops Make a Better Team? In P. Dillenbourg, J. Huang, & M. Cherubini (Eds.), *Interactive Artifacts and Furniture Supporting Collaborative Work and Learning* (pp. 1–24). Springer US. https://doi.org/10.1007/978-0-387-77234-9_3

Henri, F. (2015). *Chapitre 13. Collaboration, communautés et réseaux : Partenariats pour l'apprentissage*. Presses Universitaires de France. https://www.cairn.info/apprendre-avec-les-technologies--9782130575306-page-169.htm

Hesse, F., Care, E., Buder, J., Sassenberg, K., & Griffin, P. (2015). A Framework for Teachable Collaborative Problem Solving Skills. In P. Griffin & E. Care (Eds.), *Assessment and Teaching of 21st Century Skills* (pp. 37–56). Springer Netherlands. https://doi.org/10.1007/978-94-017-9395-7_2

Homaeian, L., Goyal, N., Wallace, J., & Scott, S. (2018). *Group vs Individual: Impact of TOUCH and TILT Cross-Device Interactions on Mixed-Focus Collaboration*. 2018 International Conference on Human Factors on Computing Systems, Montreal. https://doi.org/10.1145/3173574.3173647

Hutchins, E. (2000). *Cognition in the wild*. Cambridge, MA. MIT Press.

Hymes, C. M., & Olson, G. M. (1992). Unblocking brainstorming through the use of a simple group editor. *Proceedings of the 1992 ACM Conference on Computer-Supported Cooperative Work - CSCW '92*, 99–106. https://doi.org/10.1145/143457.143467

Jenkins, H., Clinton, K., Purushotma, R., Robinson, A. J., & Weugek, M. (2009). *Confronting the Challenges of Participatory Culture: Media Education for the 21st Century*. https://www.macfound.org/media/article_pdfs/JENKINS_WHITE_PAPER.PDF

Johansen, R. (1988). *GroupWare: Computer Support for Business Teams*. The Free Press.

Johnson, D. W., & Johnson, R. T. (2002). Learning Together and Alone: Overview and Meta-analysis. *Asia Pacific Journal of Education*, *22*(1), 95–105. https://doi.org/10.1080/0218879020220110

Johnson, D. W., & Johnson, R. T. (2011). Intellectual Legacy: Cooperation and Competition. In P. T. Coleman (Ed.), *Conflict, Interdependence, and Justice* (pp. 41–63). Springer New York. https://doi.org/10.1007/978-1-4419-9994-8_3

Jones, A., Kendira, A., Gidel, T., Moulin, C., Lenne, D., Barthès, J.-P., & Guerra, A. L. (2012, May 25). Evaluating Collaboration in Table-centric Interactive Spaces. *AVI Workshop on Designing Collaborative Interactive Spaces*. DCIS, Capri, Italy.

Jones, A., Kendira, A., Lenne, D., Gidel, T., & Moulin, C. (2011). The TATIN-PIC Project, A Multi-modal Collaborative Work Environment for Preliminary Design. *15th International Conference on Computer Supported Cooperative Work in Design*, 154–161. https://doi.org/10.1109/CSCWD.2011.5960069

Jung, C. G. (1946). *Psychological Types or The Psychology of Individuation* (G. Baynes, Trans.). Kegan Paul, Trench, Trubner & Co., LTD.

Jung, J. H., Lee, Y., & Karsten, R. (2012). The Moderating Effect of Extraversion–Introversion Differences on Group Idea Generation Performance. *Small Group Research*, *43*(1), 30–49. https://doi.org/10.1177/1046496411422130

Kennedy, R. R. (2009). The power of in-class debates. *Active Learning in Higher Education*, *10*(3), 225–236. https://doi.org/10.1177/1469787409343186

Kobbe, L., Weinberger, A., Dillenbourg, P., Harrer, A., Hämäläinen, R., Häkkinen, P., & Fischer, F. (2007). Specifying computer-supported collaboration scripts. *International Journal of Computer-Supported Collaborative Learning*, *2*(2), 211–224. https://doi.org/10.1007/s11412-007-9014-4

Koc-Michalska, K., Schiffrin, A., Lopez, A., Boulianne, S., & Bimber, B. (2019). From Online Political Posting to *Mansplaining*: The Gender Gap and Social Media in Political Discussion. *Social Science Computer Review*, 089443931987025. https://doi.org/10.1177/0894439319870259

Krajcik, J. S., Blumenfeld, P. C., Marx, R. W., & Soloway, E. (1994). A Collaborative Model for Helping Middle Grade Science Teachers Learn Project-Based Instruction. *The Elementary School Journal*, *94*(5), 483–497. https://www.jstor.org/stable/1001838?seq=1

Kumar S., V., & Mukherjee, S. (2018). Holacracy – the future of organizing? The case of Zappos. *Human Resource Management International Digest*, *26*(7), 12–15. https://doi.org/10.1108/HRMID-08-2018-0161

Ladd, G. W., Kochenderfer-Ladd, B., Visconti, K. J., Ettekal, I., Sechler, C. M., & Cortes,

K. I. (2014). Grade-School Children's Social Collaborative Skills: Links with Partner Preference and Achievement. *American Educational Research Journal*, *51*(1), 152–183. http://www.jstor.org/stable/24546676

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge University Press.

Lee, C., Li, H., & Shahrill, M. (2018). Utilising the Think-Pair-Share Technique in the Learning of Probability. *International Journal on Emerging Mathematics Education*, *2*(1), 49–64. http://journal.uad.ac.id/index.php/IJEME/article/view/8218

Lefebvre, H. (1974). La production de l'espace. *L'Homme et la société*, *31*(1), 15–32. https://doi.org/10.3406/homso.1974.1855

Lenay, C., Salembier, P., Lamard, P., Lequin, Y.-C., & Sauvee, L. (2014). Pour une recherche technologique en sciences humaines et sociales. In A. Bernard, M. Dell'Angelo, S. de Montgolfier, A.-S. Godfroy, M. Huchette, A. Mayrargue, & C. Roux (Eds.), *SHS Web of Conferences* (Vol. 13, p. 05001). https://doi.org/10.1051/shsconf/20141305001

Lenay, C., Thouvenin, I., Guénand, A., Gapenne, O., Stewart, J., & Maillet, B. (2007). Designing the Ground for Pleasurable Experience. *Proceedings of the 2007 Conference on Designing Pleasurable Products and Interfaces*, 35–58. https://doi.org/10.1145/1314161.1314165

Leontiev, A. N. (2009). *The development of mind: Selected works of Aleksei Nikolaevich Leontyev*. Marxists Internet Archive.

Lissermann, R., Huber, J., Schmitz, M., Steimle, J., & Mühlhäuser, M. (2014). *Permulin:*

*Mixed-focus collaboration on multi-view tabletops*. 3191–3200. https://doi.org/10.1145/2556288.2557405

Lom, B. (2012). Classroom Activities: Simple Strategies to Incorporate Student-Centered Activities within Undergraduate Science Lectures. *Journal of Undergraduate Neuroscience Education*, *11*(1), A64–A71. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3592730/

Malmberg, J., Järvelä, S., Holappa, J., Haataja, E., Huang, X., & Siipo, A. (2018). Going beyond what is visible: What multichannel data can reveal about interaction in the context of collaborative learning? *Computers in Human Behavior*. https://doi.org/10.1016/j.chb.2018.06.030

Manilall, J., & Rowe, M. (2016). Collaborative competency in physiotherapy students: Implications for interprofessional education. *African Journal of Health Professions Education*, *8*(2), 217. https://doi.org/10.7196/AJHPE.2016.v8i2.841

Maslow, A. H. (1943). A Theory of Human Motivation. *Psychological Review*. http://psychclassics.yorku.ca/Maslow/motivation.htm

Matthews, R., Cooper, J., Davidson, N., & Hawkes, P. (1995). Building Bridges between Cooperative and Collaborative Learning. *Change*, *27*(5), 34–40. https://www.jstor.org/stable/40165324

Mercier, E., Higgins, S., & Joyce-Gibbons, A. (2014). The effects of room design on computer-supported collaborative learning in a multi-touch classroom. *Interactive Learning Environments*, *24*, 1–19. https://doi.org/10.1080/10494820.2014.881392

Mercier, E., Vourloumi, G., & Higgins, S. (2015). Student interactions and the development of ideas in multi-touch and paper-based collaborative mathematical problem solving. *British Journal of Educational Technology*. https://doi.org/10.1111/bjet.12351

Morse, R., & Stephens, J. (2012). *Teaching Collaborative Governance: Phases, Competencies, and Case-Based Learning*. https://doi.org/10.1080/15236803.2012.12001700

Mugny, G., & Doise, W. (1978). Socio-Cognitive Conflict and Structure of Individual and Collective Performances. *European Journal of Social Psychology*, *8*, 182–192. https://web.stanford.edu/dept/SUSE/projects/ireport/articles/concept_maps/socio-cognitive%20conflict%20and%20structure%20of%20individual%20and%20collective%20performances.pdf

Newmann, F. M. (Ed.). (1992). *Student engagement and achievement in American secondary schools*. Teachers College Press.

Nijstad, B. A., Stroebe, W., & Lodewijkx, H. F. M. (2002). Cognitive stimulation and interference in groups: Exposure effects in an idea generation task. *Journal of Experimental Social Psychology*, *38*(6), 535–544. https://doi.org/10.1016/S0022-1031(02)00500-0

Norris, N. (1991). The trouble with competence. *Cambridge Journal of Education*, *21*(3), 331. https://doi.org/10.1080/0305764910210307

OECD. (2017a). *PISA 2015 Results (Volume I) | OECD READ edition*. OECD ILibrary. http://www.keepeek.com/Digital-Asset-Management/oecd/education/pisa-2015-results-volume-i_9789264266490-en

OECD. (2017b). PISA 2015 collaborative problem-solving framework. In OECD, *PISA 2015 Assessment and Analytical Framework* (pp. 131–188). OECD Publishing.

https://doi.org/10.1787/9789264281820-8-en

O'Leary, R., Choi, Y., & Gerard, C. M. (2012). The Skill Set of the Successful Collaborator. *Public Administration Review*, *72*(s1), S70–S83. https://doi.org/10.1111/j.1540-6210.2012.02667.x

Osborn, A. F. (1957). *Applied Imagination: Principles and Procedures of Creative Thinking*. Charles Scribner's Sons.

Panitz, T. (1999). *Collaborative versus Cooperative Learning: A Comparison of the Two Concepts Which Will Help Us Understand the Underlying Nature of Interactive Learning*. https://files.eric.ed.gov/fulltext/ED448443.pdf

Pastré, P. (2004). 13. Les compétences professionnelles et leur développement. In P. Falzon, *Ergonomie* (1r ed., p. 213). Presses Universitaires de France. https://doi.org/10.3917/puf.falzo.2004.01.0213

Perret-Clermont, A.-N. (2001). *Psychologie sociale de la construction de l'espace de pensée*. Constructivismes : Usages et Perspectives en Éducation, 1–2, 65–82.

Policard, F. (2014). Apprendre ensemble à travailler ensemble : L'interprofessionnalité en formation par la simulation au service du développement des compétences collaboratives. *Recherche en soins infirmiers*, *117*, 33–49. https://doi.org/10.3917/rsi.117.0033

Rabardel, P. (1995). *Les hommes et les technologies ; approche cognitive des instruments contemporains*. Armand Colin. https://hal.archives-ouvertes.fr/hal-01017462

Rajan, R. G., & Wulf, J. (2006). The Flattening Firm: Evidence from Panel Data on the Changing Nature of Corporate Hierarchies. *The Review of Economics and Statistics*, *88*(4), 759–773. http://www.jstor.org/stable/40043033

Rogers, Y., & Lindley, S. (2004). Collaborating around vertical and horizontal large interactive displays: Which way is best? *Interacting with Computers*, *16*(6), 1133–1152. https://doi.org/10.1016/j.intcom.2004.07.008

Romero, E. J., & Cruthirds, K. W. (2006). The Use of Humor in the Workplace. *Academy of Management Perspectives*, 13.

Romero, E., & Pescosolido, A. (2008). Humor and group effectiveness. *Human Relations*, *61*(3), 395–418. https://doi.org/10.1177/0018726708088999

Roth, W.-M., Radford, L., & LaCroix, L. (2012). Working with Cultural-Historical Activity Theory. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *Vol 13*, No 2 (2012): Qualitative Computing: Diverse Worlds and Research Practices. https://doi.org/10.17169/fqs-13.2.1814

Ryall, K., Forlines, C., Shen, C., & Ringel Morris, M. (2004). Exploring the Effects of Group Size and Table Size on Interactions with Tabletop Shared-Display Groupware. *CSCW '04 Proceedings of the 2004 ACM Conference on Computer Supported Cooperative Work*, 284–293. http://cs.stanford.edu/~merrie/papers/table_size.pdf

Samurçay, R., & Rabardel, P. (2004). Modèles pour l'analyse de l'activité et des compétences, propositions. In *Recherches en didactique professionnelle*. Octarès éditions.

Sanchez, É., & Monod-Ansaldi, R. (2015). Recherche collaborative orientée par la conception. *Education & Didactique*, *9*(2), 73–94. http://www.cairn.info/resume.php?ID_ARTICLE=EDDI_092_0073

Sanojca, E. (2018). *Les compétences collaboratives et leur développement en formation* *d'adultes : Le cas d'une formation hybride* (tel-01709910) [Education, Université Rennes 2]. NNT: 2018REN20001. https://tel.archives-ouvertes.fr/tel-01709910/document

Shah, C. (2008). *Toward Collaborative Information Seeking (CIS)*. Joint Conference on Digital Libraries. http://chirags.comminfo.rutgers.edu/papers/Shah_Workshop_JCDL2008.pdf

Shah, C., & Leeder, C. (2016). Exploring collaborative work among graduate students through the C5 model of collaboration: A diary study. *Journal of Information Science*, *42*(5), 609–629. https://doi.org/10.1177/0165551515603322

Shannon. (1948). A Mathematical Theory of Communication. *The Bell System Technical Journal*, *27*, 379-423,623-656. http://math.harvard.edu/~ctm/home/text/others/shannon/entropy/entropy.pdf

Sizmur, S. R. (1996). *Collaborative Concept Mapping and Children's Learning in Primary Science*. King's College.

Soller, A. (2001). Supporting Social Interaction in an Intelligent Collaborative Learning System. *International Journal of Artificial Intelligence in Education*, *12*. https://telearn.archives-ouvertes.fr/hal-00197321/document

Stahl, G. (2004). *Building Collaborative Knowing: Elements of a Social Theory of CSCL.* http://gerrystahl.net/cscl/papers/ch16.pdf

Stahl, G., Koschmann, T., & Suthers, D. (2006). Computer-supported collaborative learning: An historical perspective. In *Cambridge handbook of the learning sciences* (pp. 409–426). Cambridge University Press. http://gerrystahl.net/cscl/CSCL_English.pdf

Tardif, J. (2013). *L'approche par compétences : Un changement de paradigme*. https://www.youtube.com/watch?v=PR6N6-dJvzU

Tardif, J. (2018, Avril). *Conférence de Jacques Tardif sur l'approche compétences*. https://www.youtube.com/watch?v=Vs1flm0u_fg

Tardif, J., & Dubois, B. (2010). *Chapitre 8. Construire des dispositifs en vue de l'évaluation du développement des compétences. Comment ?* De Boeck Supérieur. https://www.cairn.info/article.php?ID_ARTICLE=DBU_PAQUA_2010_01_0131

Tardif, J., & Dubois, F. (2013). De la nature des compétences transversales jusqu'à leur évaluation : Une course à obstacles, souvent infranchissables | Cairn.info. *Revue Française de Linguistique Appliquée*, *18*, 29–45. https://www.cairn.info/revue-francaise-de-linguistique-appliquee-2013-1-page-29.htm?try_download=1#

Teasley, S., & Roschelle, J. (1995). Constructing a Joint Problem Space: The Computer as a Tool for Sharing Knowledge. In *C. O'Malley (Ed.), Computer-supported collaborative learning*. Springer-Verlag. https://pdfs.semanticscholar.org/421e/ae7de485aa33bcbacd7af0ebc0fe4c6f235e.pdf

Tucker, A., Gidel, T., & Fluckiger, C. (2019). Designing Physical-Digital Workspaces to Support Globally Collaborative Work. *Proceedings of the Design Society: International Conference on Engineering Design*, *1*(1), 109–118. https://doi.org/10.1017/dsi.2019.14

Tucker, A., Gidel, T., & Villemonteix, F. (2018). *Apprendre à collaborer : L'utilisation des tables tactiles pour les projets pédagogiques*. 10. https://www.researchgate.net/publication/327602118_Apprendre_a_collaborer_l'u tilisation_des_tables_tactiles_pour_les_projets_pedagogiques

Van den Bossche, P., Gijselaers, W. H., Segers, M., & Kirschner, P. A. (2006). Social and Cognitive Factors Driving Teamwork in Collaborative Learning Environments: Team Learning Beliefs and Behaviors. *Small Group Research*, *37*(5), 490–521. https://doi.org/10.1177/1046496406292938

Veer, R. van der, & Valsiner, J. (1994). *Understanding Vygotsky: A quest for synthesis* (Reprint). Blackwell.

Vibert, A., & Sheilds, C. M. (2003). APPROACHES TO STUDENT ENGAGEMENT: DOES IDEOLOGY MATTER? *McGill Journal of Education / Revue Des Sciences de l'éducation de McGill*, *38*(002). https://mje.mcgill.ca/article/view/8682

Villemonteix, F., Gidel, T., Bernard, F.-X., & Tucker, A. (2018, Mai). *GTNUM3: Pratiques collaboratives instrumentés en milieu éducatif.* Journées de l'ORME, Marseille, France.

Villemonteix, F., Hamon, D., Nogry, S., Séjourné, A., Hubert, B., & Gélis, J.-M. (2015). *Expérience tablettes tactiles à l'école primaire—ExTaTE* [Research Report]. Laboratoire EMA. https://hal.archives-ouvertes.fr/hal-01026077

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Wegerif. (2015). *Prof.Dr. Rupert Wegerif—Learning to learn together (L2L2)*. https://www.youtube.com/watch?v=aqU8-08wMBI&feature=youtu.be

Wegerif, R., Mercer, N., & Dawes, L. (1998, November 11). *From Social Interaction to Individual Reasoning: An Empirical Investigation of a Socio-cultural Model of*

*Cognitive Development*. http://www.leeds.ac.uk/educol/documents/000000864.htm

Westera, W. (2001). Competences in education: A confusion of tongues. *Journal of Curriculum Studies*, *33*(1), 75–88. https://doi.org/10.1080/00220270120625

Wittorski, R. (1997). *Analyse du travail et production de compétences collectives*. L'Harmattan.

Woolley, A. W., Chabris, C. F., Pentland, A., Hashmi, N., & Malone, T. W. (2010a). Evidence for a Collective Intelligence Factor in the Performance of Human Groups. *Science*, *330*(6004), 686–688. https://doi.org/10.1126/science.1193147

Woolley, A. W., Chabris, C. F., Pentland, A., Hashmi, N., & Malone, T. W. (2010b). Evidence for a Collective Intelligence Factor in the Performance of Human Groups. *Science*, *330*(6004), 686–688. https://doi.org/10.1126/science.1193147

Zagermann, J., Pfeil, U., Radle, R., Jetter, H.-C., Klokmose, C., & Reiterer, H. (2016). When Tablets meet Tabletops: The Effect of Tabletop Size on Around-the-Table Collaboration with Personal Tablets. *CHI '16 Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 5470–5481. http://hci.uni-konstanz.de/downloads/2016_CHI_zagermann.pdf

Zumbach, J., Schönemann, J., & Reimann, P. (2005). *Analyzing and supporting collaboration in cooperative computer-mediated communication*. 758–767. https://doi.org/10.3115/1149293.1149393

Zyngier, D. (2008). (Re)conceptualising student engagement: Doing education not doing time. *Teaching and Teacher Education*, *24*(7), 1765–1776. https://doi.org/10.1016/j.tate.2007.09.004

# ANNEX

## ANNEX 1: SUMMARY OF COMPETENCY FRAMEWORKS IN TERMS OF THEIR SAVOIRS, SAVOIR-FAIRE AND SAVOIR-ÊTRE

The greyed-out areas represent the empty spaces, where the authors did not mention any elements in that category. In the case of Sanojca, the *savoirs* identified are training needs mentioned by those taking the course, in which certain ones appear during the training already. These items do not appear in her final tryptic, but we feel that they are useful to include.

| | **Savoirs** | **Savoir-faire** | **Savoir être** |
|---|---|---|---|
| Sanojca, 2018 | Methods and techniques for meeting facilitation<br>Non-violent communication<br>Group decision making methods (consensus, sociocracy)<br>Analysis of effective collaboration<br>Manage conflicts<br>----<br>Project management tools<br>Non co-located collaboration technology<br>Time management methods<br>Best practice exchange methods<br>Monitoring tools | Know how to engage partners<br>Co-build the project structure<br>Lead the group to facilitate work<br>Listen to others and their ideas<br>Develop and maintain a network of actors<br>Manage information (share, make visible)<br>Care about the common good<br>Act to obtain common objectives | Have a collaborative mindset<br>Be humble<br>Be benevolent |
| Ladd, et al., (2014) | | Pay attention to colleagues<br>Listen<br>Share ideas<br>Explain ideas<br>Give opinions<br>Verbalize thoughts<br>Take turns working<br>Work well with others<br>Support colleagues<br>Act in a cooperative manner<br>Try to resolve conflicts<br>Control emotions<br>Divide work fairly | Task oriented<br>Tenacious<br>Concentrated<br>Nice<br>Empathetic<br>Willingness to try new approaches<br>Reliable |
| Hesse et al., (2015) | | Participation (Action, interaction, completion of tasks)<br>Perspective taking (adapted responses, knowledge of audience)<br>Regulation (negotiation, self-evaluation, transitive memory, responsibility)<br>Task regulation (Organize, define objectives, manage resources, accept ambiguous situations, collecting information, implementing solutions, evaluating progress) | Persistent<br>Sense of responsibility |

| | | | |
|---|---|---|---|
| | | Learn and construct knowledge (identify, formulate connections between knowledge elements; use cause and effect; adapt reasoning to changes in information or circumstances) | |
| O'Leary et al., 2012 | Facilitation<br>Reasoned negotiation<br>Collaborative problem solving<br>Group dynamics, culture, personalities<br>Mediation<br>Managing and resolving conflict<br>Technical knowledge<br>Project management<br>Time Management | Good communication (written and verbal)<br>Listening<br>Working well with others<br>Big picture thinking<br>Exercise strategic leadership<br>Creative thinking<br>Share leadership, objectives, recognition<br>Find comprises<br>Mediate | Open minded<br>Patient<br>Change oriented<br>Flexible<br>Altruistic<br>Tenacious<br>Diplomatic<br>Honest<br>Reliable<br>Empathetic<br>Goal-oriented<br>Determined<br>Likable<br>Sense of humor<br>Humble |
| Morse et Stephens (2012) | Design processes<br>Reasoned negotiation<br>Systems thinking<br>Consolidation of team and group dynamics | Analyze problems<br>Evaluate environment<br>Identify stakeholders<br>Strategic thinking<br>Engage stakeholders<br>Organize community / politicians<br>Amass social capital<br>Group facilitation<br>Listening<br>Consensus building<br>Develop action plan<br>Create governance structures<br>Engage the public<br>Network management<br>Conflict resolution<br>Performance evaluation | Collaborative mindset<br>Passion for contributing to society<br>Openness and risk-taking<br>Sense of reciprocity and relationships<br>Humble and a measured ego |
| Manilall & Rowe (2016) | Roles and responsibilities of other professionals<br>Evaluation of patient status | Encourage collaboration with other stakeholders in patient care<br>Identify problems that may lead to conflict and use collaboration skills to resolve them<br>Reflect on how to improve the functioning of the interprofessional team<br>Demonstrate the use of written and verbal communication for information transfer | Respectful attitude |
| Soller (2001) | | Active learning conversation<br>Analysis of performance and group processes<br>Effective help between peers<br>Social anchoring | Participation |
| Wegreif (2015) | | Open sharing<br>Encouraging participation<br>Active listening<br>Asking for others' opinions<br>Discussing alternatives<br>Working together to establish an accord<br>Respect and listen to opposing opinions | Group responsibility for decision making |
| Woolley et al., (2010) | | Conversational turn-taking | Social sensitivity |

## ANNEX 2 : TRANSCRIPTIONS

### *Non Instrumented Sessions*

**PSP1S19S1T4M1 – Non instrumented session; Partial transcription - Time stamp: [1:07 –30:09]**

**Student A:** De toute façon je pense qu'on va bosser sur le tableau plutôt que chacun sur sa feuille, je pense.
**Student B :** Oui
**Student C :** Oui
**Student A :** Ce sera plus intéressant donc comme ça chacun mettra ses idées
[Les élèves continuent à préparer leurs places (sortir leurs feuilles, cahiers) et étudiant A se mets au tableau et commence à écrire]
**Student A :** Je pense que c'est sur ça qu'on peut se pencher le plus. D'après ce qu'il a dit [l'enseignant], on va faire deux études differentes. Le plus important c'est la manipulation, donc on commence par la manip ?
**Student B :** Ok
**Student A :** Donc on part sur un poulpe [Student A continue à écrire au tableau.] D'après ce qu'on a vu ce matin, il faut regarder les éléments extérieurs.
**Student D :** L'objet, du coup, c'est la farine ?
**Student E :** Euh, je crois….
**Student A :** Oui, déterminer l'objet c'est… oui, manipulation de la farine
**Student C :** Manipulation de la farine
**Student E** : Mais.. ok manipulation de la farine
**Student D :** Il faut marquer farine directement dedans
**Student B :** Non, il faut pas, justement
**Student A :** Oui, il a dit qu'il faut éviter
**Student C :** Quand on veut faire des fonctions ce sera « objet »
**Student B :** Oui li faut rester objet pour avoir un degré d'abstraction
**Student A :** Cet embal, on l'envoie là
**Student D :** Mais emballage – utilisateur et une flèche à l'intérieur
**Student A :** Oui, mais en extérieur, c'est les éléments qui sont immeuble. On ne peut pas les changer. Le but, justement, c'est de changer l'emballage. On ne met pas l'emballage en extérieur, je pense.
**Student B :** C'est l'étagère… manipulation… la table
**Student A :** Oui, il faut pouvoir le poser à un moment ou un autre
**Student C :** balance
**Student D :** Utilisateur, non ?
**Student C** : Utilisateur ? Oui
**Student B :** Oui
**Student D :** Quand même.
**Student B :** Ustensiles
**Student C :** On peut faire des groupes et après s'il faut détailler
**Student A :** Oui, balance c'est pareil. Balance c'est pour les poids mais on peut aussi doser en quantité

**Student C :** Peut-être pas balance, mais mesure
**Student D :** Tu vas mettre ça dans un contenant, donc en soi la farine va réagir avec le contenant par la balance
**Student A :** Oui, dans la cuve.
**Student D :** La balance, la mesure, on s'en fou un peu, non ?
**Student A :** Contenant pour la mesure
**Student D:** Ouais

**PSP1S19T4S2M1 non-instrumented session; Partial transcription - Time stamp: [9:45 – 18:45]**

| | |
|---|---|
| **Student A:** | On est sur le stockage |
| **Student B:** | Oui, on est sur le stockage. Donc stockage, c'est placard, étagère |
| **Student C:** | Cave |
| **Student B:** | Bah... bac de stockage |
| **Student D:** | Ben, je ne comprends pas parce qu'en fait les éléments extérieurs à un moment ils sont communs quel que soit le truc, quoi. |
| **Student A:** | Non, le poulpe, tu le fais dans une situation de vie. Donc on se dit « situation de vie : stockage » l'objet emballage…fin… du coup l'objet quand il est dans la configuration stockage avec quoi il interagit ? |
| **Student E:** | Ah d'accord |
| **Student D:** | Mais du coup, le poulpe, il |
| **Student A:** | C'est ça, uh ? [Regarde Student B] |
| **Student B:** | Oui, mais il y a quelque part.… oui c'est ça |
| **Student A:** | C'est ça, uh ? |
| **Student E:** | Non je comprends, mais j'avais compris ça comme ça |
| **Student A:** | Oui, mais c'est ça |
| **Student B:** | Moi il me semble que c'est ça… mais il interagit avec le placard, il interagit avec l'utilisateur. Il interagit euh… avec... La lumière, des choses comme ça ? |
| **Student C:** | Là ça rentre dans le placard… lumière, l'humidité |
| **Student A:** | Ouais |
| **Student C:** | Est-ce qu'on peut mettre |
| **Student B:** | Si, on peut mettre les différents trucs parce que |
| **Student C:** | On peut détailler |
| **Student B:** | Il faut que ton truc, ton emballage, il faut qu'il résiste à l'humidité |
| **Student E:** | Ouais |
| **Student A:** | Chacun peut écrire sur un…fin... |
| [Student B jette des post-its vers les autres membres du groupe] | |
| **Student B:** | Du coup les sous parties… il n'y a pas une autre grande partie ? |
| **Student C:** | Est-ce que ça peut être important de parler des normes ? |
| **Student B:** | Des normes ? |
| **Student C:** | Le respect des normes ? |
| **Student B:** | C'est pas dans les fonctions, ca |
| **Student A:** | Tous les éléments extérieurs |
| **Student E:** | Il faut aussi être recyclable |
| **Student C:** | Ça ne peut pas polluer…. Dans le sens où |

**Student A:** Je pense qu’on n’est pas dans les éléments extérieur de stockage
**Student B:** Là c’est pas un truc avec lequel il interagit. Ça c’est un autre...
**Student A:** Une contrainte
**Student B:** C’est un autre
**Student C:** D’accord
**Student B:** Ça c’est le truc, genre… je sais pas
**Student E:** On peut mettre chimiquement inerte parce qu’il conserve la farine, donc euh…
**Student B:** Oui, mais ça ce sont les trucs liés à l’emballage directement
**Student E:** C’est l’emballage directement qui interagit avec la
**Student C:** Oui, ça me va. Tandis qu’il reste … [inaudible]
**Student B:** Par contre il faut l’écrire si non on va
**Student A:** Mais si, regarde [Student A begins to write on a post-it]
**Student C:** Tu as écrit « main ? »
**Student B:** Oui, j’ai écrit « main » … de l’utilisateur
**Student C:** Je m’attendais pas à ça [rire]
[Enseignant arrive dans la salle]
**Teacher TG:** Je regarde juste les différentes équipes, si j’ai bien ça dans ma liste
**Student A:** C’est un peu le gaspillage de créer un post-it par idée
**Teacher TG:** Vous mettez les post-its sur la table ?
**Student B:** Non ?
**Teacher TG:** Si, pourquoi pas ?
**Student B:** Pourquoi pas ? Il faut pas faire comme ça ?
**Student E:** Il sera peut-être mieux de les mettre sur le tableau donc on peut utiliser les feutres
**Teacher TG:** Là c’est mettre les différents éléments environnement du poulpe, uh ? C’est ça ?
**Student B:** Oui… en stockage
**Teacher TG:** Il faut pas écrire sur la table
**Student B:** Non !
**Teacher TG:** [Rire]
**Student A:** Non, c’est sûr que les liens on ne va pouvoir les faire sur la table. Il faut les faire là [indique le tableau]
**Teacher TG:** Donc vous êtes dans la situation de vie stockage
**Student B:** Oui
**Teacher TG:** Très bien
**Student B:** Mais du coup, il y a pas beaucoup de trucs
**Teacher TG:**
**Student C:** Ouais on a du mal à voir…
**Student A:** Est-ce qu’on mettrai pas éventuellement comme tu dis [regarde Student D]
**Student D:** Moi c’est dans l’utilisation
**Student A:** Non, quand c’est dans le stockage… tu peux avoir une corbeille dans ton étagère... comme differentes corbeilles
**Student B:** Tu pensais pas à un bac ?
**Student E:** Imperméable, c’est ça ?
**Student B:** Parce moi, j’ai un bac et je mets ma farine puis je la jette
**Student E:** Ah tu le mets dans un truc en verre, ou un truc comme ça ?
**Student B:** Ouais
**Student A:** Ah

| | |
|---|---|
| **Student C:** | Du coup, ton emballage ne sert plus à rien |
| **Student B:** | Bah ouais |
| **Student D:** | Oui, ça peut se faire |
| **Student A:** | Du coup ton emballage ne sert à rien pendant le stockage |
| **Student B:** | Du coup c'est genre transvasé |
| **Student A:** | Mais en fait, il est absente, ton emballage, une fois tu le vides |
| **Student B:** | Oui… du coup il est disparu |
| **Student A:** | Du coup il est disparu [rire]. .. mais c'est important, je pense, de.. |
| **Student E:** | Tu pourras peut-être l'ouvrir et du coup le... |
| **Student C:** | Est-ce que ça rentre dans l'utilisation ou pas ? Le fait de le vider dans ton bocal pour le stocker |
| **Student E:** | Oui, pour moi oui. C'est une façon de l'utiliser. Tu l'utilises dans cette façon et la farine c'est autre chose |
| **Student B:** | ouais |
| **Student A:** | Moi, ce que j'entends par utilisation, c'est utilisation du contenu... de la farine, quoi ? |
| **Student C:** | Oui, mais là on se focalise sur le contenant |
| **Student A:** | Oui, non mais… le stockage, c'est pour le stocker. Fin dans l'objectif de le stocker. Tu le prends et tu vas vider comme dit [Student B] dans ton pot quoi |
| **Student D:** | Alors il faut valoriser le contenant pour faciliter l'utilisation du contenu |
| **Student E:** | De tout façon on n'est pas sur le contenu, il faut se concentrer sur le contenant |
| **Student A:** | Oui, mais.. |
| **Student D:** | Oui, mais c'est ca l'idée |
| **Student A:** | De ? |
| **Student D:** | Valoriser le content pour faciliter, en gros, son utilisation |
| **Student E:** | C'est vrai ca [se retourne vers l'enseignant] on valorise le contenant pour faciliter l'utilisation du contenu [retourne vers Student D parce que l'enseignant ne le regarde pas]… c'est pas du visuel en soit. Situation de vie... je sais pas moi, si tu veux faire un emballage joli à voir, ca rentre pas dans ce cadre là |
| **Student A:** | Non, mais non |
| **Student C:** | Tu mets des… [à Student B qui écrit sur un post-it] |
| **Student B:** | Je mets des idées |
| **Student C:** | Oui, c'est ça [rire] des solutions parce que… des contraints et des solutions |
| **Student B:** | Bahhh le fait qu'il est dans le placard, il faut qu'il soit hermétique et opaque |
| **Student C:** | D'accord |
| **Student A:** | Mais ce n'est pas du tout dans le poulpe… les éléments extérieurs |
| **Student E:** | Imperméable |
| **Student C:** | Non, mais c'est pas grave, on note les idées |
| **Student B:** | Bah non, mais c'est comme ça alors. C'est des liaisons. |
| **Student D:** | [à l'enseignant] Est-ce qu'on peut avoir des choses dans le poulpe de deux situations de vie differentes ? |
| **Teacher** | Non.. fin.. tu peux éventuellement réutiliser certains éléments environnement d'un poulpe dans un autre. Mais.. |
| **Student D:** | Parce que du coup on est.. |
| **Teacher:** | Là il faut étudier les fonctions dans.. Justement vous allez voir que les fonctions vont être diffèrent. Il peut y avoir certains qui sont les mêmes dans deux situations |

de vie differentes, euh ?

**Student A:** Bah, oui

**Teacher** Mais là justement ils sont différents. Ce que vous expérimentiez tout à l'heure en disant « effectivement » je crois qu'il y a une personne qui disant « moi je prends la farine, le paquet de farine, je le verse dans un pot et après je jette le paquer de farine. » Donc il y a.. vous expérimentez differentes typologies d'utilisation de farine, etc… mais pour vous mettre dans la situation le plus classique où vous gardez

**Student A:** Oui, on garde normalement

**Teacher** Le paquet de farine en phase d'utilisation. Si non, du coup, là effectivement, il y a une utilisation tout au départ et on peut acheter la farine en vrac et on fait son pot de farine maintenant comme ça se fait dans certains magasins ou on va directement récupérer sans emballage. Le fabricant est encore dans la condition ou il vend son paquet de farine avec la farine dedans. Et c'est utilisé comme ça. Mais, potentiellement, vous pouvez noter comme une des solutions, une ouverture vers une possibilité parce que si on fait ça, ça dit aussi quelque chose sur la problématique. Pourquoi est-ce qu'on est obligé de se transvaser et finalement et l'utilise que pour le transporter du magasin jusqu'à chez toi et après a tellement envie de se débarrasser que…

**Student D:** Il y en a qui choisissent ca... fin... on va pas proposer ça quoi

**Student A:** Non, c'est juste un élément de réflexion

**Teacher TG:** Ne vous interdisez pas de penser a des solutions qui va vers ça. C'est-à-dire, la en fait ce qu'on est en train de dire… c'est que de quelque sorte ça serait... les paquets de farine ne seraient plus que des recharges et il y aura un autre ustensile à côté. Au moins, c'est ça que j'entends moi.

**Student A:** Bah oui.

**Student C:** Ça marche plutôt bien pour les cafés ou les pâtes. Pourquoi pas pour la farine ? Monsieur, la livrable, ce que vous voulez à la fin de la séance, c'est des solutions

**Teacher TG:** Ce que je veux... L'objectif de ce TD c'est d'apprendre à formuler bien les fonctions. Déjà, d'un point de vu pédagogique c'est de bien rédiger les fonctions. D'un point de vue, après, plus intellectuelle et utilisation de ces outils, c'est pourquoi est-ce qu'on fait des fonctions ? C'est après pour trouver des solutions. A priori, plus que vous avez rédigé des fonctions avec un haut niveau d'abstraction, plus vous aurez des solutions un peu en ruptures et innovantes, qui vont arriver. Si ça a bien fonctionné, c'est-à-dire si d'un point de vue pédagogique vous avez bien rédigé les fonctions, normalement vous allez trouver des solutions intéressantes.

**Student A:** Donc en mirrore de ça, on les écrit, les fonctions ? L'objet permet de… machin.

**Student B:** Bah... L'objet permet de saisir la farine

**Student A:** Je les écris ou pas ?

**Student B:** Oui

**Student C:** Il faut rentrer dans les détails, peut-être

**PSP1S19T3S2M3's session A coordination; Partial transcription - Time stamp: [2:45 – 4:00]**

| | |
|---|---|
| **Student A** | Ça serait bien si chacun prenait un couleur diffèrent comme ça on peut voir… |
| **Student B** | Tu prennes le violet |
| **Student C** | Mais, moi, j'anime, moi. |
| **Student B** | Mais tu as des idées aussi, non ? |
| **Student C** | Ouais ouais |
| **Student A** | Alors, l'outil… Vous mettez… en fait on va créer un poulpe à partir de |
| **Student D** | Des différentes idées qu'on a |
| **Student A** | [Indique sa pile de post-it] Du coup-là tu mets genre un mot clé ou un espace et le but c'est d'en mettre |
| **Student B** | Et on rapport avec ca [indiquant la feuille où le cas d'étude est décrit] |
| **Student A** | Ouais, chercher les fonctions du coup |
| **Student D** | Mais avec un mot c'est compliqué |
| **Student A** | Oui |
| **Student B** | On peut pas reprendre ce qu'on fait depuis deux semaines, juste… ca sert à quoi, machin... tu extrais pas l… |
| **Student D** | On mettra pas « L'objet permet à l'utilisateur de… » |
| **Student A** | Oui, oui. C'est ça. |
| **Student D** | Ça c'est la finalité |
| **Student C** | Mais je comprends ce que {Student A} veut faire. Il veut juste d'abord qu'on dégage les idées principales, brainstorming |
| **Student A** | Oui, faire un genre brainstorming. On verra si ça comprend tout, mais on n'a qu'une heure |
| **Student C** | Bon vous faites comme vous voulez, moi je... [Se lève et se dirige vers le tableau avec sa pile des post-its violet] |
| **Student A** | Toi, tu écris toi, mais on essaye de définir trois fonctions techniques, on est d'accord ? |

***Session A***

**PSP1S19T4S1M1 session A; Partial transcription - Time stamp: [0:00 – 25:00]**

[Student A se connecte à la table puis au tableau]
[Student B, C et D testent les fonctionnalités de la table]
[Chercheur leur indique comment créer un projet et comment créer des documents dans ce projet]

| | |
|---|---|
| **Student D**: | ça va? |
| **Student E**: | Oui oui je me suis remis. |
| **Student D**: | encore? |
| **Student E**: | Non, non, j'ai fait le don du sang, sur la fin ils m'ont gardé parce que j'ai failli faire un malaise. |
| **Student D**: | C'est qu'aujourd'hui le don du sang ? |
| **Student E**: | ouais jusqu'à 18h. |
| **Student D**: | Ah j'ai bu du café moi, la personne qui va chopper mon sang elle va être … |

[L'enseignant rentre dans le box]

| | |
|---|---|
| **Teacher:** | c'est bon? |
| **Student D**: | normalement c'est bon. |

**Teacher:** C'est bon ? Vous vous concentrez avant d'y aller c'est ça ?
**Student D**: c'est ça, on médite …
**Teacher:** ouais c'est normal.
[Student A et E déplacent leur puit respectif sur la table]
[Student C interpelle student A et lui montre quelque chose au tableau, ils se rassoient ensuite]
[Student A, B et D créent des post-its sur la table]
**Student C** [En cliquant à plusieurs endroits en même temps] : comment est-ce qu'on fait une analyse de la valeur sur cette table ?
[Student C et D lisent le sujet]
[Chercheur vient montrer, en indiquant avec le doigt, à student A comment utiliser un format donné au tableau]
[Student A créé un post-it sur le tableau puis revient s'asseoir, student C déplace son puit]
**Student A**: Donc on part de là [créé un post-it sur la table]. Donc déjà en parce que on va partir sur les conditions automatiques je pense.
**Student C**: C'est parce qu'elle a envie d'utiliser la voiture.
**Student D**: Ouais c'est plutôt ça, parce que c'est dangereux.
**Student A**: Ah oui moi je vais direct… Ouais t'as raison
**Student C**: On peut aussi mais ça doit être deux branches différentes.
**Student D:** Oui, on peut faire ça.
[student A s'assoie]
**Student C**: Parce qu'elle veut se déplacer.
**Student D**: On n'a pas besoin d'écrire ça à chaque fois , c'est peut-être trop long si on met parce que à chaque fois.
**Student A**: Oui je crois que c'est écrit que les barres…
**Student D**: Automatiquement tu as parce que.
**Student A:** [S'adressant à student C] : tu veux le clavier ? Parce qu'au pire il y en a qu'un seul qui écrit, tout le monde parle, et au clavier c'est peut-être plus rapide.
**Student D**: [S'adressant à student C] : vas-y, tu veux écrire au clavier toi ?
**Student C**: Non moi ça va [essaie d'agrandir son clavier mais le fait tourner]
[rires]
**Student D**: Si si, on va te donner un clavier à toi.
[Student C se lève et va chercher un clavier sous le tableau]
**Student D**: Par contre oui il n'y a que lui qui va écrire sinon ça va bugger tout le temps. [S'adresse à student C] Est-ce que c'est le bon ?
**Student C**: Faut bien que j'écrive sur ce tableau ?
**Student A:** Oui.
**Student D**: Nan mais est-ce que c'est le bon ? Vas-y écris [student C créé un post-it] Non mais tape, tape des trucs.
[Student C tape sur le clavier]
**Student A**: Non, ça écrit sur ton … [désigne le post-it de student C]
**Student C:** [Prends le deuxième clavier, pose le premier sur le rebord de la table] : si quelqu'un veut l'utiliser.
**Chercheur :** Si vous pouviez éviter d'utiliser les claviers.

**Student C**: ah
[Student C repose les deux claviers sous le tableau puis va se rasseoir]
**Student A:** Nan c'est juste que des fois il y a des ratés de lettre et c'est vrai que c'est pas pratique.
**Student C:** Nan c'est que des fois il y a des lettres qui sont bien mises plutôt.
[rires]
**Student D:** [S'adressant à student C] : tu mets quoi toi, visibilité ?
[Student A, B, C et D écrivent sur des post-its]
[inaudible]
**Student D**: En sécurité, de manière sûre… Elle veut utiliser sa voiture, tu t'en fous du givre si tu veux utiliser ta voiture tu vois… Sous les normes…
**Student A**: Ah et … C'est interdit par la loi en plus.
**Student D**: c'est vrai?
**Student C:** [En tapant sur un post-it] : en toute légalité, ok.
**Student A**: et sécurité.
**Student D:** [S'adressant à student E] : ah oui, on n'a pas fait le brief.
**Student A**: Et non… [s'adresse à student E] bah tu as vu le TD ? On a juste cette phrase-là de base [désigne le tableau]
**Student E**: ok.
**Student D**: Ils s'en foutent ou pas les profs ? Pourquoi ils font l'appel?
**Student A**: Il l'a fait le premier je crois oui mais après il l'a pas fait. Mais il voit … Quand il est venu il a vu qu'il y avait 5 personnes …
**Student B**: Du coup on commence par l'objet qu'on met là-bas ou…
**Student D**: Nan ça c'est bon. C'est « l'objet permet à l'utilisateur d'enlever le givre des vitres ». Il est écrit là-bas [désigne le tableau]
**Student B**: Vous voulez commencer comment alors ?
**Student D**: Bah ça c'est au milieu…
**Student A**: Non mais elle veut le début de la phrase je pense. Donc c'est en gros…
**Student D:** On n'en a pas besoin
**Student A:** Ouais tu as pas besoin de mettre tout ça au début. L'objet permet à l'utilisateur d'enlever le givre de sa voiture. PARCE QUE la voiture avait du givre par exemple.
[Student D se lève et se dirige vers le tableau]
**Student A:** [S'adressant à student B] : donc tu commences juste. La voiture … et après on va faire les traits ça va sous-entendre le parce que.
[Student A,B et C écrivent sur des post-its sur la table, student D écrit au tableau]
[Student D retourne à sa place, envoie des post-its dans son puit puis retourne au tableau pour les y placer]
**Student C**: Elle veut se déplacer, pourquoi ?
**Student D:** [Désigne le tableau, s'adresse à student C] : c'est toi qui as écrit ça ?
[rires]
**Student A**: Nan mais il faut… Je sais pas où le monter en fait.
**Student C:** Elle veut se déplacer, pourquoi ? En gros elle veut … elle permet … [lis le tableau] Elle veut utiliser sa voiture en toute sécurité, légalité et sécurité. Ça c'est le premier [student D réorganise des post-its sur le tableau]. Après pourquoi, parce qu'elle veut se déplacer.

**Student D**: Pour se déplacer [déplace un post-it]
**Student C**: Mais pourquoi elle veut utiliser sa voiture ?
**Student D**: Sa voiture … ça c'est parce que … [déplace un post-it]
**Student A:** Non, au-dessus « elle veut se déplacer je pense ».
**Student C**: Oui oui, je l'avais vu au-dessus.
**Student D**: ah ouais?
**Student A**: Parce que l'objet ne te permet pas de se déplacer. L'objet il permet de retirer le givre.
**Student D:** [Pointe student A puis déplace un post-it] : c'est ça ! [Ressors un post-it d'un puit]
**Student A**: Déjà moi les deux que j'ai mis là c'est vraiment tout en haut [déplace deux post-its].
[Student C déplace un autre post-it]
**Student D**: Nan mais enlève moi ça [rires]. Sérieux [rires].
**Student C:** Elle veut se déplacer pourquoi, bah …
**Student D:** Au moins le prof va rigoler, c'est sûr.
**Student C:** Après on pourrait mettre … [déplace un post-it]
**Student D**: Ah non c'est vraiment … C'est parce qu'elle veut aller au boulot.
**Student E:** Elle est attendue à 8h à son travail ouais donc …
[Student B se lève et se dirige vers le tableau]
**Student C**: [Déplaçant des choses au tableau] : … de la voiture à … Comment on fait ça?
**Student A**: Alors ça et ça… Puisqu'en fin de compte le givre c'est une combinaison de froid et d'humidité. C'est pour ça que forcément, voilà, la voiture était givrée.
**Student C**: [Déplaçant quelque chose] : ah oui et il y a aussi une combinaison de la voiture et …
**Student D**: Bon bah attends, déjà, il est où le givre là ? Il faut en créer une là. C'est ça plus ça plus ça fait …
**Student C**: la voiture est givrée.
**Student A**: Enfin les vitres sont givrées.
**Student E:** [inaudible]
**Student C** [Se tourne vers student E] : tu veux du sucre ?
**Student A :** C'est ce que j'allais dire.
**Student E:** Si, j'ai mangé avant de venir.
**Student C:** J'ai pris des m&m's si jamais tu as besoin. [Se retourne vers le tableau]
[Student B retourne s'asseoir, student C et D déplacent des post-its sur le tableau]
**Student A**: Alors celui-là je pense qu'il faut le déplacer, il faut le déplacer vraiment… [s'avance vers le tableau et déplace un post-it] [inaudible]
**Student A**: Soit tu fais ça, soit tu ressers les 3 [déplace quelque chose]
**Student E:** Sinon il faut agrandir celui d'en dessous.
[student D agrandit un post-it]
**Student A:** Ouais on peut le remonter et l'agrandir un petit peu.
**Student C**: C'est pareil dans l'autre côté elle veut se déplacer.
**Student D:** nan … Attends … Parce que …
**Student C:** … la visibilité … [déplace un post-it]

**Student B:** En fait c'est pas parce qu'elle a rendez-vous … C'est parce qu'elle doit aller travailler.
**Student D**: Ah oui oui [rires]. C'est une blague de …
**Student B:** ah d'accord.
**Student C:** Non.
**Student D**: Je pense que t'as écrit ça.
**Student C**: Non je voulais écrire quelque chose mais c'est à cause du clavier.
[rires]
**Student E**: Elle a rendez-vous avec le garant c'est ça ?
**Student A:** [S'adressant à student B] : là je fais le dernier ….
[L'enseignant rentre dans le box]
[Student A et B rédigent des post-its sur la table, student C,D et E regardent le tableau]
**Teacher**: Vous avez des choses sympas là c'est bien parti. Juste un conseil que j'ai oublié de rappeler en briefing, c'est que dès que vous avez quelque chose qui commence à avoir de l'allure pour vous, vous le lisez à voix haute, en une seule grande phrase, lourde mais logique et vous verrez bien …
**Student C**: d'accord.
[l'enseignant sort du box]
**Student C** [Désigne quelque chose au tableau] : pourquoi, parce que les voitures sont givrées…. Je sais pas si les deux…
**Student A**: Les trois, ouais les deux-là c'est assez … [pointe au tableau] Pour toi elle veut se déplacer, pour se déplacer elle est obligée d'utiliser sa voiture. Est-ce que c'est par … Ouais ouais ce n'est pas déconnant.
[Student B se lève et s'approche du tableau, désigne quelque chose puis sort un post-it d'un puit]
**Student C**: euh, ah ouais.
**Student A:** [En désignant le tableau] : non, pour moi c'est pareil c'est au-dessus, parce que l'objet il permet pas de … L'objet il permet de … C'est un moyen de dégivrer ta voiture.
**Student D:** Non mais parce que le temps que tu passes à dégivrer… Il faut mettre éventuellement le temps que tu passes à enlever le givre.
[Les étudiants discutent à proximité du tableau]
[Inaudible]
[Student A se dirige vers sa place à la table, créé un post-it, student D lit ce qu'il écrit]
[Student B et C discutent en désignant le tableau, student D se retourne pour observer ce qu'ils font]
**Student D**: Je comprends pas bien la logique là. Là on parle de l'objet ou on parle de la fonction ? On parle de l'objet le grattoir ou on parle de la fonction d'enlever le givre.
**Student C**: Ah ouais c'est une bonne question ça.
**Student D:** Normalement c'est la fonction, on parle de FP normalement.
**Student B:** Moi je pense que c'est ça et ça ensemble [désigne le tableau]
[Student B et C interagissent avec le tableau en déplacent des post-it]
**Student C:** Elle vaut avoir une visibilité…
**Student B:** ensuite …
**Student C**: Parce que si tu dis ça, ça veut dire l'objet permet …

**Student E**: Mais non il faut retirer les « permet », pour obtenir une vision exempte de givre, pour avoir une visibilité meilleure.

[Student C déplace un post-it au tableau, tout le monde est tourné vers le tableau]

**Student D:** Oui c'est des verbes d'action carrément…

[Student A interagit avec le tableau, student D y désigne quelque chose puis va se rasseoir]

**Student B :** [Désigne le tableau] : parce qu'elle a une bonne visibilité.

**Student A:** Il y a quelque chose que je pige pas, l'objet permet de retirer le givre. Pourquoi tu veux le retirer le givre ? Pour être dans la légalité.

**Student D**: On en revient à ça, est-ce qu'on parle de l'objet ou de la fonction ? Parce que si tu parles de l'objet…

**Student A:** Oui tu arrives qu'à retirer le givre.

**Student D**: Oui, donc là c'est la fonction de retirer le givre des vitres, et là tu peux dire pourquoi, tu as pour et parce que. Si tu parles que de l'objet ça fait bizarre.

**Student A**: C'est un but, d'obtenir la légalité ? Ou est-ce que c'est une cause ? Parce que c'est illégal, que je peux pas le faire.

**Student D**: Dans les deux cas … Normalement c'est parce que c'est illégal.

**Student A**: Ouais c'est parce que c'est une obligation un petit peu… Ah et puis dans son exemple il avait mis la loi en haut.

**Student D:** ah tu as suivi?

[Rires]

[Student C continue à interagir avec le tableau sans parler, student A intervient et déplace quelque chose, student B et E observent]

[Student D se retourne, récupère son sujet et le lis]

[inaudible]

**Student D:** Il faut écrire du temps, parce qu'ici quand tu dis … [lit son sujet]

**Student A:** Oui, c'est important je pense.

**Student D**: À un moment donné quand tu dis « c'est pas assez rapide »

**Student C**: Ok c'est bien … Parce qu'on a … [désigne un ensemble de post-it] On veut aller au travail à temps…

**Student D**: Pourquoi ce serait en haut ?

[Student C déplace des post-its, student A et B désignent le tableau]

**Student A**: Non, non non, pourquoi… Ou alors [déplace quelque chose] effectivement en haut, mais pourquoi ? Pourquoi elle veut aller travailler à temps ? Parce qu'elle s'est partie trop tard, parce qu'elle est sortie trop tard de chez elle. Pourquoi elle est sortie trop tard ? Parce qu'elle s'est levée trop tard…

**Student D:** C'est vrai qu'il faut juste…

**Student A**: Il y avait cet aspect un peu mindfuck

**Student D**: Cette UV c'est un peu mindfuck… [se retourne vers l'entrée du box] ah il est pas là cool.

[rires]

**Student C**: Il avait dit qu'on pouvait dire n'importe quoi…

**Student D**: Non, on est filmés… oui … Bref… Et là tu écrirais la notion de temps ?

**Student A**: Il t'a dit le prof, elle rippait, etc. C'est pas assez bien fait, c'est pas assez rapide. Ca manque de technologie, entre guillemets.
**Student A**: Ouais je pense qu'on peut rajouter … Elle est sortie trop tard de chez elle, pourquoi ? parce qu'elle a pris son temps… Parce qu'elle s'est couchée tard, parce qu'elle a fait la fête …
**Student B:** [Désigne quelque chose au tableau] : elle veut se déplacer en voiture… [student C déplace un post-it puis écrit quelque chose] [inaudible]
**Student A:** C'est pareil tu pourrais aller beaucoup plus loin [pointe au tableau]. La voiture elle a passé la nuit dehors pourquoi ? Parce qu'elle a pas de place de parking, parce qu'elle a pas eu le temps de rentrer sa voiture… Mais là je pense qu'on sort vachement du scope de …
**Student D**: C'était quoi les deux trucs ? Zone ou périphérie …
[Student A désigne le tableau]
**Student D**: L'objet permet à l'utilisateur d'enlever le givre des vitres de sa voiture, on a pas de lien entre … Les vitres de la voiture sont givrées et…

**PSP1S19T4S2M1 session A; Partial transcription - Time stamp: [27:30 – 27:46]**

**Student A:** J'ai l'impression qu'on travaille tous dans son petit coin.
**Student B :** Bah ouais, mais c'est un brainstorming
**Student C :** Mais on brainstorm ensemble
**Student A :** Mais ce n'est pas du travail d'équipe
**Student C :** C'est pas grave mais si tu veux on se fixe un horaire mais dit pas que c'est pas un travail d'équipe. Après on synthétise, mais…

**PSP1S19T3S2M3 session A; Partial transcription – Time stamp: [11:40 – 12:07]**

Students A, B and C are typing on the board. Students D and E are behind them at the table.
**Student C :** Allez les gamins. Parce que…parce que ?
**Student E :** Parce que... chais pas.. uh.. manque de visibilité
**Student B:** [cutting off student E] Parce qu'elle
**Student A :** [Loudly, cutting off Student B] parce qu'elle doit aller au travail
**Student B** Oui mais pourquoi tu
**Student A** Attends !
**Student D** Parce qu'elle en retard
**Student A** En retard pour quoi ?
**Student D** Pour
**Student A** [Loudly] Attends attends attends! Aller au travail c'est un parce que ou c'est un pour ? Aller au travail. Elle degivre pour aller au travail
**Student C** [loudly, cutting off student A] mais il a dit
**Student A** [Continue] mais il faut dégivre parce qu'elle doit aller au travail
**Professor** Shhhh
**Student A** [More quietly] : tu vois ?

*Session B*

**PSP1F18T5M2 - Partial transcription - Time stamp: [4:30 – 7:30]**

Students begin sitting around the table, having just logged into their accounts on their tablets.

| | |
|---|---|
| **Student A :** | On met plein d'idées |
| **Student B :** | Oui, plein d'idées. On commence par les buts et tout ça ? Ou… qu'est-ce que vous voyez ? |
| **Student C :** | Ah, oui ? Moi, j'aurais… |
| **Student A :** | De toute façon, on fait comme on veut, ouais ? |
| **Student D :** | Ouais, c'est ça. |
| **Student B :** | Ouais, voilà, mais dans le cours il a dit que c'est plus simple que les causes |
| **Student D :** | On met chacun nos idées et on verra |
| **Student B :** | Oui, dans les causes et les... ouais c'est ça. |

[Each student begins writing ideas on their tablet, then sending them directly to the board. Student C stands and goes to move one of her post-its from the wormhole into the collective-public space of the board.]

| | |
|---|---|
| **Student B :** | Du coup, c'est des phrases plus simples en fait… les parce que, moins de formalisme |
| **Student A :** | Bah, ouais |

[Student C returns to the table and continues writing with the others]

**PSP1S19T5S1M2 – Original French**

| | |
|---|---|
| ***Student B :*** | *Est-ce qu'on fait en…* |
| ***Student A :*** | *En vrac* |
| ***Student B :*** | *Ouais, genre façon FAST. On balance plein d'idées et ensuite on ensuite on fait la remise ou est-ce qu'on réfléchit et…* |
| ***Student A :*** | *Ah non, non. Plutôt en vrac.* |
| ***Student B :*** | *Plutôt vrac ?* |
| ***Student C :*** | *Ouais.* |

**PSP1S19T3S1M3**

| | |
|---|---|
| **Student A** | Recul toi, comme ça je vois aussi le tableau |
| **Student B** | Attends, mais je vais me mettre au milieu |

[Student B positions himself against the table, then walks forward to open a keyboard]

| | |
|---|---|
| **Student A** | Mais je ne vois plus le tableau. |

*Session C*

**PSP1F18T4M1 – Partial transcription - Time stamp: [43:17-45:09] Original French**

| | |
|---|---|
| **Student A** | Juste au-dessous de lui |
| **Student B** | Pourquoi ? C’est la même chose que ça, hm ? |
| **Student C** | [Déplace un post-it sur le tableau] |
| **Student D** | Voilà, c’est ça. En gros ce que je voulais dire là-dedans c’est qu’elle a fait son truc |
| **Student A** | Elle a pas mis de temps de plus pour |
| **Student D** | Voilà, c’est ça |
| **Student C** | C’est pour montrer la rapidité |
| **Student D** | Ouais |
| **Student B** | [Déplace plusieurs post-its et change des éléments esthétiques] |
| **Student C** | [Déplace un post-it] |
| **Student B** | Nooon ! Tu niques le tout ! |
| **Student C** | Non, je veux juste le mettre là |
| **Student B** | [Tourne le dos et marche vers la table] |
| **Student C** | Lou Lou ! [Continue de bouger les post-its] |
| **Student E** | [Rire] |
| **Student C** | Attend, mais je vais le rendre tellement beau et tu vas pas comprendre… |
| **Student B** | [Retour vers le tableau] Mais tu..tu.. tu vas mettre des liens ? |
| **Student C** | Non, je vais pas mettre des liens [Continue de bouger les post-its] Regarde |
| **Student B** | Oh c’est laid [couvre sa bouche avec la main] Ahh ! Je vais m’assoir [Se dirige vers la table pour s’assoir] Ah putain. Ah non mais là, tu me perds |

[Tous les autres Students rient]

| | |
|---|---|
| **Student C** | Tu arrêtes, LouLou. |
| **Student B** | Mais c’est moche ! |
| **Student C** | Tu arrêtes, LouLou. |
| **Student B** | Mais c’est moche ! j’arrête pas j’ai le droit de donner mon avis |
| **Student C** | Mais dessin-le ! [Indique le tableau blanc] Dessin-le là |
| **Student B** | On ne peut pas faire Pomme-Zed ? |
| **Student C** | Pomme-zed? Non. |
| **Student B** | Moi j’ai un Pomme zed…Marion t’es où ? C’est toi, Student C? |
| **Student C** | Oui |
| **Student B** | [Efface quelque chose sur un feuille de papier] Je ne supporte pas quand les gens marquent des choses sur mon papier |
| **Student C** | Ok [retourne vers le tableau] |
| **Student B** | C’est moche. Ça marche, mais c’est moche. |

## ANNEX 3: MODES OF INTERACTION EXAMPLES (ORIGINAL FRENCH)

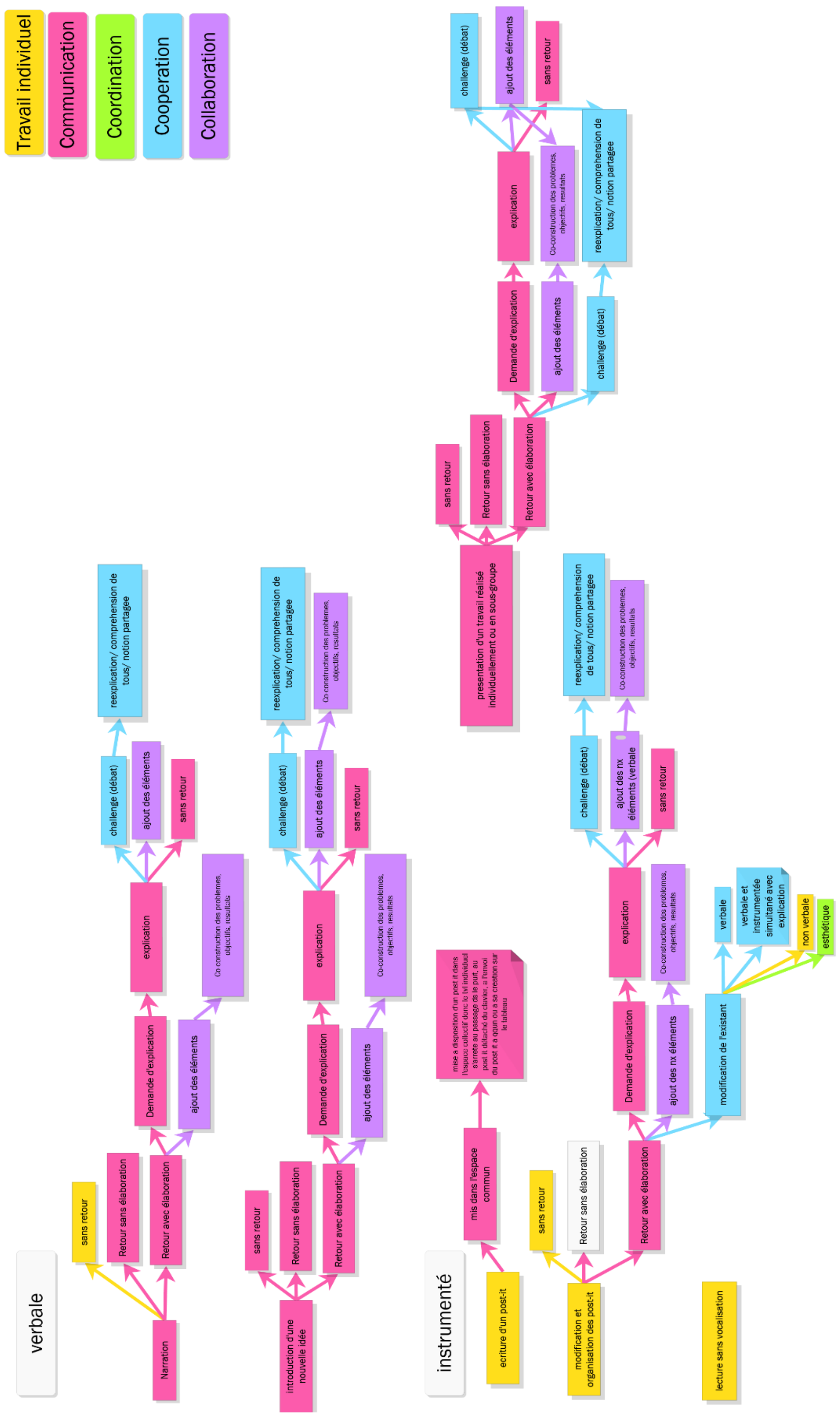
| **19-20-2018 – TD DI05 – Table 3 – Séance NI [14:30]** | |
|---|---|
| **Communication** | **Etudiant 1 :** L'objet doit permettre de contenir la farine *(Introduction of new idea)*<br>**Etudiant 2:** Ok *(Feedback without elaboration)* |
| **3-10-2018 TD DI05 – Table 5 – Tablettes – Partie 1 [37 :04]** | |
| **Communication** | **Etudiant 4 :** Je ne sais pas quelle phrase on dit pour descendre… *(Request for information)*<br>**Etudiant 1 :** « Donc », je crois *(providing information)* |

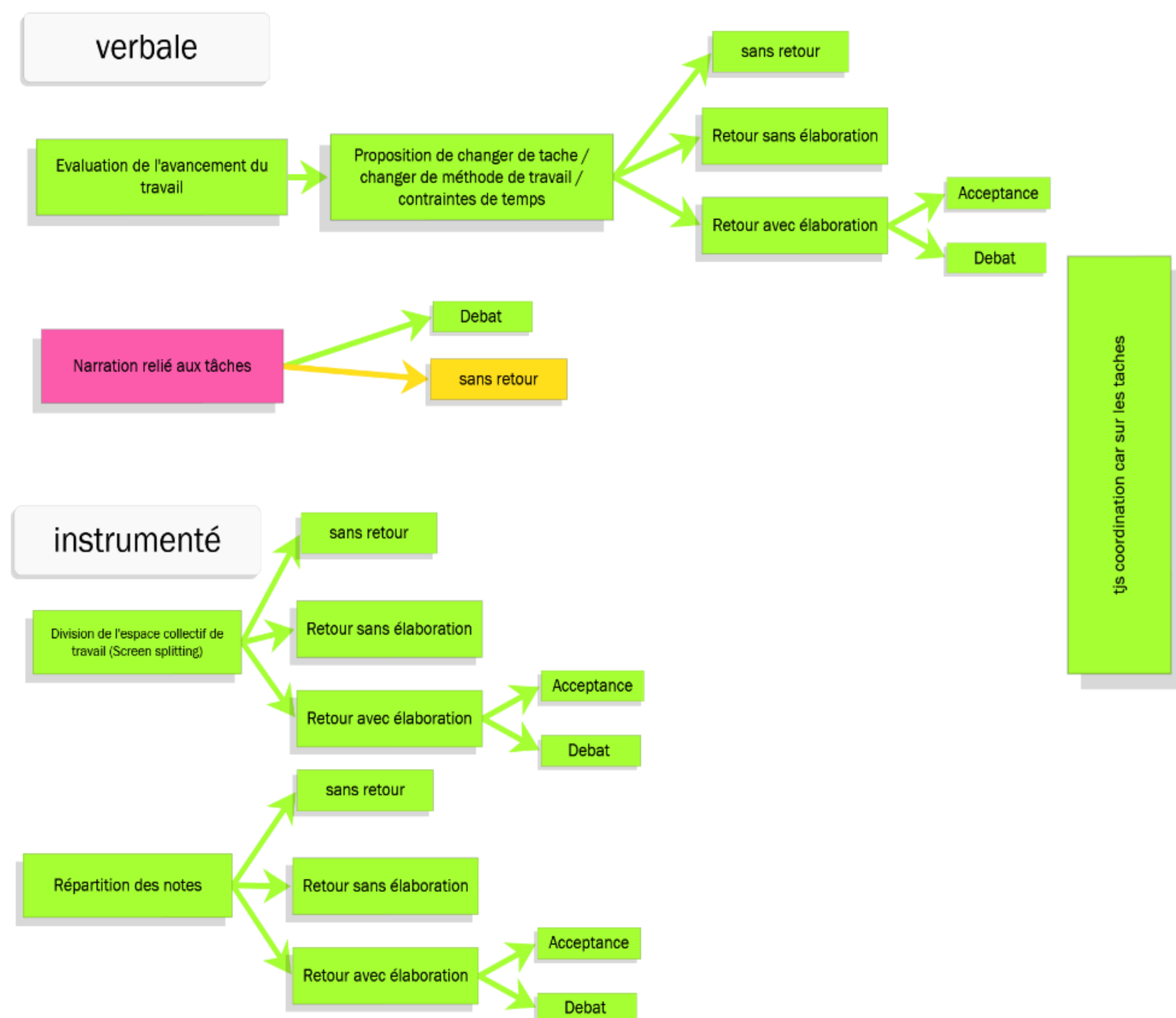
| **3-10-2018 TD DI05 – Table 5 – Tablettes – Partie 1 [4 :30]** | |
|---|---|
| **Coordination** | **Etudiant 1 :** Du coup, on fait comme la dernière fois ? *(recommending a method of work)*<br>**Etudiant 2 :** Ouais (*Acceptance)*<br>**Etudiant 3 :** Ouais c'était pas mal *(Acceptance)*<br>**Etudiant 1 :** On met pleins d'idées (*Acceptance)*<br>**Etudiant 2** : Pleines d'idées ouais... on commence par les buts ? c'est plus simple. *(Acceptance and élaboration)*<br>**Etudiant 4** : Ah ouais ? Moi j'aurais… *(debate)*<br>**Etudiant 2 :** Fin...<br>**Etudiant 1 :** De toute façon, on commence où on veut, eh ? *(debate)*<br>**Etudiant 3 :** Oui, c'est ça<br>**Etudiant 2 :** ouais... dans le cours il disait que c'est plus simple … que les causes *(debate)*<br>**Etudiant 3 :** On met chacun ses idées<br>**Etudiant 2 :** Ouais c'est ça *(acceptance)* |

| **3-10-2018 TD DI05 – Table 4 – Table/Tableau – Partie 1 [58 :30] Collaboration with transition to cooperation** | |
|---|---|
| **Communicatio** | **Etudiant 1 :** C'est peut-être chiant mais est-ce que le « conduire » on pourrait pas le remplacer par uh… *(Introduction of new idea)* |

| | |
|---|---|
| **Collaboration** | **Etudiant 2 :** se déplacer ? *(elaboration)*<br>**Etudiant 1 :** Oui, un truc comme ça *(acceptance)*<br>**Etudiant 3 :** Parce qu'elle veut pas conduire en fait *(elaboration)*<br>**Etudiant 1 :** Voilà, c'est ça *(acceptance)*<br>**Etudiante 3 :** Ouais, t'as raison, t'as raison*(acceptance)*<br>**Etudiant 2 :** Ouais mais du coup on met où conduire ? *(request for clarification)*<br>**Etudiant 3 :** Bah... juste après *(Response)*<br>**Etudiant 2 :** se déplacer ? *(request for clarification)*<br>**Etudiant 4 :** Ouais ça peut être**…** *(incomplete utterance)*<br>**Etudiant 3 :** ou alors tu mets… *(incomplete utterance)* |
| **Cooperation** | **Etudiant 2** : Pour moi c'est ça, se déplacer [indication d'un autre post-it au tableau] *(Challenge to idea)*<br>**Etudiant 3 :** Mais tu pourras le mettre entre les deux *(Negotiation)*<br>**Etudiant 2 :** Au niveaux d'abstraction, c'est plutôt en bas *(Negotiation)*<br>**Etudiant 1 :** Bah, non parce que se rendre à ton travail c'est le truc final ... genre elle veut y être *(Defense of Idea)*<br>**Etudiant 2 :** Oui *(Acceptance)*<br>**Etudiant 1 :** Elle veut pas se déplacer **(***Defense of Idea cont..)*<br>**Etudiant 4 :** Mais entre les deux tu peux mettre « se déplacer » *(Negotiation)*<br>**Etudiant 3 :** Ouais, j'avoue *(Acceptance)*<br>**Etudiant 2 :** Alors c'est … conduire pour se déplacer pour se rendre à temps au travail. Ça me va. *(Acceptance – conclusion of accord)* |

# ANNEX 4: MODE OF INTERACTION IDENTIFICATION EXAMPLES (FRENCH)




verbale
Evaluation de l'avancement du travail
Proposition de changer de tache / changer de méthode de travail / contraintes de temps
sans retour
Retour sans élaboration
Retour avec élaboration
Acceptance
Debat
Narration relié aux tâches
Debat
sans retour
tjs coordination car sur les taches
instrumenté
Division de l'espace collectif de travail (Screen splitting)
sans retour
Retour sans élaboration
Retour avec élaboration
Acceptance
Debat
Répartition des notes
sans retour
Retour sans élaboration
Retour avec élaboration
Acceptance
Debat

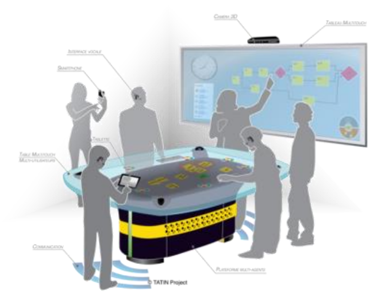
## ANNEX 5: HIGH SCHOOLER REPORTS AFTER FIRST SESSION (ORIGINAL FRENCH)

These are modified slightly to protect the identities of participants.

### *Report 1*

***<u>Compte rendu de la séance à l'UTC  où nous avons pu tester la Halle Numérique</u>***

Le but de cette séance était d'échanger nos idées sur un projet consistant à créer un musée éphémère sur le thème de la guerre par groupe de six. L'UTC nous a donc ouvert ses portes, et nous avons pu profiter des tables numériques de la *Halle Numérique*.



Cette salle est équipée d'une table permettant d'échanger nos idées et de les noter via un clavier numérique, et de les transférer au tableau via des puits qui interagissent entre la table et le tableau. Une fois au tableau les informations peuvent être classées à notre convenance…

Cela a donc permis à chacun d'entre nous de pouvoir écrire des post-its, de dessiner, de pouvoir faire des recherches web et donc de transférer ses idées pour que ces dernières soit classées.

Sur six personnes, deux d'entre nous étaient au tableau pour classer les informations et/ou les modifier et les quatre autres cherchaient des informations sur la table.

Pour les personnes qui ont un projet précis mais qui ne savent pas s'organiser ou quoi chercher, ce type de matériel est très bien, il permet d'échanger un maximum d'idées en un minimum de temps…

Comparé aux heures de TPE, en trois heures nous avions réalisé plus de choses que ce que nous avions fait en trois ou quatre séances de TPE, puisque là chacun d'entre nous avait une sorte d'ordinateur et à la fin tout  le monde s'y retrouvait, on voyait ce que chacun avait fait et l'évolution de notre travail. Ce type de matériel permet de favoriser notre autonomie et notre créativité.

L'utilisation de cette salle est très intuitive et est à portée de tout le monde, je dirais que le seul inconvénient que nous avons rencontré est celui du tactile, puisque le clavier manque de réactivité…

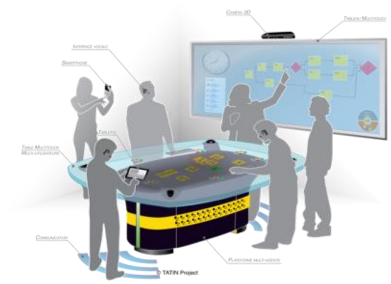

En conclusion, cette séance à l'UTC nous a été bénéfique, puisqu'elle    nous a permis d'organiser notre travail et de mieux comprendre la  consigne… Je trouve ce matériel utile pour les entreprises et  les projets  comme le nôtre, pour favoriser la communication, l'organisation et l'autonomie.

***Report 2***

**Compte-rendu, UTC Halle-numérique**

Lors de notre passage à la *Halle Numérique* l'UTC dans le cadre d'un projet de musée éphémère sur la Guerre au XIX-Xxè siècle nous avons pu tester la table numérique de la *Halle Numérique*.

Notre avis :



Nous nous sommes installés autour d'une table tactile, chacun pouvait créer des post-it, utiliser un navigateur web, faire un dessin, envoyer ses idées aux autres. Un chef de projet s'occupait d'organiser les idées (post-it, schémas) sur l'écran plat tactile sur le mur en faisant des connexions entre les différentes idées.

<u>Efficacité ?</u>

Pendant une heure nous n'avancions pas, mais nous avons finalement réussi à trouver un thème pour le projet, c'est à partir de là que nous avons commencé à organiser nos idées faire des connexions, faire une répartition des tâches. Nous nous occupions de rechercher des informations échangions nos points de vue, idées,

Nous sommes partis de zéro et nous avons réussi à trouver des pistes des idées en beaucoup moins de temps qu'il ne nous en aurait fallu autrement.

<u>Défauts ?</u>

Nous avons eu peu de problèmes, l'utilisation est plutôt intuitive, cependant la détection de contact par laser était par moment assez embêtante, un seul contact avec sa manche et l'on pouvait faire des erreurs. De plus taper sur le clavier tactile pouvait être parfois compliqué…


<u>BILAN</u>

Cette visite à la *Halle Numérique* a été plutôt bénéfique, elle nous a permis d'organiser nos idées plus facilement et de partager plus aisément nos idées avec les autres membres du groupe.

Nous trouvons donc le dispositif idéal pour du travail de groupe, et utile pour la communication et l'organisation dans un groupe.

***Report 3***

## Compte Rendu de l'après midi à la *Halle Numérique* de l'UTC

Notre classe de [redacted] a eu le privilège d'être la première classe de lycéens à pouvoir travailler au sein de la *Halle Numérique* de l'UTC(Université Technologique de Compiègne) ce lundi [redacted] de 14h à 17h.

Un privilège ? Pourquoi ? Eh bien parce que la *Halle Numérique* de l'UTC est un espace de travail particulier où l'on peut s'organiser, s'instruire, communiquer, collaborer et produire nos idées à l'aide d'une table et d'un tableau tactile sophistiqué produit par l'UTC. Nous étions divisés en 5 groupes de 6 personnes dans 5 salles différentes. Chacune d'entre elles étaient disposées de la même façon : une grande table tactile servant à un groupe pour faire ses recherches individuelles et un tableau tactile afin d'y regrouper les idées.

Ainsi le travail collaboratif peut être mis en valeur et est source de créativité pour les utilisateurs.

C'était une expérience agréable. Nous aurons encore le plaisir d'y retourner après les vacances.

***Report 4***

A l'occasion d'une sortie pédagogique à la *Halle Numérique* de l'UTC (Université Technologique de Compiègne), la classe de [redacted] du lycée a été conviée à tester les nouvelles tables tactiles permettant de mener à bien un projet. Ce projet étant de réaliser un musée éphémère portant sur la guerre du 19ème siècle à nos jours.

Ces tables facilitent le travail de groupe, chaque salle est munie d'une grande table tactile, où 6 personnes peuvent travailler ensemble, il y a aussi 4 écrans tous raccordés pour former un seul écran, toutes les informations trouvées sur la table sont ensuite envoyées en temps réel sur l'écran.

Nous avons plutôt apprécié ce concept car c'est une autre méthode de recherche et de travail sans papier et sans distance, c'est-à-dire que les recherches se font sur place et non chacun de son côté, cela facilite le travail de groupe pour les entreprises par exemple, mais l'UTC veut étendre ce projet pour le public scolaire, comme c'est notre cas.

***Report 5***

Lundi 13 Novembre nous avons eu la chance de nous rendre à la *Halle Numérique* de l'UTC dans le but de travailler en groupe sur un projet de musée éphémère. Pour ce faire, nous avons expérimenté exceptionnellement un concept de tables tactiles de travail collaboratif, ces tables sont conçues pour travailler en groupe autour d'un sujet commun. Elles sont conçues pour favoriser les échanges et la synthèse des idées grâce notamment à des fonctionnalités variées et ludiques. Cette après-midi nous a vraiment plu, chaque groupe a pu réunir ses idées et proposer un thème pour sa salle. On espère que ces tables vont se démocratiser car cela permettrait d'obtenir de meilleures performances de groupe.

***Report 6***

## Sortie UTC la *Halle Numérique*

Ce lundi [redacted] les élèves de la [redacted] ont vécu une expérience inédite à l'UTC au centre de transfert.

En effet, cette expérience leur a appris de nombreuses choses. Ces élèves sont allés travailler dans un monde différent de tout ce qu'ils ont pu connaître jusqu'à maintenant.
Ils se sont rendus à la *Halle Numérique* où ils ont découvert une toute nouvelle forme de technologie leur permettant de mieux collaborer entre eux et de créer une nouvelle forme de pédagogie.

Cette halle est composée de tables tactiles numériques de grande dimension et également d’un énorme écran tactile. Ce qui donne un travail beaucoup plus productif et ludique.


## Avis des élèves :

Cette sortie nous a permis de faciliter les interactions entre le groupe et d’avancer très vite dans notre projet. Cela a aussi permis de développer notre esprit d’équipe et de nous passionner dans notre travail.

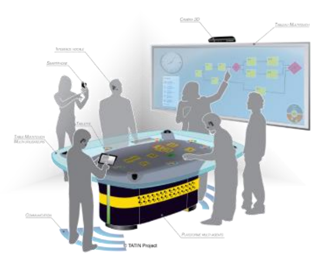
***Report 7***

### *La Halle Numérique,*
### *un espace collaboratif*

Le lundi 13 novembre, notre classe de [redacted] a eu l’opportunité de découvrir la *Halle Numérique* de l’UTC. Nous avons pu travailler sur notre projet de « musée éphémère».

## Qu’est ce que la *Halle Numérique* ?

C’est une table tactile où plusieurs personnes peuvent partager leurs idées simultanément, les écrire et ensuite les envoyer sur un tableau qui est lui aussi tactile. Ce système permet à tout le monde de participer au projet. Cette halle a pour objectif d’aider le travail collaboratif, c’est-à-dire améliorer la qualité du travail et ses conditions.

## Notre ressenti :

Nous avons aimé travailler à la *Halle Numérique*.

En effet, tout le monde a pu participer au projet, même les personnes qui n’osent pas s’exprimer. Ce dispositif favorise la communication. L’environnement a amélioré la qualité de notre travail, il est plus efficace, on a pu mettre nos idées en commun plus facilement grâce à l’écran tactile.

C’est beaucoup plus ludique, nous n’avions pas l’impression de travailler. C’était une très bonne découverte.

***Report 8***

<u>Sortie à l'UTC</u>

La *Halle Numérique* est un bon espace de travail, il y a une table tactile pouvant accueillir jusqu'à six personnes avec un tableau lui aussi tactile. Cela permet de travailler en groupe d'une manière nouvelle, plus simple. Étant fait pour travailler en groupe il est possible de mettre facilement des documents en commun, ce qui est un gain de temps non négligeable. Grâce à un petit rond de couleur assigné à chaque membres du groupe le travail peut donc être fait individuellement pour finir par être mis en commun avec le tableau recueillant les documents envoyés par les membres du groupe. Cependant la table est extrêmement sensible lorsque l'on laisse notre doigt à un centimètre de la table celle-ci ouvre automatiquement le menu. Ce n'est pas un problème en soi mais ce peut être déstabilisant la première fois que ça arrive. Pour " descendre " un fichier word par exemple il faut qu'il soit converti au format pdf sinon son utilisation est impossible. Par contre il n'a qu'un ou deux ports USB. Globalement la *Halle Numérique* est plutôt pratique et agréable.

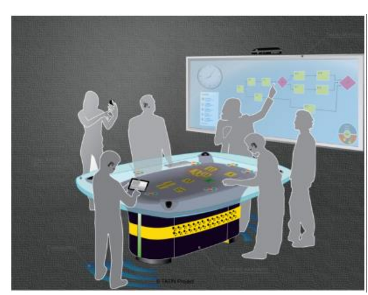
***Report 9***

Journée à la *Halle Numérique* de l'UTC :

Le lundi [redacted] nous sommes allés à la *Halle Numérique* de l'UTC pour nous aider à travailler en groupe sur notre projet de musée éphémère. Nous avons eu l'occasion de tester les tables tactiles et les écrans interactifs.
Ces tables très intuitives ont rendu le travail en groupe plus facile et nous ont permis d'être plus productifs.
L'espace de travail est aménagé pour développer la créativité et nous permettre d'être dans une bonne ambiance de travail (couleurs, décors, disposition de la salle…).

***Report 10***

**<u>Une sortie à l'UTC fructueuse.</u>**



Le projet de conception de cinq musées éphémères par groupe a offert aux élèves de la classe de [redacted] la possibilité de se rendre à la toute nouvelle *Halle Numérique* de l'UTC. Ce projet a été possible avec l'aide de madame [redacted] (professeure de français), madame [redacted] (professeure d'histoire) et madame [redacted] (professeure de sciences de l'ingénieur).

Le cadre de travail était propice au travail partagé, il a également permis une ouverture du dialogue avec les professeurs, les étudiants présents auprès de nous et au sein du groupe. Le travail fourni nous a semblé facilement organisé et efficace grâce aux outils numériques mis à notre disposition tels que la table numérique ou encore un tableau d'organisation tactile. Nous sortons conquises de notre première après-midi à l'UTC.

Nous sommes désireuses d'y retourner et nous remercions grandement nos professeures.

## ANNEX 6: QUESTIONNAIRE (ORIGINAL FRENCH)

### Que ferez-vous dans la situation suivante ?

Mise en situation pour les questions suivantes :
Vous travaillez en groupe au collège… Comment agissez-vous dans les situations suivantes ? Choisissez une seule réponse par question.

1. Vous vous rendez compte que vous avez des informations que les autres n'ont pas, mais vous n'êtes pas certain/certaine que ces informations soient utiles.
   a) Vous décidez de ne pas partager ces informations parce que vous doutez qu'elles soient utiles
   b) Vous partagez l'information malgré tout
   c) Vous attendez, pour voir si les informations pourraient être utiles plus tard
2. L'un de vos camarades est très doué dans le sujet que vous travaillez, alors …
   a) Vous lui demandez de faire tout le travail
   b) Vous lui demandez comment faire
   c) Vous décidez de ne pas en tenir compte : c'est un membre du groupe comme les autres
3. Vous n'êtes pas certain/certaine de savoir comment faire. Alors, …
   a) Vous débrouillez
   b) Vous demandez l'avis des autres élèves du groupe
   c) Vous demandez l'avis de l'enseignant
4. Un de vos camarades ne fait pas son travail. Alors, …
   a) Vous ignorez l'élève : s'il ne fait pas son travail, ce n'est pas votre problème
   b) Vous ignorez l'élève, mais vous faites le travail à sa place
   c) Vous parlez avec les autres élèves de votre groupe et vous décidez de vous partager son travail pour le faire à sa place
   d) Vous parlez avec l'élève et vous lui demandez de faire son travail comme tout le monde
5. Vous pensez que le groupe se trompe. Alors, ...
   a) Vous ne dites rien et vous suivez les autres : ils ont finalement peut-être raison ?
   b) Vous posez des questions aux autres élèves de votre groupe pour mieux comprendre leurs idées
   c) Vous demandez au professeur de vous expliquer l'activité
6. Vous vous rendez compte qu'il y a beaucoup de choses à faire pour réussir l'activité. Alors, …
   a) Vous proposez aux autres une organisation/un plan pour faire le travail
   b) Vous commencez la première activité immédiatement
   c) Vous annoncez que vous allez faire la partie qui vous intéresse le plus
7. Un de vos camarades est triste car son idée a été rejetée par le groupe Alors, …
   a) Vous lui dites que c'était une mauvaise idée
   b) Vous lui dites qu'il avait une idée intéressante et qu'il devrait continuer à en proposer d'autres
   c) Vous ne dites rien

8. Votre groupe s'est mis d'accord : vous vous êtes réparti le travail et vous avez tous décidé de le faire à la maison… mais une fois chez vous, vous vous apercevez qu'il y a un problème. Alors, …
   a) Vous décidez d'arrêter le travail : vous verrez plus tard avec vos camarades
   b) Vous essayez quand même de faire le travail comme demandé
   c) Vous modifiez le travail selon vos idées : vous expliquerez les changements aux autres quand vous les verrez
9. La plupart des membres de votre groupe souhaite travailler sur une idée que vous n'aimez pas. Alors, …
   a) Vous décidez de ne pas les aider
   b) Vous décidez de les aider quand même
   c) Vous décidez de faire l'activité selon votre idée

**Informations complémentaires**

10. Combien de fois travaillez-vous en groupe au collège ? (Choisissez une seule réponse.)
    a) Jamais
    b) 1 ou 2 fois par semaine
    c) 3 ou 4 fois par semaine
    d) Presque tous les jours
11. Quand vous travaillez en groupe, combien êtes-vous en général ? (Choisissez une seule réponse.)
    a) 2 élèves
    b) 3 à 4 élèves
    c) 5 à 6 élèves
    d) Plus de 6 élèves
12. Quand je suis au collège, je préfère travailler :
    a) Tout(e) seul(e)
    b) Avec d'autres élèves

    Expliquez votre réponse :

    ___________________________________________
13. Quand le professeur vous demande de travailler en groupe :
    a) Vous divisez le travail entre vous
    b) Vous participez ensemble à toutes les tâches

    Pourquoi ? :

    ___________________________________________
14. Quand votre professeur vous laisse former votre groupe, vous cherchez quelqu'un qui…. (Donner au moins 3 éléments)

    ___________________________________________

## ANNEX 7: DETAILED ANALYSIS OF COLLABORATIVE PROCESSES

### *Collaborative Processes*

Analysis on data was carried out in two ways: the first focused on collaborative processes and tool usage, while the second on collaborative competencies. First, the videos of group work were coded based on CIAO. The videos were coded in 30 second segments and annotated based on the modes of interaction which appeared within that time frame, for example one 30 second period could have individual work, communication and cooperation. Videos were coded blindly by two separate coders based on CIAO. Difference in coding was acceptable. Cohen's kappa was calculated, after controlling for coding errors, based on each mode of interaction as follows:

- Collaboration: 0.97 – near perfect alignment
- Cooperation: 0.97 – near perfect alignment
- Coordination: 0.64 – substantial agreement
- Communication: 0.62 – substantial agreement
- Individual Work: 0.45 – fair agreement

Upon further examination and a discussion between coders after the coding was completed blindly, it was determined that the most error was relative to the method itself (using chunks of 30 seconds) rather than the model. One coder would code an event in one thirty second block, and the other in the next if the event crossed over into the following 30 second coding block. Once adjusted, the alignment between the coders for Collaboration, Cooperation, Coordination and Communication were considered acceptable. We were surprised that the coding for individual work revealed the most difficulty, while the coders agreed verbally in a co-coding session, which was arranged to help pinpoint the source of the difference, the amount of activity in a given section of video often meant that the individual work went unnoticed or was easily missed. Rather than true disagreement, the low Cohen's kappa rating points to the challenge of observing several individuals and catching each action that one could consider to be individual work, despite rewatching the video segments.

### Table-Board Modality

In this section, we'll briefly discuss the Table-Board Modality as a physical digital workspace then we'll present the results of the CIAO analysis for each group using the

Table-Board Modality. Finally, we'll discuss the overall implications of the table-board-modality on the group's ways of working and analyze the results from an activity mediation perspective based on Rabardel's Collective Instrumented Activity Model described in Section0

The table and board modality consists of two separate work surfaces. The table, being a large, horizontal surface, affords an individual-public space to each user. The board, on the other hand, was designed to give the group a collective-public space in which they could finalize their ideas and see the "big picture". This modality does not provide a private space for students, requiring users to perform the external parts of their individual work in an area visible to all participants.

***PSP1F18T4M1***

The first group results were collected in the Fall 2018 session. Session A was recorded without the use of the *Halle Numérique* platform. We refer to these sessions as non-instrumented, i.e. without the support of computer tools. This initial session was used to establish a baseline for collaborative processes within the group. Table 38 shows the results from each session for PSP1F18T4M1.

The results are presented as a percentage of time spent by the group in each mode of interaction. The percentages pass 100% because the group members can be, and often are, in different modes of interaction at any given time. For example, while one student is reading or writing a new post-it note, two others can be discussing the organization of work or negotiating meaning of a separate idea.

In the baseline analysis (session A), PSP1F18T4M1 was evaluated as being significantly more cooperative with very low levels of collaboration. While the group continued this trend of being more cooperative, there was an increase in time spent collaborating during instrumented sessions, a 12.63% increase on average.

| | Session A | Session B | Session C | Session D | Average[‡‡] |
|---|---|---|---|---|---|
| **Off topic** | 3.77% | 5.03% | 35.93% | 4.64% | 15.20% |
| **Technical** | 0% | 3.77% | 1.20% | 4.12% | 3.03% |
| **Neutral/setup** | 0% | 7.55% | 7.19% | 6.19% | 6.98% |
| **Teacher Intervention** | 8.49% | 18.87% | 14.37% | 9.79% | 14.34% |
| **Individual Work** | 78.30% | 62.89% | 47.31% | 48.97% | 53.06% |
| **Communication** | 65.09% | 42.24% | 36.53% | 25.77% | 29.57% |
| **Coordination** | 21.70% | 7.55% | 32.34% | 24.75% | 21.55% |
| **Cooperation** | 33.02% | 40.88% | 25.15% | 30.14% | 32.06% |
| **Collaboration** | 3.77% | 16.98% | 16.77% | 15.46% | 16.40% |

**Table 38: PSP1F18T4M1 CIAO Analysis Results - % of time per mode of interaction**

---

[‡‡] The average here is calculated based on Sessions B, C and D only. It is an average of the instrumented sessions.

Figure 73 shows 30 minutes of PSP1F18T4M1 Session A. Each mode of interaction is represented on a separate line, with collaboration on the top-most line, followed by cooperation, and so on. Each dot represents a single 30-second time frame in which the mode of interaction appeared.

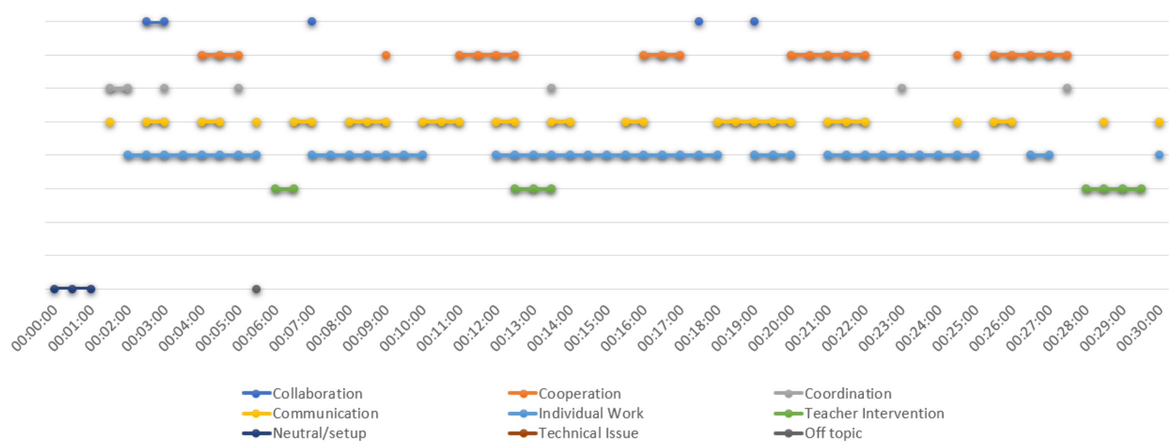



**Figure 73 : PSP1F18T4M1 – Session A - Non-instrumented the session CIAO timeline**

This graph representation allows us to see the modes of interaction fragmenting and overlapping as the group members move between them over the course of their session. For this group, 78.3% of their time is spent performing individual work, with note-taking activities accounting for much of this time. In order to not lose the information and ideas that they had generated, students spent time copying their group work into their personal notes. Communication is entirely oral, with three members dominating the conversation. Cooperation makes up 33% of this session, an indication that more time was needed to establish shared meaning for new ideas. Collaboration was very low, so little co-building occurred.

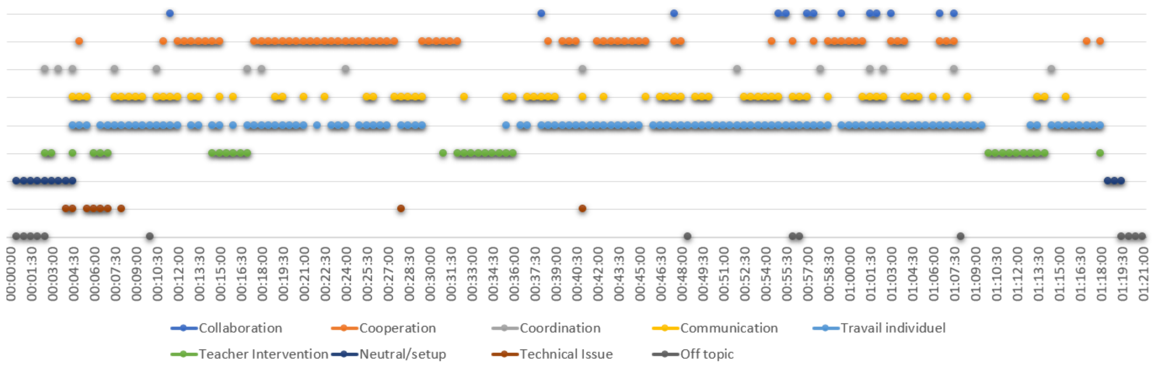



**Figure 74: PSP1F18T4M1 – Session B - Table/Board Modality CIAO timeline**

In Session B students used the table and board modality. The results, in terms of time spent, were very similar to session A. In this case, however, individual work time was dedicated to writing digital post-it notes, reading those written by others and reading the supporting text. The ability to capture the work completed digitally led fewer students to spend time copying the work into their notebooks. Instead, they opted to capture an image of the final work and e-mail it to themselves. We see little change in the amount of time spent in communication in this session, but the communication is happening differently. Rather than thoughts being externalized only orally, individuals are using the table space to create written traces of their ideas, which are then being shared with the larger group. As a result, students who may not typically participate are asked to explain what they meant. This puts them in a position to need to explain and possibly defend their ideas, which they may have otherwise not taken the chance to articulate. We also see an increase in collaboration, from 3.77% to 16.98% as the group moves to using the physical-digital workspace.

The above figure depicts the full session from group PSP1F18T4M1, lasting one hour and 21 minutes. In this graph, we see most of the time dominated by individual work, cooperation and communication. Collaboration is infrequent and grouped mostly towards the beginning and the end of the session.

The off-session time spent increased significantly in session C. We also see a spike in coordination numbers and the emergence of interpersonal conflict. While coordination is important for the group's functioning, a high level of coordination seems to point to a disfunction in the group, as they fail to agree on how to go about their work.

In the following exchange, we see what happens between [43:15 – 45:09], recorded as cooperation, then as off-topic discussion as it changes from a discussion about the organization of post-its at the board becomes an interpersonal conflict. For context, an “introverted” member of the group is explaining what she wrote on a post-it note so that the group can decide how and if to integrate it. As the group begins to come to an agreement, Student B does not express agreement and her actions do not communicate it. She begins to move items around the board, but not in a way that reflects that she understands or agrees with the proposition (i.e. she does not reposition the post-it in question to the location expressed by Student A or modify its content). Student C attempts to rearrange the digital objects to be in line with what the rest of the group is has decided in order to communicate the intention to Student B.

| | |
|---|---|
| **Student A** | Just under that one. |
| **Student B** | Why? It’s the same as that one, right? |
| **Student C** | [Moves a post-it on the board] |
| **Student D** | There, that’s it. What I meant in this one is that she does her thing |
| **Student A** | She didn’t give herself extra time to do it |
| **Student D** | There, that’s it |
| **Student C** | It’s to show how quickly |
| **Student D** | Yeah |
| **Student B** | [Moves several post-its and changes some esthetic elements] |
| **Student C** | [Moves a post-it] |
| **Student B** | Nooo! You’re fucking it all up! |
| **Student C** | No, I just want to put it there. |
| **Student B** | [Turns her back and walks towards the table] |
| **Student C** | {Student B’s name in a familiar/diminutive form}! [Continues to move post-its] |
| **Student E** | [Laughs] |
| **Student C** | Wait, I’m going to make it so nice and you’re not going to understand … |
| **Student B** | [Returns to the board] But you... you... you’re going to put lines? |
| **Student C** | No, I won’t put the lines [Continues to move post-its] Look |
| **Student B** | Oh, it’s so ugly [covers her mouth with her hand] Ahh! I’m going to sit down. [Returns to the table and sits] Damn it. Ah no, there, you’re losing me. |
| [All students (except B) laugh] | |
| **Student C** | Stop it, {Student B’s name in a familiar/diminutive form}. |
| **Student B** | But it’s ugly! |
| **Student C** | Stop it, {Student B’s name in a familiar/diminutive form}. |
| **Student B** | But it’s ugly! I’m not stopping, I have the right to give my opinion! |
| **Student C** | But draw it! [Points at the whiteboard on the wall] Draw it there. |
| **Student B** | We can’t do a Command-Z?[8] |
| **Student C** | Command-Z? No |
| **Student B** | I’ve got a Command-Z… {Student C’s name} where are you? Is that you, {Student C’s name}? |
| **Student C** | Yes |
| **Student B** | [Erases something on a sheet of paper] I cannot stand it when people write on my paper. |

[8] Command-Z (*Pomme-Zed* in French) refers to undoing an action on a Mac.

**Student C** Ok [Turns back to the board]
**Student B** [Looking back at the board] It's ugly. It works, but it's ugly.

For the rest of the session, Student B remains seated at the table, writing in her notebook. She participates very little for the remaining 20 minutes of the session, while the other students continue working. Student C does attempt to involve Student B further. On these occasions, Student B does give her opinion, but returns to her notebook. She contributes one further written post-it note over the remaining time.

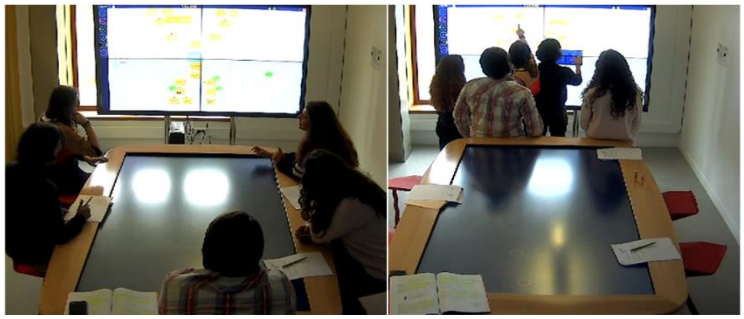


**Figure 75: PSP1F18T4M1 - Movement around the space**

Session D seems to be a fresh start for the group, as they return to working together with little conflict. However, we do start to see a change in the usage of the table and board modality, in terms of movement around the space. In the non-instrumented session, students stayed at the table with a single person writing. In sessions B and C, movement flowed between the table and the board, with the whole group being at one or the other for a majority of the session (Figure 75). This changes in session D and returns to a scenario like the non-instrumented session, where students remained at the table most of the time. However, instead of a single person being at the whiteboard, students would produce post-it notes at the table, then go up and make changes one or two at a time (Figure 76). While the quality of the arguments was acceptable, the group did not always succeed in making decisions, instead opting to do the same work twice in two different ways on a few questions and not finishing as much of the assignment as other groups.

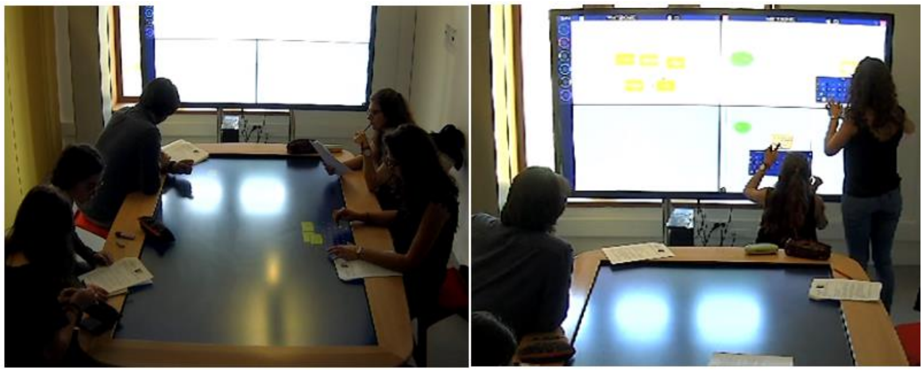


**Figure 76: PSP1F18T4M1 - Movement during Session D (Stationary)**

***PSP1S19T4S1M1***

PSP1S19T4S1M1 baseline session (A), like PSP1F18T4M1, was ranked as slightly more cooperative, with only a difference of 7.03% of time spent in each mode of interaction, versus a difference of 29.25% in the Fall 2018 group. This trend continued across all work sessions, with an average difference of 10.26% between cooperative and collaborative modes of interaction.

During session A, this group spent only 27.34% of their time on individual work, which consisted of note-taking activities throughout the session. While it is likely that other individual work was occurring, it was not externalized in a way that we could easily identify as individual work (writing, reading). As with PSP1F18T4M1, this group's conversation was dominated by a small part of the group and communication was entirely oral except for on the part of the animator who used the whiteboard to record decisions and check with the group on the accuracy of what was written. Often, the questions posed by the animator were the drivers behind the cooperative activity. Collaboration, while not particularly high, did occur once the group reached shared understandings. This collaboration looks much the same as cooperation in terms of tool usage, where the animator recorded the decisions being made, but the writing was often done collaboratively, as multiple people would dictate what to write, each adding complementary elements.

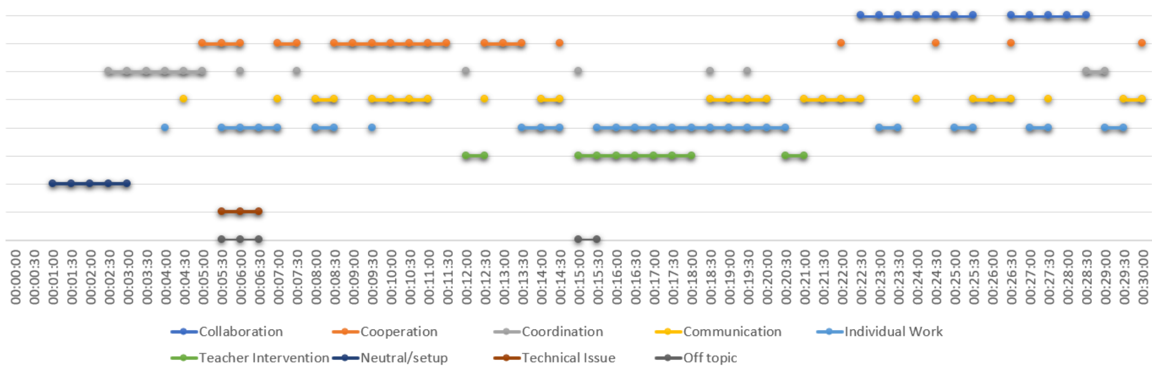



**Figure 77: PSP1S19T4S2M1 – Session A - Non-instrumented session CIAO timeline**

| | Session A | Session B | Session C | Session D | Average |
|---|---|---|---|---|---|
| **Off topic** | 2.34% | 14.38% | 18.98% | 15.23% | 16.20% |
| **Technical** | 0.78% | 5.23% | 3.65% | 4.64% | 4.51% |
| **Neutral/setup** | 5.47% | 4.58% | 12.41% | 12.58% | 9.86% |
| **Teacher Intervention** | 27.34% | 12.42% | 15.33% | 13.25% | 13.67% |
| **Individual Work** | 36.72% | 48.37% | 61.31% | 58.28% | 55.99% |
| **Communication** | 54.69% | 41.18% | 37.96% | 41.06% | 40.07% |
| **Coordination** | 7.81% | 5.23% | 9.49% | 13.91% | 9.54% |
| **Cooperation** | 26.56% | 28.76% | 41.61% | 32.06% | 34.14% |
| **Collaboration** | 19.53% | 20.26% | 22.63% | 11.26% | 18.05% |

**Table 39: PSP1S19T4S1M1 CIAO Analysis Results - % of time per mode of interaction**

In Session A, PSP1S19T4S1M1 displays a clear pattern of transition between cooperation and collaboration, in which cooperation precedes collaboration, but cooperation does not always lead to collaboration. Surprisingly, this pattern is not evident in the other groups as one might expect based on the nature of these modes of interaction. As individuals produce and introduce new ideas, conflict occurs. When the conflict is resolved, the opportunity to co-build based on the shared understanding becomes available. However, in the absence of conflict, the groups may pass directly into collaboration and only later identify a divergence.

Upon arriving in the room, PSP1S19T4S1M1 immediately decided to work without the use of individual space:

***Student A:*** *Anyway, I think we're going to work more on the board than* *each with our paper, I think.*

***Student B:*** *Yes*

***Student C:*** *Yes*

***Student A:*** *It'll be more interesting, so that way everyone can share their ideas.*

This may explain why this group's collaborative (19.53%) and cooperative (26.56%) activity levels were closer in terms of the percentage of time spent in those modes of interaction than those in the other two groups. However, this way of working led to production blocking and limited airtime issues common in collaborative work (Hymes & Olson, 1992). For example, Student E (female) contributed very little during the session. This student's native language is Spanish, where she was in a group composed entirely of male students of French origin, speaking French. Though she did make several attempts to

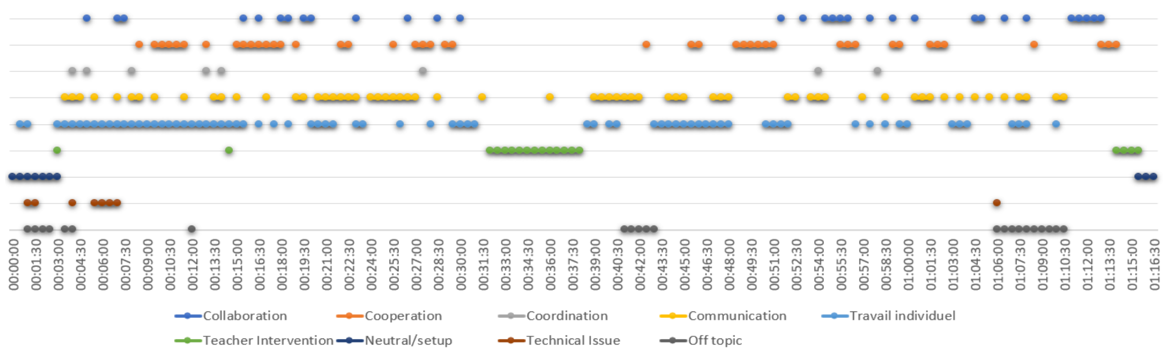



**Figure 78: PSP1F19T4S1M1 – Session B - Table/Board Modality CIAO timeline**

contribute orally, she was often spoken over during this first session. Individual work, as in PSP1F18T4M1, was limited to some notetaking by one or two people and time that the animator spent writing on the whiteboard.

PSP1F19T4S1M1's session B lasted one hour 16 minutes and 30 seconds. During their session, we see a much different pattern. In session B, while individual work and communication still hold the highest percentage of time spent, we see a more even mix of time spent in cooperation and collaboration, with the group transitioning between them quickly throughout.

The following is an excerpt from PSP1F19T4S1M1's session B between 4:30 and 11:30. During this time, we see examples of all 5 modes of interaction and some examples of how the group uses the table and the board. While the group does not explicitly decide to work individually, group members use the table as a means to write their own ideas.

However, the ideas are not discussed while they are on the table. They are sent to the board for discussion. As such, the table serves to generate intermediate objects and the board allows the group to inspect and modify those intermediate objects and use them to form a coherent whole. The ease of moving objects on the board allows students to use it as a way to externalize their own thinking about the problem, also giving the opportunity to other group members to identify divergence between their own understanding of the problem and that of other group members. This particular usage scenario is not possible, or at least does not occur frequently, with the whiteboard since it can be time consuming to write several iterations of the same thing in a different order. The nature of the digital tool comes into play here, allowing students to easily make and undo changes.

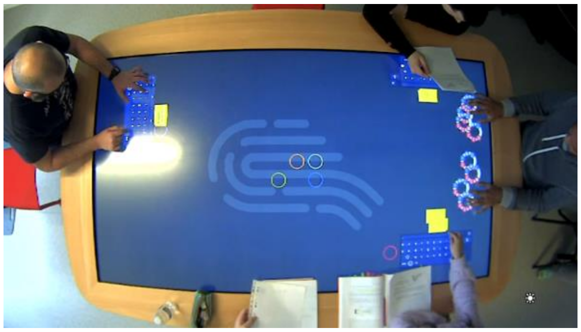


**Figure 79: PSP1F19T4S1M1 - Beginning of Session B**

*The students sit at the table and begin opening digital keyboards. One student writes, one student plays with the menus. Student A sends a post-it that he has written to the board and places it in the middle of the screen (Figure 79).*

***Student D:*** *The object allows the user to [mumbles as he reads what student A put on the board]*

***Student D:*** *So, it's uh…*

***Student A:*** *Already, in the "because", we can start putting the weather conditions, I think.*

***Student B:*** *Because she wants to use her car.*

***Student D:*** *Yeah, it's more that... because*

***Student A:*** *Ah yes, I was going directly for… um... Yeah, you're right.*

***Student D:*** *Yeah, but they can be two different branches.*

***Student A:*** *Yes*

***Student E:*** *Because she wants to go to work*

***Student C:*** *Because she wants to go somewhere*

In the transcription above, we see how an attempt to coordinate work becomes cooperation: Student A has suggested a starting point for the group, with the idea that the "because" is necessarily related to the weather. To challenge this, Student B gives a counter example of why the person in question might want to remove ice from her car. This allows the group to widen their area of reflection. At this point, students begin to work individually to write their ideas in their individual space on the table, covering both of the suggested categories.

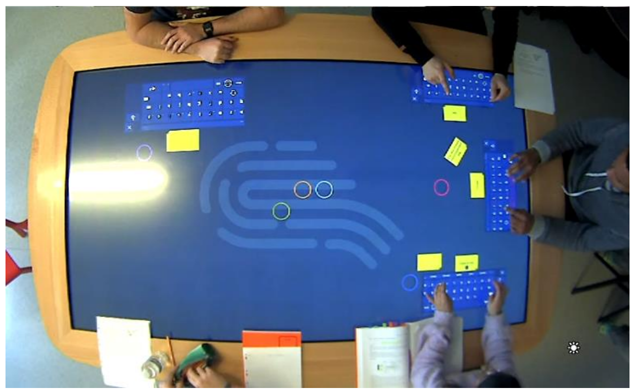


**Figure 80: PSP1F19T4S1M1 - Students begin individual work phase**

This phase of individual work is broken on several occasions with questions about what others are writing and clarification on the form in which they should be written, which we classify as coordination. This coordination leads to collaboration in the following lines, as Student D asks what others are writing:

***Student D:*** *What are you putting? Visibility? Are you doing visibility? [to student E]*

***Student E:*** *Yes*

***Student D:*** *What about you, what are you writing? [to Student C]*

***Student B:*** *[laughs] drive her car*

***Student D:*** *Safely? She wants to use her car safely*

***Student B*** *Legally*

***Student D:*** *And safely… ah yes, you didn't see the briefing [to Student C]*

It is here that we see the advantage of having an individual-public space. Student D read what student B had written. He then decides to contribute another element to it, growing the idea from driving legally to driving legally and safely.

As the group realizes that one of the students was not present in the briefing, they quickly explain what they are doing.

***Student C:*** *No*

***Student A:*** *Did you see the workbook?*

***Student C:*** *Yes, Yes*

***Student A:*** *We just have that phrase there to start from [points to the board where there is only one post-it.]*

***Student C:*** *Ok*

*[Students continue to write individually]*

After writing post-its for less than a minute, Student E asks for clarification about how the work should be achieved, specifically the form that the ideas should take, an example of coordination.

***Student E*** *So, do we start with "the object allows…?"*

***Student B:*** *No, it's fine because « the object allows the user to remove the ice" [ reading from the board]*

***Student E:*** *What do we start with, then?*

***Student D:*** *That, in the middle*

***Student A:*** *No, she wants to know how to start her sentence, I think.*

***Student E:*** *Yes*

***Student A:*** *Well, um...*

***Student D:*** *We don't need a sentence starter*

***Student A:*** *Yes, you don't need to put all that at the beginning "The object allows the user to remove the ice from her car" because… the car had ice on it, for example. Just above that, then we use lines and the "because" is implied.*

*[Students continue to write individually. Student D goes to the board and moves the post-it from the very middle of the board to make it easier to read. Post-its start arriving in the wormholes* (Communication). *Student D begins putting them on the board.* (Individual Work)*]*

It is here that we see another example of cooperation emerge as the result of individual work, as the group uses the collective-public space to interrogate each other's ideas. Rather than explaining their vision verbally, they use the collective-public space and written post-it notes to organize individually (starting with Student D positioning the post-it notes his colleagues are sending by himself). However, he does not understand one of the post-it notes and asks for clarification. Student B verbally explains the idea he had started to detail on the post-it note in question, but student A notices that the message did not pass properly because Student D did not move the post-its in the "correct" way on the board.

> ***Student B:*** *Why does she want to go somewhere?*
>
> ***Student D:*** *[Points at a post-it on the board and talks to student B] Did you write that?*
>
> ***Student B:*** *[Laughs] I don't know how to go up from there, actually. She wants to go somewhere… why?*
>
> *[Student D moves the several post-its around the board]*
>
> ***Student B:*** *Yes… she wants… she wants… She wants to use her car safely…legally and safely. Then why? Because she wants to go somewhere. Why does she want to use her car?*
>
> *[Student D moves several post-its]*
>
> ***Student A:*** *No. Above "She wants to go somewhere" I think.*
>
> ***Student B:*** *Yes, I meant above.*
>
> ***Student D:*** *Oh yeah?*
>
> ***Student A:*** *Because the object doesn't allow her to go somewhere. The object allows her to remove the ice.*
>
> *[Student D nods his head and moves the post-it]*

At this point, Students A and B decide to use the board to demonstrate their idea to Student A, leading, eventually, to an agreement.

> ***Student A:*** *So, me, the two that I put there, they're really at the top.*
>
> *[Student A and B get up and move to the board. They change the positioning of several post-its.]*
>
> ***Student D:*** *No… seriously? [Laughs and covers his face with his hand]*
>
> ***Student B:*** *She wants to go somewhere. But why?*

***Student D:*** *But the professor is going to laugh at that…*

***Student B:*** *Well, we could put [Changes the positioning of several post-its on the board]*

***Student A:*** *[Moves two post-its] Like that, because the ice is a combination of the cold and the humidity.*

***Student B:*** *Yes*

***Student D:*** *Yes*

This method of using the table as a space for generation and the board as a space for sharing and repairing divergence is common to all groups using the table and board modality.

Along with these positive quality changes in student experience, we also see signs of distraction as the off-topic numbers begin to rise with students spending slightly more time on their own devices, engaged in social conversations or playing with the table/board functionalities (Figure 81).

**Figure 81: Engineering student playing with functionalities on the table surface**

In session C, again, we see a higher average of cooperation over collaboration and patterns demonstrating the transition from cooperation to collaboration. We also see again the presence of significant communication activities with high individual work, demonstrating the link between the work completed and the sharing of the work into the group. The first seven minutes is spent reading the case and asking questions to help interpret its meaning. This is where we see the initial communication (questions) and cooperation (negotiating meaning). We also see a new animator, who is struggling to open the correct template take up some time in the first ten minutes. This struggle, however, does lead to some coordination and epistemic conflict as the group pays closer attention to which tool they should use.

Overall, this group prefers to remain positioned around the table, with a single animator (referring to a person at the board). At the table, the group has discussions out loud and each individual writes his/her ideas as the group progresses. Additionally, someone may write a post-it note with an idea developed collectively, but this tends to occur towards the end of the session as the group has established and maintained a shared understanding. As such, communication is occurring both orally and through writing. However, the animator is not necessarily always engaged with the group. On many occasions their back is turned, and they need to ask people to repeat themselves, leading to some socially awkward interactions as described by Rogers & Lindley (2004). However, this awkwardness does not prevent the group from advancing or completing their work. This kind of occurrence is infrequent enough to not be particularly detrimental.

Coordination occurred out loud and related to which tool to use, how to structure written notes, and requests to move objects on the board to specific locations (rather than going to the board to do it themselves). Cooperation, in which the group engaged most frequently was most commonly the result of trying to understand what someone wrote on a post-it note, leading to attempts to integrate it with others' ideas or into the group's already collective work on the board. As the group reached agreements, items could be modified on the board or new post-its generated on the table. Sometimes these modifications were made individually, with one user writing his/her interpretation of the final idea or collaboratively, as different people dictated what to write. Collaboration could also occur right away. The assumption was sometimes made that the group members shared the same vision, so they began co-building, writing post-its collectively (either on the table or board). However, the group would sometimes encounter a divergence, leading to a return to cooperation.

***PSP1S19T4S2M1***

Modes of interaction in group PSP1S19T4S2M1 were considered more cooperative overall in both baseline and group sessions.

| | Session A | Session B | Session C[9] | Session D | Average |
|---|---|---|---|---|---|

[9] Due to technical issues, the recording data for this session was lost. As such, we are unable to report any

| | | | | | |
|---|---|---|---|---|---|
| **Off topic** | 6.92% | 18.42% | | 9.50% | 13.96% |
| **Technical** | 2.31% | 8.55% | | 0.82% | 4.69% |
| **Neutral/setup** | 9.32% | 5.26% | | 4.13% | 4.70% |
| **Teacher Intervention** | 21.54% | 19.74% | | 10.74% | 15.24% |
| **Individual Work** | 42.31% | 60.53% | | 31.82% | 46.18% |
| **Communication** | 41.54% | 39.47% | | 25.21% | 32.34% |
| **Coordination** | 13.85% | 10.53% | | 6.20% | 8.37% |
| **Cooperation** | 40% | 42.11% | | 28.31% | 35.21% |
| **Collaboration** | 22.31% | 16.45% | | 19.83% | 18.14% |

**Table 40: PSP1S19T4S2M1 CIAO Analysis Results - % of time per mode of interaction**

In PSP1S19T4S2M1 (Figure 82) we see distinct segments of cooperation and collaboration. In this case, we are seeing the initial introduction of ideas (communication) and attempts to resolve disagreements (cooperation) that one might expect at the beginning of a task. However, the group is struggling to come to an agreement on the primary focus of their analysis: the flour or the packaging:

***Student A:*** *Me, what I understand by usage is the usage of the contents… the flour, right?*

***Student C:*** *Yes, but here we're focusing on the container.*

***Student A:*** *Yes, no but the storage, it's for storing. I mean, the objective is to store it. You take it and you empty it like [Student B] says, in your jar.*

***Student D:*** *So, you have to enhance the container in order to facilitate the usage of the contents.*

***Student E:*** *At any rate, we're not on the contents, we have to focus on the container.*

***Student A:*** *Yes, but…*

***Student D:*** *Yes but, that's the idea*

***Student A:*** *To?*

***Student D:*** *To enhance the container to facilitate, overall, its usage.*

---

data for PSP1S19T4S2M1from Session C. All other sessions are intact.

**Student E:** *It's true that [turns towards the teacher] that we enhance the container to facilitate the usage of the content [turns back towards student D because the teacher did not look at him] it's not about the visual. Life situation… I don't know, if you want to make a package that's nice to look at, it doesn't go with what we're talking about now*

**Student A:** *No, but… no*

At a certain point, the group asks the teacher to mediate their disagreement. The teacher, who had been listening, gives his opinion and instructs students not to limit themselves. This intervention resolved the disagreement, allowing the group to enter a new phase, which they began by communicating new ideas followed by co-building their "poulpe" model, punctuated occasionally by a challenge or request for explanation.

During this time, PSP1S19T4S2M1 had been writing their ideas on post-it notes, which they left on one end of the table (Figure 83). The teacher notes this when he first

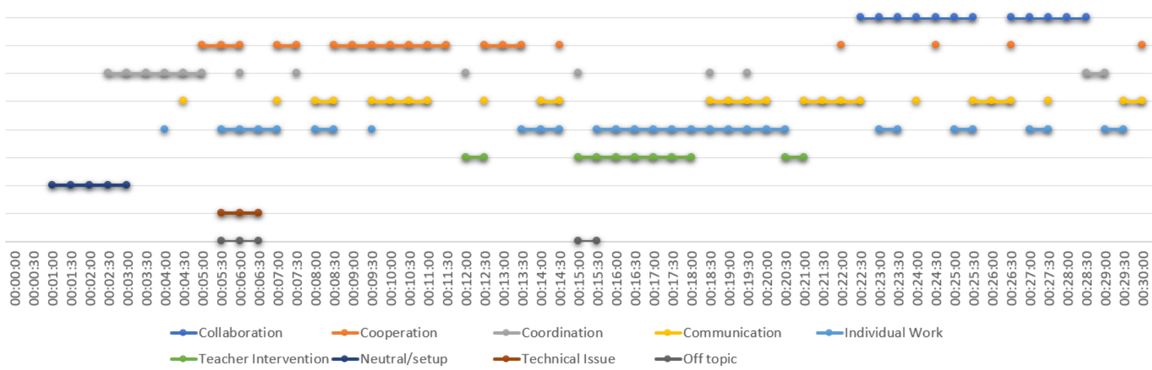



**Figure 82: PSP1S19T4S2M1 – Session A - Non-instrumented session CIAO timeline**

arrives, leading to a point of coordination in the group at the 12:00 mark in Figure 82.

**Figure 83: PSP1S19T4S2M1 grouping post-it notes on one side of the table**

| | |
|---|---|
| ***Teacher TG:*** | *You're putting the post-its on the table?* |
| ***Student B:*** | *No?* |
| ***Teacher TG:*** | *Yes, why not?* |
| ***Student B:*** | *Why not? Because we shouldn't?* |
| ***Student E:*** | *Maybe it would be better to put them on the board and then use the markers.* |
| ***Teacher TG:*** | *Here, you're putting the different environmental elements of your « poulpe », right?* |
| ***Student B:*** | *Yes… in storage* |
| ***Teacher TG:*** | *So long as you don't write on the table.* |
| ***Student B:*** | *No!* |
| ***Teacher TG:*** | *[Laughs]* |
| ***Student A:*** | *No, for sure we can't make the lines on the table. We'll need to do it there [points at the board].* |

This seemingly innocuous investigation of how the group is working with the post-it notes on the table leads the members to reconsider how they are working. Notably, by student B says "Because we shouldn't" [work this way] when asked about it. This is telling of the student's action schemas, in which people working together should have a common view of their work on a vertical collective-public surface. As it stands, they have limited the possibility of interaction with the items in the collective space to 3 of the 5 students present because the area where the ideas are being organized are not in arm's length or easily legible from their positions.

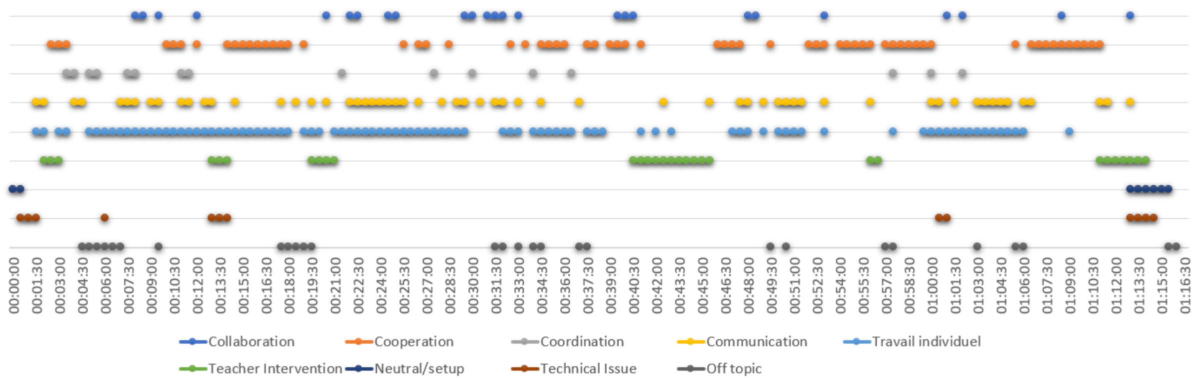


**Figure 84: PSP1F19T4S2M1 – Session B - Table/Board Modality CIAO timeline**

***Table-Board Analysis***

Across all activities, the table and board modality demonstrated higher levels of cooperative activity and is identified as cooperation heavy (Figure 48: Table and Board: CIAO Averages (Instrumented Sessions)). Towards the beginning of the first instrumented sessions, students agreed to complete a brainstorming session in which they each write down their ideas at the table (individual collective space) and then pool them together. In action, this translated to sending the finished post-it notes directly to the board. Rarely, students would keep a post-it note on the table, tucked into a corner. Occasionally, another student may ask what is on a post-it note when still in the individual-collective space. As such, this space served as a means of production and a means to gauge the participation of others, and sometimes as a space for communication, with this function being left largely to the board. The table served an epistemic function (Rabardel, 1995), allowing each student the opportunity to reflect on the object of their activity, search for information and externalize their thoughts. These externalizations in a public space also served as a means of written communication with other students, once the subject sent the note to the board or as other subjects observed the writing process.

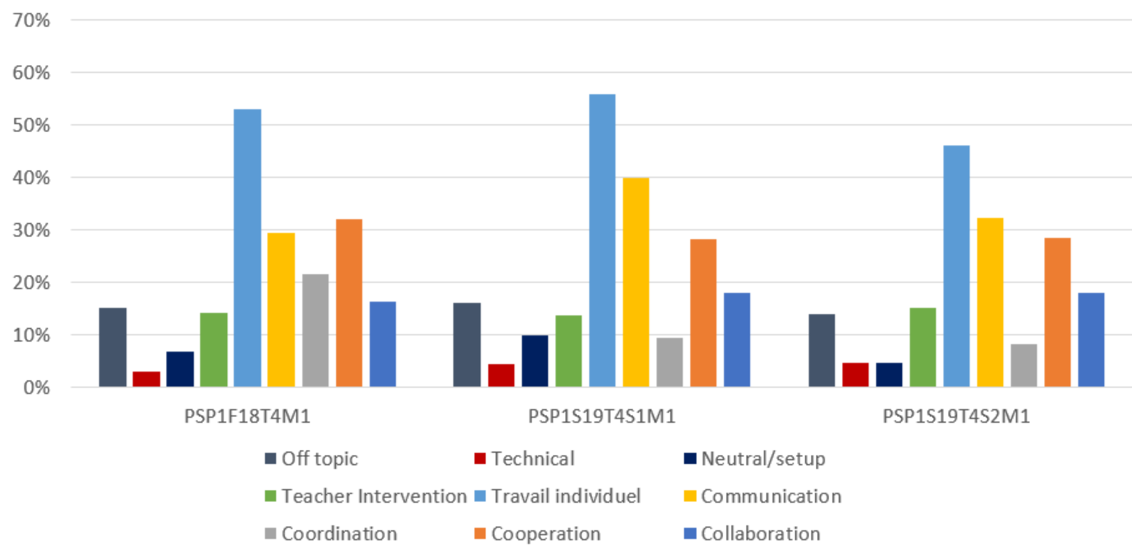



**Figure 85: Table/Board CIAO Averages (Instrumented Sessions) - % of time spent in each mode of interaction**

With most of the production being done individually, at least initially, it was accompanied by a phase of communication in which group members explained the ideas they had produced. During these phases of communication team members would pose questions, give feedback or challenge the idea. These interventions led to cooperative work involving negotiation, defense and modification of the individual's work in an effort to form a coherent product. Individual activity was high during all work sessions, as students spent time generating written notes to share, sometimes using the drawing features to illustrate their ideas or finding images or information online. Some students also took personal notes for prolonged periods of time, increasing the individual work count substantially. This did not occur to the same extent in other groups and is likely not related to the tool but to individual study and work habits.

We noted slightly higher levels of interpersonal conflict around this modality, likely related to the increase in epistemic conflict. For example, in the ice scraper analysis, one student had organized notes on the board in a logical, but aesthetically pleasing way. When changed by someone else, the student called it ugly and withdrew to the table to take notes. For the first half of the session she had played an active role, but after the reorganization she only commented when necessary or when asked for input. The need to integrate ideas, which had been produced individually, was an opportunity for creativity and epistemic conflict, but also generated a risk of interpersonal conflict within the group. It is important to not necessarily interpret this element as a negative aspect, especially if learning to collaborate is a primary focus. Putting students into situations where conflict can occur will allow them to activate and develop conflict-resolution skills.

The board served both pragmatic and epistemic functions, used as the primary means of communicating new ideas outside of speaking (as students sent their post-it notes directly to the board) and as a means of organizing ideas to advance the group's reflection. Different groups developed different utilization schemes related to this Subject-to-Other Subjects communication. For example, some groups used colors to indicate the person who produced a written note, while other used colors to indicate thematic links between ideas. When colors were used to indicate thematic links, the group was more likely to engage in epistemic conflict (Doise & Mugny, 1981) around the nature of the ideas and whether or not they fit into the agreed upon categorizations.

This dual usage made the board central to the table-board groups' progress and primary focus of the activity in the latter half of the sessions, relegating the table to a position of relative obscurity after the initial ideation phases. However, the table still had a role to play, as it was used to produce written notes based on the group's discussion. This prevented blocking others' view of the board space. The central role of the board likely also relates to the students' action schema that have been years in the making: using chalkboards, whiteboards and more recently smartboards as a central focus for communicating to a large group in a classroom setting.

The board also served as a form of reflexive mediation, allowing the individual to reflect upon and capture his/her thoughts as they were developing. This was seen as students rearranged items on the board without discussing it with others (individual work). Thus, this became both a way for the subject to help formulate and integrate others' ideas with their own and a way for "other subjects" to use the board to get a glimpse of the subject's developing understanding and potentially intervene when the subject's new arrangement ceased to match the group's shared understanding in order to repair the divergence.

Student feedback via questionnaires indicated that while some believed that the table / board modality had merit as a way to produce ideas and make decisions, they found both surfaces to be "too slow". As a result, they felt it necessary to return to traditional tools, such as the whiteboard, in order to externalize their ideas more quickly, especially when it came to drawings.

> *I don't deny that it is practical, but I think I spend too much time with my computer for notetaking already. I find that it is detrimental to my reflection; more and more I prefer old methods (board, sketching…) which are effective and stimulating.*

> *I found the technology that was made available to us to be useful for everything around brainstorming. However, it's too "long" to use when you really want to draft something.*

They also reported that the tool's usage was not always evident, meaning that information flow between the tool and user regarding its usage needs to be made clearer. Some technical issues must be confronted for this to be possible. For example, on most portable devices (tablets, smartphones, etc.) pressing with your finger in a text box will allow the text to be edited, where on the table or board you must click a pencil icon to edit the text first. Difficulty in differentiating between a desire to move an object or edit an object led designers to make this decision, which users find frustrating as it does not fit into a common usage schema seen in similar technologies.

Overall, the table and board modality lent itself to a more cooperative approach as higher rates of cooperation were consistent throughout the activities versus other modalities. The baseline for these groups, however, was also more cooperative, indicating that the modes of interaction used with the table and board modality follows closely with those used with paperboards/whiteboards and traditional post-it notes. However, we do not discount this tool as less globally collaborative. Previous research has shown that it still carries value in increasing shared talk time amongst group members, an element linked with higher collective intelligence (Jones et al., 2011). The around-the-table (Buisine et al., 2012) nature of this modality lends itself to this. Additionally, cooperation is a mode of interaction which we link to creativity, divergence and epistemic conflict, making it an important part of globally collaborative work.

## Tablets-Board Modality

In this section, we'll briefly discuss the Tablets-Board Modality as a physical digital workspace then we'll present the results of the CIAO analysis for the Table-Board Modality groups and finally analyze the results from an activity mediation perspective based on Rabardel's Collective Instrumented Activity Model described in Section 1.2.

The tablets and board modality is outside of the designer's original scope. The table was intended to provide a way to see what others are doing to generate further ideas during brainstorming phases; the table space is both individual and public, but rarely collective as users tend to operate within the space in front of them unless they have been given something to focus on in the table space (such as we see in the case of a digital board game that uses one or both surfaces). The tablets, on the other hand, provide an individual space that is both private and mobile. It is more difficult to see what is being written and the device can be moved, flipped over to hide the screen or the screen can be turned off. When comparing to the use of laptops from the descriptive study, there are two primary differences: the ability to lay the tablet flat on the table, thus giving some visibility to others, and the ability to easily move with the tablet. It is this ease of mobility combined with an aspect of comfort (related to using one's own device) that led the designers to create a mobile interface (described in 0). I will reiterate here that students were not using their own devices, but tablets provided by the researchers to ensure continuity in the experience across individuals and groups.

### *PSP1F18T5M2*

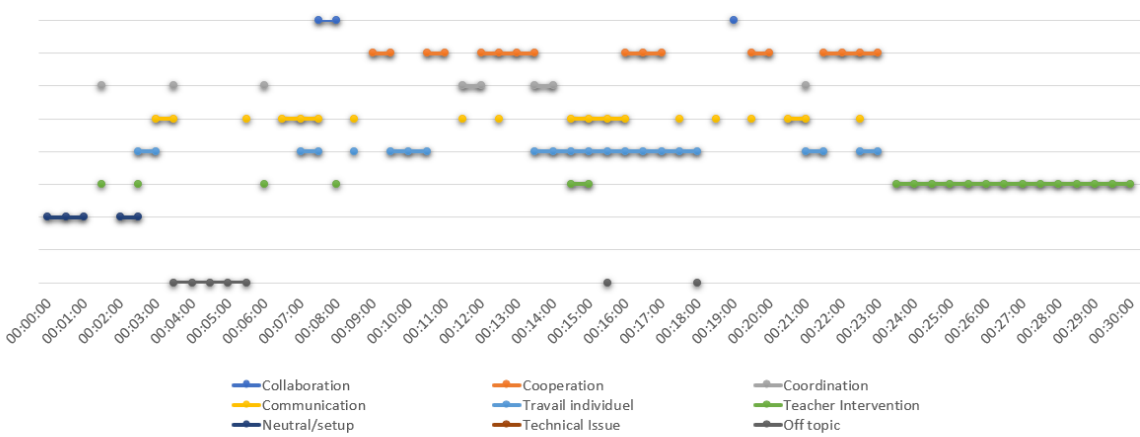
PSP1F18T5M2 baseline session (A), was ranked as more cooperative, with a difference of 23% of time spent in each mode of interaction. This trend changed when the group started to use the tablets and board modality. with an average difference of 0.16% between cooperative and collaborative modes of interaction across these instrumented sessions. Due to the low difference in time spent in the two primary modes of interaction, we term the results of this group to have changed from highly cooperative at the baseline to "balanced" during instrumented sessions.

| | Session A | Session B | Session C | Session D | Average |
|---|---|---|---|---|---|
| **Off topic** | 11.48% | 0.65% | 0% | 4.43% | 1.69% |

| | | | | | |
|---|---|---|---|---|---|
| **Technical** | 0% | 2.58% | 5% | 1.48% | 3.02% |
| **Neutral/setup** | 8.20% | 7.10% | 0.71% | 5.91% | 4.57% |
| **Teacher Intervention** | 32.79% | 13.55% | 22.86% | 10.34% | 15.58% |
| **Individual Work** | 36.00% | 12.90% | 66.43% | 57.64% | 45.66% |
| **Communication** | 31.00% | 24.52% | 58.57% | 36.95% | 40.01% |
| **Coordination** | 13.00% | 10.97% | 8.57% | 18.23% | 12.59% |
| **Cooperation** | 27.90% | 41.29% | 29.29% | 32.02% | 34.20% |
| **Collaboration** | 4.90% | 39.35% | 37.14% | 25.62% | 34.04% |

**Figure 86: PSP1F18T5M2 - CIAO Analysis Results - % of time per mode of interaction**

The first group session was recorded without the use of this modality (non-instrumented, i.e. without the support of computer tools) in order to establish a baseline for collaborative processes within the group. The results are presented as a percentage of time spent by the group in each mode of interaction. The percentages pass 100% because the




group members can be, and often are, in different modes of interaction at any given time.

**Figure 87: PSP1F18T5M2 – Session A**

During their non-instrumented session, like many of the groups, this one chose not to use the provided post-it notes and opted for using the whiteboard. Students stayed at the table while one person took notes about their discussion on the board. All communication was oral, with the content on the board representing the group's final decisions after periods of cooperative interaction, as the group worked towards negotiating meaning. This is the typical setup and interaction type seen in most groups during the non-instrumented session. One element that we noted here, as well as with other groups, was a certain respect for the person at the board. Other students hesitated to approach or pick up a marker. At least once when this did occur, the approaching student backed off immediately, holding their hands in front of them, a gesture we interpret as apologizing to the animator, as if it would be encroaching on their role.

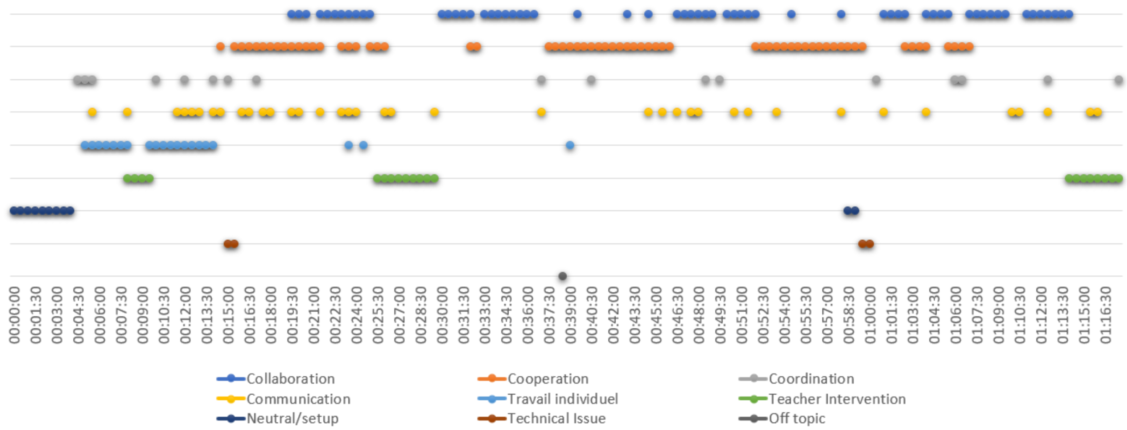



**Figure 88: PSP1F18T5M2 – Session B**

Session B saw a significant change in the working habits of this group. The following transcription is from [4:30 – 7:30] of Session B for group PSP1F18T5M2. In this segment, we see coordination as the group decides how to go about their work, then several minutes of silence, broken only by the occasional statement or clarification over the next several minutes.

*Students begin sitting around the table, having just logged into their accounts on their tablets.*

***Student A:*** *We put lots of ideas?*

***Student B:*** *Yes, lots of ideas. We start with the purpose and all that? Or... what do you guys see?*

***Student C:*** *Ah, yes? Me, I would have…*

***Student A:*** *At any rate, we do what we want to, yeah?*

***Student D:*** *Yeah, that's it.*

***Student B:*** *Yeah, like that, but in class he said that it's easier to start with the causes.*

***Student D:*** *We each write our ideas and we'll see?*

***Student B:*** *Yes, in the causes and the… yeah, that's it.*

*[Each student begins writing ideas on their tablet, then sending them*

*directly to the board. Student C stands and goes to move one of her post-its from the wormhole into the collective-public space of the board.]*

***Student B:*** *So, it's simple phrases, in fact…the because, less formal.*

***Student A:*** *Bah, yeah*

*[Student C returns to the table and continues writing with the others]*

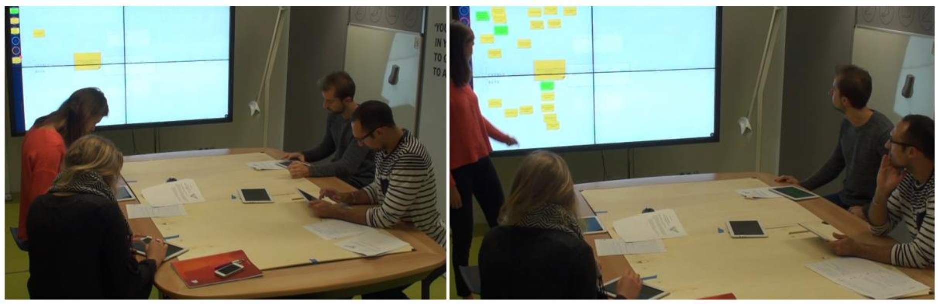


**Figure 89: PSP1F18T5M2 - Brainstorming (First 15 minutes of session B)**

For the first 15 minutes, the group continues to work individually, filling the board with ideas (Figure 89). Once this initial brainstorming phase ends, the group repositions itself around the table. They begin by interrogating the ideas that were produced individually, making attempts to ensure that they each understand what each post-it means. During this time, they move the post-its around the board and edit them directly in the board's space. Around 22 minutes into the session, a few group members grab their tablets and start noting the ideas that the group generated together in their individual-private space (Figure 90). Like the table in the table-board modality, the usage of the tablets changes as the group progresses through treating the case-study. Rather than remaining solely a space of individual reflection, it becomes one that is collective.

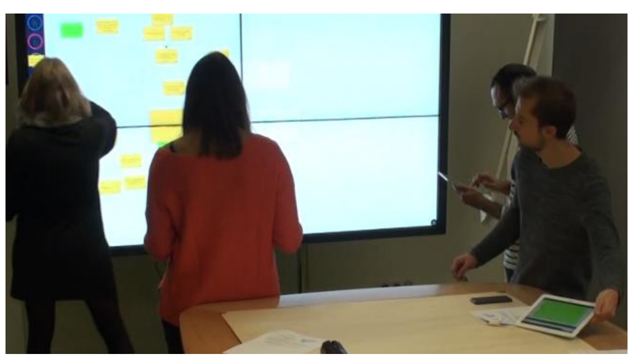


**Figure 90: PSP1F18T5M2 - Use of tablets in a "shoulder-to-shoulder" discussion**

The group stays in this "shoulder-to-shoulder" organization for the remainder of the session. This is different from what we saw with the table/board group (See Figure 75), where students would group around the table, then around the board, then back to the table, so on and so forth. The mobility of the individual-private space played a key role in allowing students to stay in a decision-making position, while still allowing a recourse for individual production.

The students did not follow the same scenario in session C as in session B. When the group arrived in the room, they began re-reading the case study and discussing it aloud. They used this initial portion to perform calculations related to the case study. As they worked through this together, two students used their tablets to record notes for the group from their position at the table (Figure 91). It is around the 10-minute mark, for the first time, that the tablets are used to externalize individual work. Despite seeing the typical "around-the-table" positioning in this session, there was no specific animator, or a person selected to interact with the board. At various points throughout the session, each group member approached the board to make a change, but we did not see the grouping around the board in this session as in Session B.

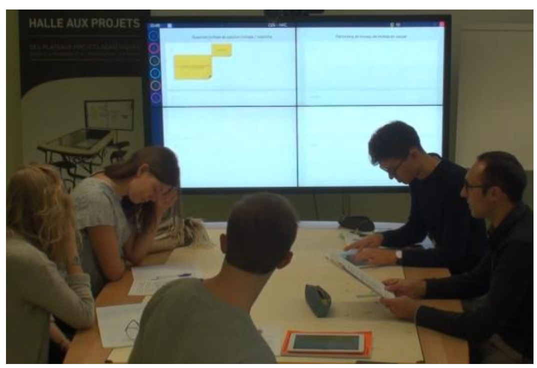



**Figure 91: Tablets used to take collective notes**

In Session D, we saw a return to the working method seen in Session B, where the group began with a brainstorming session, lasting about 4 minutes. The case study in session D required the students to switch between different methodological tools to approach a single question from different angles. As the group worked through one tool, they would do an initial brainstorming in an "around-the-table" format, then move into a "shoulder-to-shoulder" format to finalize it, before moving on to the next question. This would restart the process and students would return to their positions at the table and begin a new brainstorming phase. We see a pattern emerge as the group goes through the individual work in the brainstorming, followed by cooperation as they negotiate the meaning of each person's ideas, finally moving into collaboration. This cycle occurs twice and begins a third time, just before the teacher's intervention at the one-hour mark, a last cycle is completed as the session ends.

***PSP1S19T5S1M2***

The PSP1S19T5S1M2 baseline session (A), was ranked as balanced, with a difference of 1.54% of time spent in each mode of interaction. This trend remained the same when the group started to use the tablets and board modality. with an average difference of 7.49% between cooperative and collaborative modes of interaction across instrumented sessions. This is the highest difference in the three groups using the tablets and board modality. This group was rated with a balanced baseline and balanced instrumented sessions.

| | Session A | Session B | Session C | Session D | Average |
|---|---|---|---|---|---|
| **Off topic** | 6.92% | 8.50% | 8.63% | 11.03% | 9.39% |
| **Technical** | 10.77% | 4.58% | 0.72% | 4.41% | 3.24% |
| **Neutral/setup** | 10.77% | 7.19% | 3.60% | 2.21% | 4.33% |
| **Teacher Intervention** | 15.38% | 18.95% | 33.81% | 18.38% | 23.71% |
| **Individual Work** | 59.23% | 58.82% | 39.57% | 69.85% | 56.08% |
| **Communication** | 53.08% | 44.44% | 41.73% | 50.00% | 45.39% |
| **Coordination** | 13.85% | 16.99% | 9.35% | 19.85% | 15.40% |
| **Cooperation** | 39.23% | 27.45% | 38.85% | 49.26% | 38.52% |
| **Collaboration** | 40.77% | 38.56% | 28.78% | 25.74% | 31.03% |

**Figure 92: PSP1S19T5S1M2 - CIAO Analysis Results - % of time per mode of interaction**

During session A this group worked in similar ways to other groups, with an animator taking notes on the whiteboard. The majority of the interactions over the first 17 minutes are collaborative in nature, as the group works to complete the "poulpe" with a few challenges throughout. The individual work occurring throughout the session is largely completed by the animator, as he works to take notes while others look on. Rather than simply taking notes and recording the group's decisions, he often adds new information and ideas as he goes. This activity generates the challenges we see leading to the cooperative interactions. In this group, rather than the board serving only as a collective memory, as it has been in other groups, it becomes the facilitator's way of externalizing new ideas, while the rest of the group continues to work aloud.

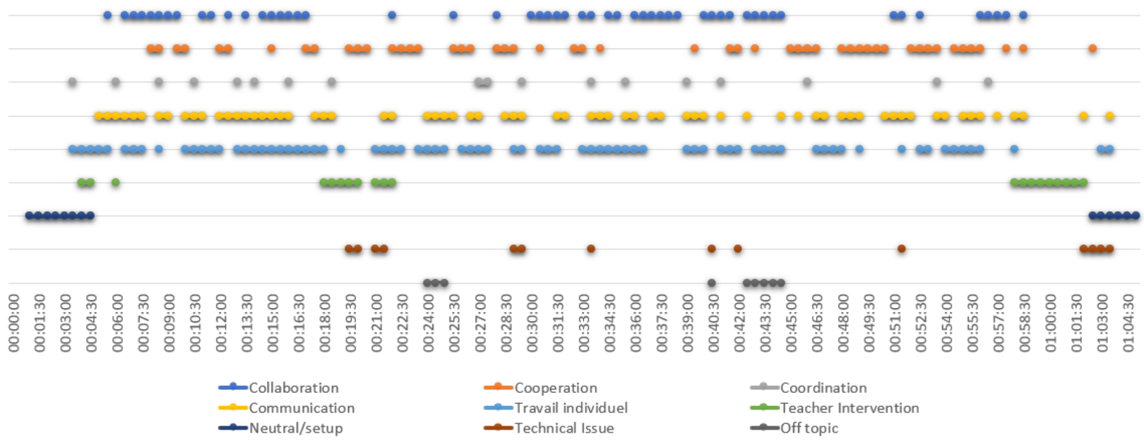



**Figure 93: PSP1S19T5S1M2 – Session A**

Below are transcriptions of the coordination phase in session A as the students chose how to work together. Professors had asked students to choose one person to drive the conversation and someone else to keep track of the group's progress (a secretary and a facilitator.) PSP1S19T5S1M2 did not choose a facilitator outright or declare who the facilitator would be:

> ***Student A:*** *So, if I understood correctly, I think we need to start with a "poulpe" and then go out from there.*
>
> ***Student B:*** *Yes, the principal functions.*
>
> ***Student A:*** *Principal functions and then move towards abstraction.*
>
> ***Student B:*** *Do we use the board?*
>
> ***Student A:*** *Well, yeah.*

Student B in this excerpt self-selected as the facilitator after asking if they should use the board. Students A and B, both, continued to guide the group's conversation throughout the session. The group continued in this way for the majority of the session, discussing ideas out loud with Student B noting ideas on the board and adding his own, then discussing afterwards.  However, around 55 minutes into the session, almost all the students were around the board, a progressive change which occurred one student at a time. After this point, movement around the board became much more fluid, with different students approaching the boards note their ideas and make modifications to previous work. This became a principle means of communication, allowing them to express their ideas and show how they fit together (See Figure 94). Despite this new acceptance of movement and fluidity, one student, who we consider introverted (J. H. Jung et al., 2012) based on her low level of oral input, did not move from her space at the table. This is one of the few groups in which the whiteboard became a collective-public space, rather than an individual-public space, as more people began using it.

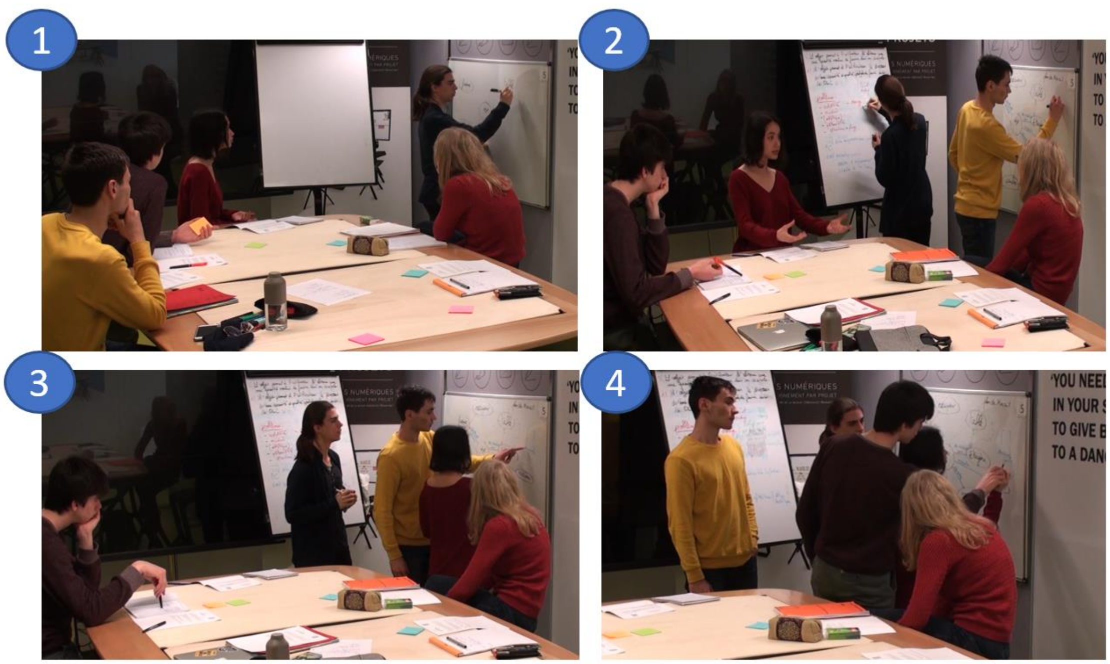



**Figure 94: PSP1S19T5S1M2 – Session A - The group moves progressively to the board**

Session B did see a change in the group's way of working, as students began with a brainstorming phase, where each person used their tablet to write their ideas "in bulk".

***Student B:*** *Do we do…*

***Student A:*** *In bulk*

**Student B:** *Yeah, like the FAST. We put lots of ideas and then we put them together or we reflect and ...*

**Student A:** *Ah no, no. Rather, in bulk.*

**Student B:** *In bulk?*

**Student C:** *Yeah.*

We saw a similar fluidity of movement and changing roles in this group as with PSP1F18T5M2. Sometimes students stood at the board with their tablets, others remained at the table while others worked directly in the space on the board as the group's reflection advanced (Figure 95: PSP1S19T5S1M2 - Fluidity of movement.

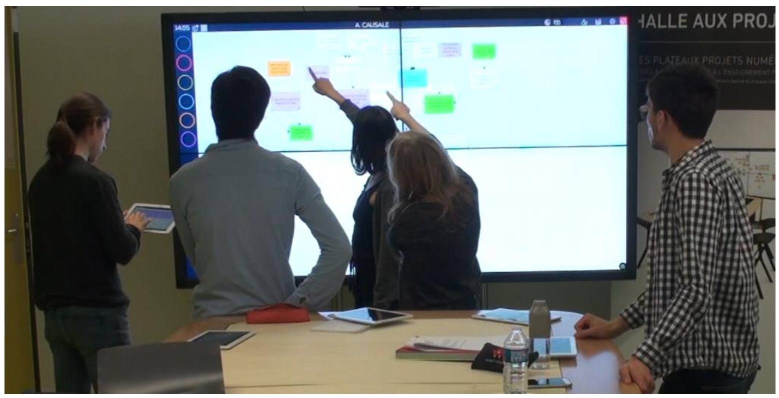


**Figure 95: PSP1S19T5S1M2 - Fluidity of movement**

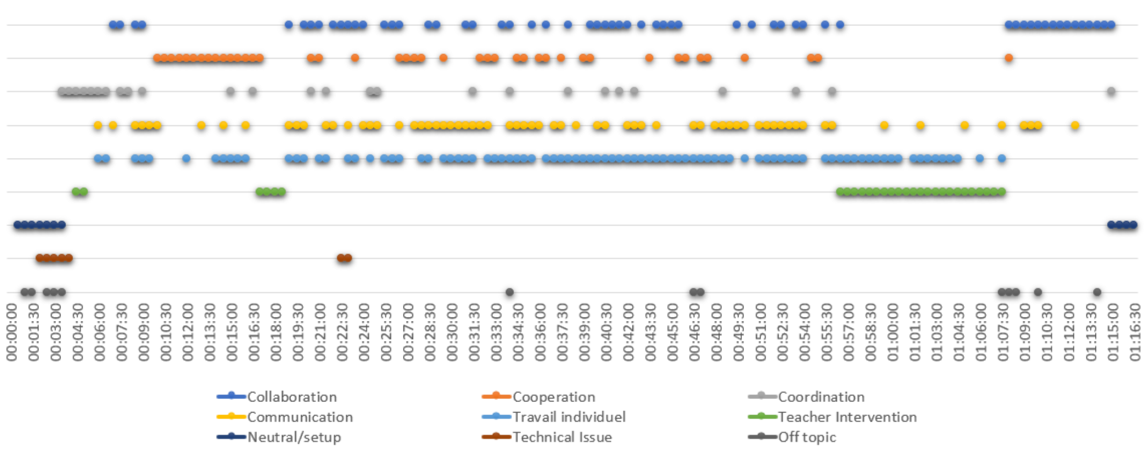



**Figure 96: PSP1S19T5S1M2 – Session B**

In session C, there is a slight increase in the amount of cooperation versus other sessions. With a difference of 10.07% of time spent in these two primary modes of interaction (38.85% for cooperation and 28.78% for collaboration). As before, they begin with a brainstorming session. However, this brainstorming is short lived as one narrates his idea as he writes it, it ignites a phase of cooperative work during which only one student generates new post-its from his tablet. Following an intervention by the teacher, the animator proposes to do a "poulpe". The response is an immediate no, because "it will take too long to draw it on the board. If we had a board…with chalk." The group laughs and returns to their discussion. This comment is in line with our observation regarding the usage of the *Halle Numérique* platform for drawing: few groups use it despite the presence of the functionality.

As the group works, we see a return to the traditional usage of a board, with the group seated at the table and one person handling moving items at the board. However, the animator remains at the table for the majority of the session. She approaches the board when others send new post-it notes, then returns to the table and to the discussion, which seems to ease the awkwardness we saw with PSP1S19T4M1.

The first time we see a major difference in time spent in modes of interaction is in Session D. This session, which was designed to help students prepare for their exam, led to higher amounts of epistemic conflict. The tablet-board modality affords a high amount of flexibility, allowing the group to move easily between different modes of interaction, adapting the usage of the space to their needs. Such fluidity can also be seen to some extent in the table-board modality, but lacks in the board-only modality, as we will see in the next section. In these last two sessions, we really see the emergence of the "around-the-table" phenomenon in this modality. During Session D, the movement around the room very much resembled that of Session C, with most group members staying seated, discussing aloud, and individuals generating post-its throughout the discussion. Occasionally a co-written post-it was also made.

***PSP1S19T5S2M2***

| | Session A | Session B | Session C | Session D | Average |
|---|---|---|---|---|---|
| **Off topic** | 9.92% | 12.95% | 6.13% | 10.00% | 9.69% |
| **Technical** | 0.76% | 10.07% | 4.91% | 5.83% | 6.94% |
| **Neutral/setup** | 8.40% | 5.04% | 6.75% | 7.50% | 6.43% |
| **Teacher Intervention** | 19.08% | 15.11% | 12.27% | 14.17% | 13.85% |

| | | | | | |
|---|---|---|---|---|---|
| **Individual Work** | 41.98% | 72.66% | 73.62% | 55.83% | 67.37% |
| **Communication** | 54.96% | 56.12% | 54.60% | 45.00% | 51.91% |
| **Coordination** | 23.66% | 25.18% | 13.50% | 10.83% | 16.50% |
| **Cooperation** | 25.19% | 21.58% | 29.45% | 26.67% | 25.90% |
| **Collaboration** | 31.30% | 28.06% | 28.83% | 27.50% | 28.13% |

**Figure 97: PSP1S19T5S2M2 - CIAO Analysis Results**

The PSP1S19T5S2M2's baseline session (A), was ranked as balanced, with a difference of 6.11% of time spent in each mode of interaction. This trend remained as the group started to use the tablets and board modality, with an average difference of 2.23% between cooperative and collaborative modes of interaction across these instrumented sessions.

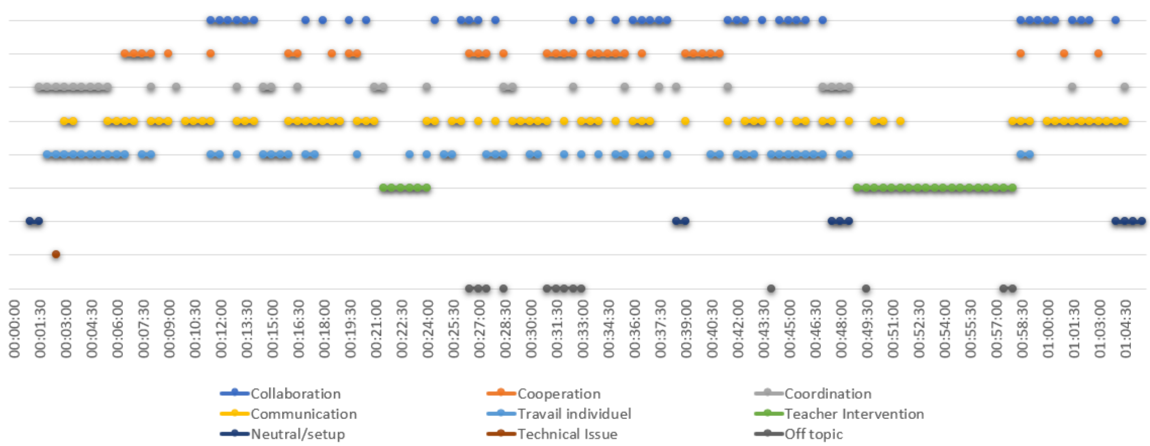



**Figure 98: PSP1S19T5S2M2 – Session A**

In the following transcription from the initial coordination phase of PSP1S19T5S2M2 session A, we see the coordination of several different elements: roles within the team, methodological tools to be used, and physical arrangement of the tools in the provided space. This group was one of the few who used the post-it notes available to them (See Figure 99). The assumption made by the designers of the *Halle Numérique* platform was that post-its would be used primarily as an individual-public brainstorming object, then later become a collective-public intermediate object. However, in this non-instrumented session, we see the group using them for collective notes right away. After a phase of cooperation, one student writes the idea on the post-it note and sticks it to the board. As such, this group spent a fair amount of time on ideas which were already constructed together, primarily. Once the ideas were on the board, they were often subject to collaboration as students would co-build on the initial idea.

***Student A:*** *There's a board*

***Student B:*** *[Passes a stack of post-it notes to student A]*

***Student C:*** *I want to write the questions.*

***Student A:*** *Do you want to facilitate with me?*

***Student C:*** *Yes, go for it.*

***Student A:*** *Let's go then. [Goes to board, looking at the post-its in his hand.] [Addressing student B] Actually, why did you give me this?*

***Student B:*** *Uh, it's what we need to put post-its. [Makes writing motions in the air]*

***Student D:*** *[Speaking to student B] But no, it's us [Gestures to students around the table] who write the post-its and then she'll [referring to student C] stick them to the board.*

***Student C:*** *No!*

***Student B:*** *Then I'll be the secretary [takes post-it notes back from Student A]*

***Student D:*** *In a group of 5, I don't know that we need 2 facilitators.*

***Student C:*** *Yes, he [the professor] said 2 facilitators.*

***Student E:*** *I think he said a facilitator and a secretary*

***Student A:*** *[Draws on the board] We need to... There are two life situations. There's the storage and usage.*

***Student D:*** *Do it directly on the board. Separate the two situations and then put the two functions.*

***Student A:*** *But there's the...*

***Student D:*** *No [approaches board]*

***Student C:*** *We have to do the "Poulpe" too*

***Student A:*** *But there are two boards*

***Student D:*** *[Goes to second whiteboard] We'll do a working board and a synthesis board. So, on that one you draw the charts.*

***Student C:*** *I think there's been a change of facilitators.*

*[Students C & E laugh]*

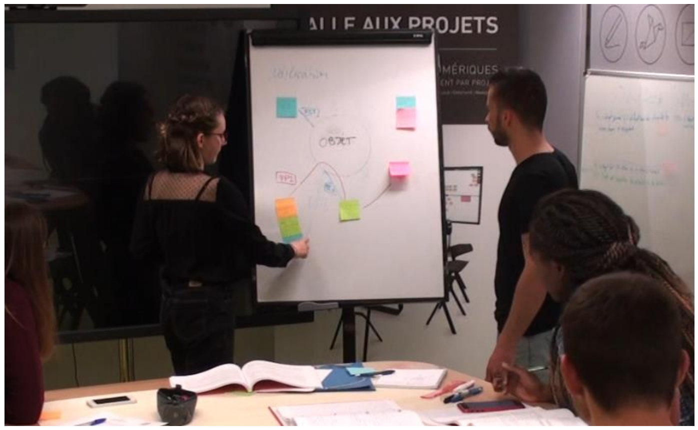


**Figure 99: S19T5S2M2 Post-it usage**

The post-its were "controlled" by two people during this session, even though every student had access to them. This limitation may have been related to the number of people you can have working on the board. Where the digital tool offers a quick way to put the post-it into the collective space, a physical post-it requires someone to stand and carry it to the board, where there are already a number of people working, however as in PSP1S19T5S1M2, by about 40 minutes into the session, every group member is standing around the board, but contributions continue in the same way. The conversation continues to be dominated by the three who have had control of the board since the beginning of the session.

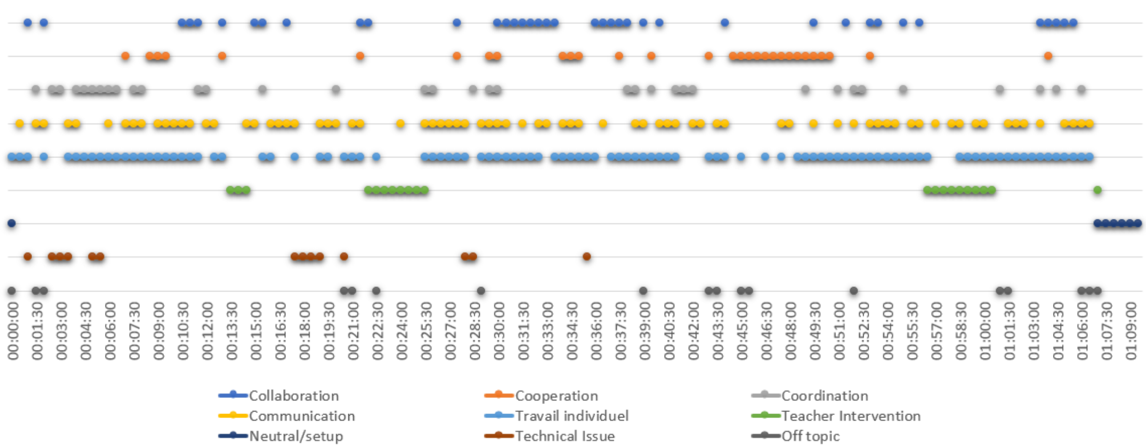



**Figure 100: PSP1S19T5S2M2 – Session B**

In Session B, during the coordination phase, the group elected to go "little-by-little", rather than doing a bulk brainstorming phase. One student said that he felt like they struggled to put their ideas together afterwards, suggesting that working more collaboratively would make the process easier. As such, there was no individual brainstorming phase that occurred. However, students did still use their tablets throughout to send new ideas to the board, there was simply no coordinated phase where all members of the group worked alone at the same time. This resembled the ways of working we saw in PSP1S19T3S1M3's sessions C and D. However, in Session C, we see the group transitioning between "around-the-table" and "shoulder-to-shoulder" positioning towards the end of the session (Figure 101).

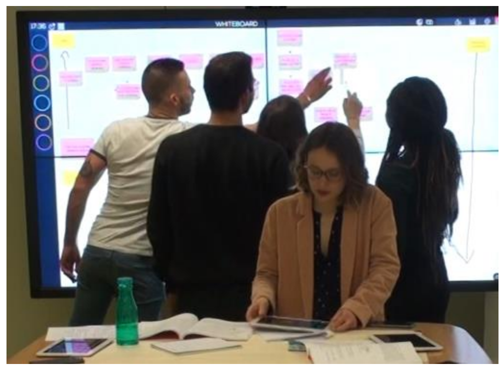


**Figure 101: PSP1S19T5S2M2 - Around the Board**

Session D sees a return to the "around-the-table" positioning, as students stay at the table, except for one animator, who moves items around the board. As with PSP1S19T5S1M2, this group discusses aloud, occasionally generates post-its as a group and individuals generate post-its throughout.

***Tablets-Board Analysis***

The individual private space afforded by the tablets allowed the students a place to reflect and write their ideas, modify them and then send them to the board directly or delete them. While a majority of the production was still done orally, the access to an individual space provided a way to act to all group members, at all times. The tablets in this modality served an epistemic function (Rabardel, 1995), allowing each student the opportunity to reflect on the object of their activity, search for information and externalize their thoughts. These externalizations in a private space, however, removed the ability of others to see what was being done, unlike in the table-board modality. However, the interactions we saw around this were much the same – in both cases students would ask others what they were writing as they were writing it. In the case of the individual-public table space, it was possible to simply read it directly. However, in the individual-private space, sharing the information became a choice, though we did not observe anyone declining to share.

As in the other two modalities, the board served as a way for students to reorganize their thoughts and put them into relationships with those of other group members. However, rather than always starting with a brainstorming phase, the three groups observed sometimes preferred not to use the individual space provided for individual reflection at all. Instead, throughout the session they worked aloud, using the tablets as a means to write down the decisions made by the group. For this modality, the added mobility in the individual space allowed all group members to move as they wished, and interact in the collective space without losing that access or needing to separate from the group to have it, if everyone else remained at the board. This fluidity afforded by the tablet-board modality contributed to the groups' ability to adapt the tool to their working styles and the pedagogical scenario.

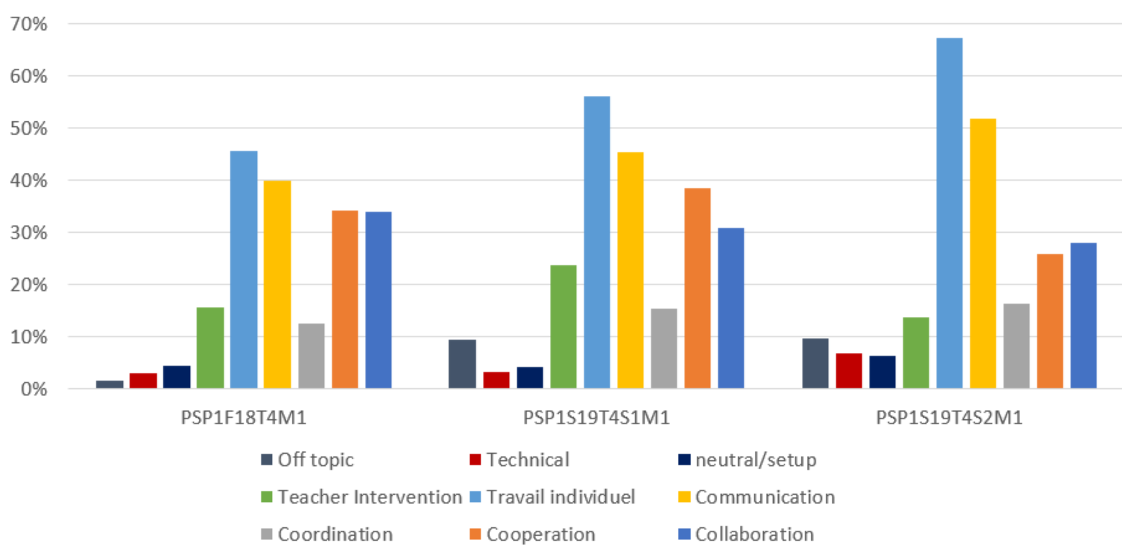



**Figure 102: Tablets and Board - CIAO Averages (Instrumented Sessions)**

While the Table-board modality was clearly more cooperative, the tablet-board modality allowed for a good deal more flexibility. Therefore, we have classified this modality as "balanced" – a more or less even mix between collaboration and cooperation is possible with this modality, with the ability to adapt it to fit one or the other readily.

Evaluations by teachers determined that all three tablet-board groups were successful across all their case study sessions. Student feedback via questionnaires indicated a positive experience with this modality.

> *Very good support. Allowed us to study individually with the tablet before sharing our ideas afterwards on the digital board.*
>
> *I really liked the screen + tablet system because it allowed us to put our own ideas forward (even if shy) and then work on them together.*
>
> *Technology that is effective and adapted to group work because each person can express their ideas. Very intuitive system that makes working in a team easier.*

**Board Modality**

The board alone, as with the tablet-board modality, is outside of the scope of the original design for the *Halle Numérique*. However, the company who commercializes the software used in this research (Ubikey) reports that most of their clients prefer this modality.

At its heart, this modality is collective-public, as all participants may interact and see the activity taking place in the workspace at any time. This modality has no space that is considered purely individual.

***PSP1F18T3M3***

PSP1F18T3M3 baseline session (A), was ranked as more cooperative, with a difference of 10.45% of time spent in each mode of interaction. This trend changed drastically when the group started to use the tablets and board modality. with an average difference of 53.12% between cooperative and collaborative modes of interaction across these instrumented sessions.  Due to this wide difference in time spent in the two primary modes of interaction, we term the results of this group to have changed from cooperative at the baseline to "collaborative" during instrumented sessions.

| | Session A | Session B | Session C | Session D | Average |
|---|---|---|---|---|---|
| **Off topic** | 1.14% | 9.58% | 8.98% | 17.50% | 12.02% |
| **Technical** | 0% | 1.80% | 0.60% | 1.50% | 1.30% |
| **Neutral/setup** | 0% | 5.99% | 4.19% | 3.50% | 4.56% |

| | | | | | |
|---|---|---|---|---|---|
| **Teacher Intervention** | 38.03% | 12.57% | 10.18% | 8.50% | 10.42% |
| **Individual Work** | 57.75% | 27.54% | 37.72% | 46.50% | 37.25% |
| **Communication** | 45.07% | 32.93% | 23.95% | 38% | 31.63% |
| **Coordination** | 7.04% | 9.58% | 23.95% | 19.50% | 17.68% |
| **Cooperation** | 33.80% | 4.19% | 8.38% | 27.50% | 13.36% |
| **Collaboration** | 23.35% | 71.86% | 67.07% | 60.50% | 66.48% |

**Figure 103: PSP1F18T3M3 - CIAO Analysis Results - % of time per mode of interaction**

No new behaviors were detected in this session versus previous groups. The group stayed at the table, with one animator at the board. Students took notes, communicated aloud. Individuals used their notebooks and the whiteboard to keep track of the group's decisions.  This continued throughout the session.

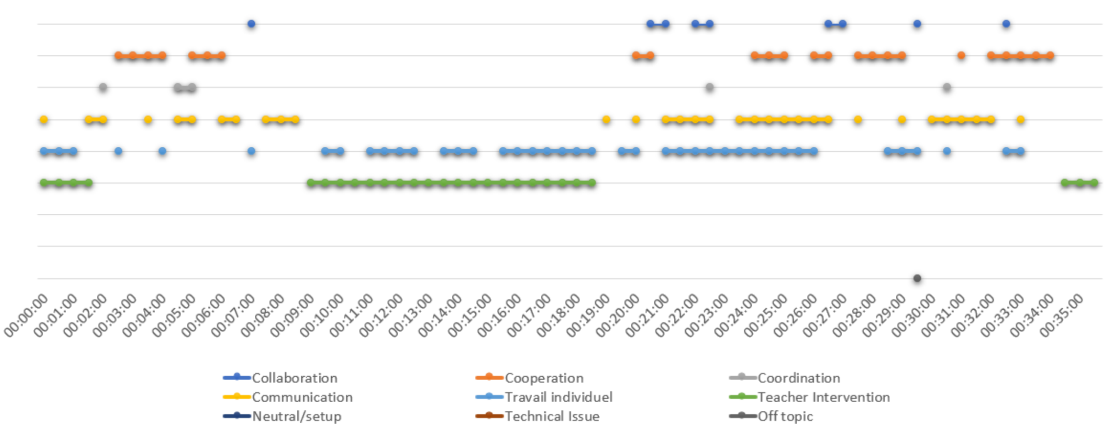



**Figure 104: PSP1F18T3M3 – Session A - Non-instrumented the session CIAO timeline**


**Figure 105: PSP1F18T3M3 - Non-instrumented session**

During much of the session B, the groups work is fragmented, often working in sub-groups with collaborative co-building happening within the subgroup. The cooperation often occurs as the group brings the sub-groups' ideas back together and some explanation, negotiation and decision making are necessary to fit the pieces in the overall scheme. We see this occur periodically, but at much lower levels than other modalities, perhaps due to a degree of flexibility in membership in these sub-groups as students, especially those without a direct access to the board, move between conversations.

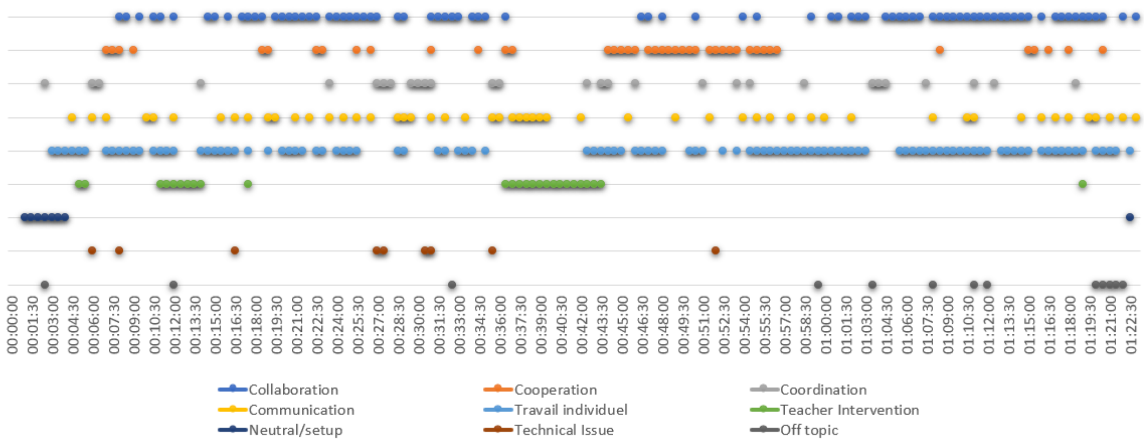



**Figure 106: PSP1F18T3M3 – Session B – Board-only Modality CIAO timeline**

As Session B begins, the students are seated around a physical table, reading the case study brief. One student writes the "central" post-it and places it.  Three students remain seated at the table while the three others remain at the board. Two of the students begin writing post-its, with the third making oral contributions while the three students at the table debate amongst themselves (Figure 107).

**Figure 107: PSP1F18T3M3 – Sub-group cooperation and individual work**

With no agreement reached, the group at the table moves to position themselves around the board. Those originally working there open three blank post-its. As one begins to write, another looks at what she is writing and begins asking her questions and challenge what she is writing, requiring her to explain aloud as she externalizes her thoughts via writing (Figure 108).

**Figure 108: PSP1F18T3M3 - New sub-groups with collaboration and individual work**

Even those spaces which would typically be considered individual, as only one person interacts with them, become collective in this modality. In Figure 109, we see such an example as two users interact simultaneously with a digital keyboard.

**Figure 109: PSP1F18T3M3 - Keyboard Sharing**

***PSP1S19T3S1M3***

PSP1F18T3M3 baseline session (A), was ranked as more cooperative, with a difference of 8.66% of time spent in each mode of interaction. This trend changed when the group started to use the tablets and board modality. with an average difference of 5.64% between cooperative and collaborative modes of interaction across these instrumented sessions.  Due to the low difference in time spent in the two primary modes of interaction, the results of this group changed from cooperative at the baseline to “balanced” during instrumented sessions.

| | Session A | Session B | Session C | Session D | Average |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| **Off topic** | 0% | 6.08% | 25.69% | 32.89% | 21.55% |
| **Technical** | 0% | 10.14% | 0 | 0% | 3.38% |
| **Neutral/setup** | 9.45% | 2.70% | 6.25% | 6.04% | 5.00% |
| **Teacher Intervention** | 18.90% | 20.95% | 15.97% | 17.45% | 18.12% |
| **Individual Work** | 45.67% | 39.86% | 50.00% | 63.09% | 50.98% |
| **Communication** | 36.22% | 27.70% | 43.00% | 34.23% | 34.98% |
| **Coordination** | 11.02% | 8.11% | 6.94% | 6.71% | 7.25% |
| **Cooperation** | 37.01% | 27.70% | 18.75% | 30.87% | 25.77% |
| **Collaboration** | 28.35% | 45.27% | 19.44% | 29.53% | 31.41% |

**Figure 110: PSP1S19S1T3M3 - CIAO Analysis Results - % of time per mode of interaction**

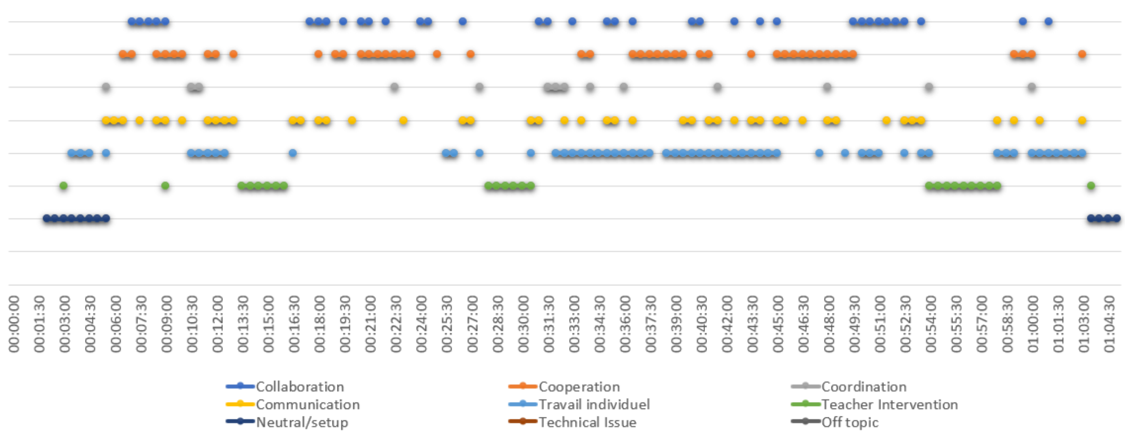



**Figure 111: PSP1S19T3S1M3 – Session A - Non-instrumented the session CIAO timeline**

This group's session was split into two sections. This is one of the few groups in which students immediately grouped around the whiteboard in a shoulder-to-shoulder positioning. Additionally, while there was one person who did the initial animation, a second person took up a marker to contribute only 11 minutes into the session. However, he worked silently, without the input of the others, using the collective public space as a space of individual reflection for a few minutes. The teacher came to check on the group as this was happening, so the student explained the reasoning to the teacher directly and the teacher coached the group through changes to the individual work produced on the board. After this, the group worked together to complete the poulpe. Once finished, the students all return to an around-the- table position, just as the teacher arrives for a second check-in, after which, students remain at the table for the remainder of the session. During this time, students discussed solutions aloud and recorded the group's final decisions in each of their notebooks. As such, notebooks are not used as a means of reflection, but rather a means to keep the collective memory of the group at the individual level.

At the beginning of Session B, the students again start in a shoulder-to-shoulder position. With five students in the group, one student notes immediately that the positioning makes it difficult for her to see:

> **Student A** Back up so that I can see the board too
> **Student B** Wait, I'll put myself in the middle.
> [Student B positions himself against the table, then walks forward to open a keyboard]
> **Student A** But I can't see the board anymore.

This time, rather than regrouping at the end of the session to discuss potential solutions, students stayed at the board for the duration of the session.

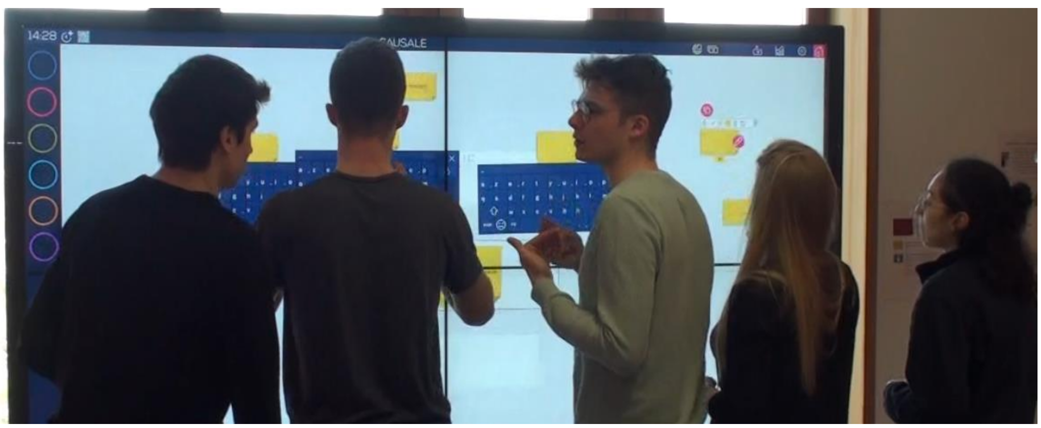


**Figure 112: PSP1S19T3S1M3 - Shoulder-to-Shoulder**

While the group does still have a relatively high amount of cooperation when compared in session B, it is less than during their base-line session while collaboration increased significantly.

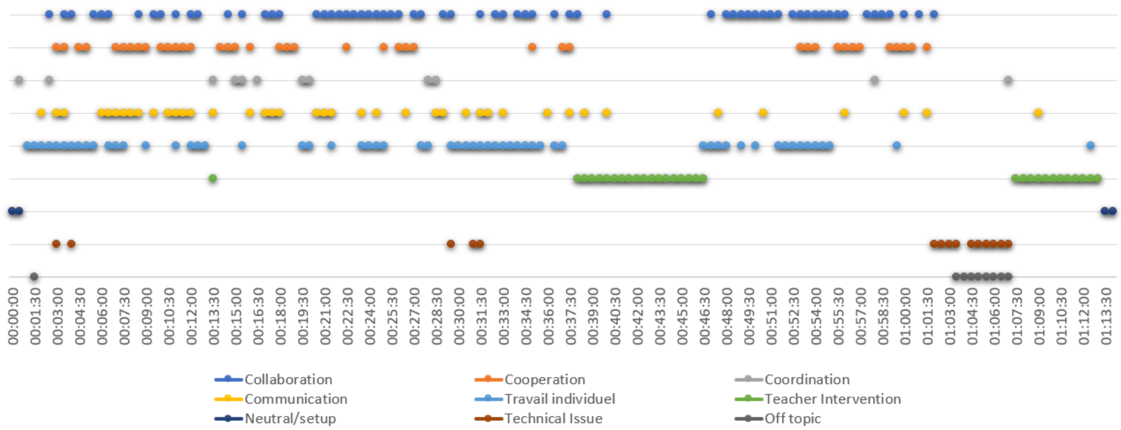



**Figure 113: PSP1S19T3S1M3 – Session B – Board-only Modality CIAO timeline**

However, during both sessions C and D, there is a significant increase in time spent off topic, which likely impacted the amount of collaboration and cooperation we saw in this group. In session D, 32.89% of the working session (25 minutes) was spent with at least one group member (and often several) not focused on the activity.

In addition to this off-topic time, with the lack of an individual space, we see issues related to participation of introverted students return. In Figure 114, we see just one such occasion as the student in orange attempts to speak. However, the conversation is being dominated by the male students in the group and she is unable to break in with her hand signal, so she withdraws and ultimately does not attempt to find another point to give her idea.

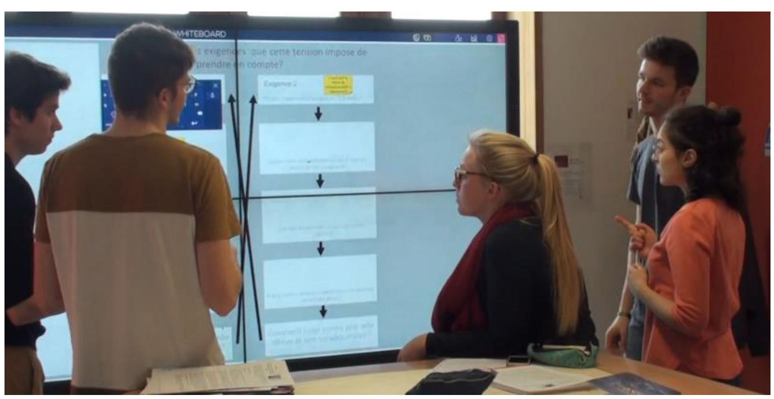



**Figure 114: PSP1S19T3S1M3 – An introvert attempts to contribute**

***PSP1S19T3S2M3***

PSP1F18T3M3 baseline session (A), was ranked as more cooperative, with a difference of 20.32% of time spent in each mode of interaction. This trend changed when the group started to use the tablets and board modality. with an average difference of 8.93% between cooperative and collaborative modes of interaction across these instrumented sessions. Due to this difference in time spent in the two primary modes of interaction, we term the results of this group to have changed from cooperative at the baseline to "collaborative" during instrumented sessions.

| | Session A | Session B | Session C | Session D | Average |
|---|---|---|---|---|---|
| **Off topic** | 10.16% | 23.78% | 47.83% | 30.97% | 34.19% |
| **Technical** | 6.25% | 0.70% | 3.11% | 5.31% | 3.04% |
| **Neutral/setup** | 7.03% | 3.50% | 5.59% | 15.04% | 8.04% |
| **Teacher Intervention** | 20.31% | 24.48% | 21.74% | 18.58% | 21.60% |
| **Individual Work** | 16.41% | 58.74% | 39.13% | 60.17% | 52.68% |
| **Communication** | 28.91% | 44.06% | 38.51% | 46.90% | 43.16% |
| **Coordination** | 15.63% | 11.09% | 9.94% | 6.19% | 9.07% |
| **Cooperation** | 46.09% | 22.38% | 37.27% | 29.20% | 29.62% |
| **Collaboration** | 17.97% | 37.06% | 31.68% | 46.90% | 38.55% |

**Table 41: PSP1S19T3S2M3 - CIAO Analysis Results - % of time per mode of interaction**

At the beginning of Session A, the group decided to make use of the post-its they had, saying that "companies work like this a lot." They agreed to have each person use their own color for their own ideas. After agreeing on how the post-it notes would be used, they divided the board space into two categories: one for each of the situations they needed to treat (storage and usage of the flour).

| | |
|---|---|
| **Student A** | It would be good if we each took a different color that way, we could see … |
| **Student B** | You take purple |
| **Student C** | But I'm animating |
| **Student B** | But you have ideas too, right? |
| **Student C** | Yeah |
| **Student A** | So, the tool… you put… we are going to create a poulpe from… |
| **Student D** | From different ideas that we have |
| **Student A** | [Points to a stack of post-its] So there you put like a key word or a space and goal is to put them |
| **Student B** | And in line with that [points to a sheet of paper on which the case study is described] |

**Student A** Yeah, to find the functions
**Student D** But that's complicated with one word
**Student A** Yes
**Student B** We can't take what we've been doing for the last two weeks, just …. What's the point of this thing… you don't extract the…
**Student D** We wouldn't put "the object allows the user to…"
**Student A** Yes, yes. That's it.
**Student D** That's the goal.
**Student C** But I understand what {Student A} wants to do. He just wants to start by getting out the principal ideas, brainstorming.
**Student A** Yes, do like a brainstorming. We'll see if that covers everything, but we only have an hour.
**Student C** Well you guys do what you want, I'm going to… [stands up and goes to the whiteboard with her stack of purple post-its]
**Student A** You, you're writing, but we try to define three technical functions, do we all agree?

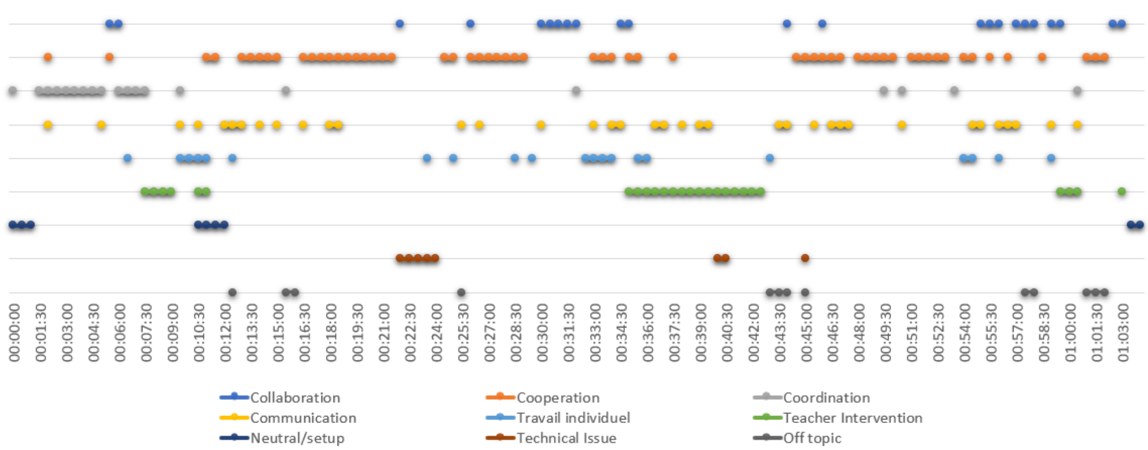



**Figure 115: PSP1S19T3S2M3 - Session A - Non-instrumented the session CIAO timeline**

The group first took the time to discuss some rules about how the work would be carried out, then started trying to work aloud before returning to the plan they had come up with for a brainstorming session. However, unable to decide if they should do both situations at once or one and then the other, they asked the teacher to intervene. The teacher recommended doing them one at a time and doing their planned brainstorming session. It is around ten minutes that they began their individual work, writing their post-it notes individually, but what to write was still unclear, so they began coordinating and arguing over what needed to be written. In addition to writing their ideas, they also say the idea out loud as they write it, which leads to this increase in cooperation as students respond immediately to the ideas.

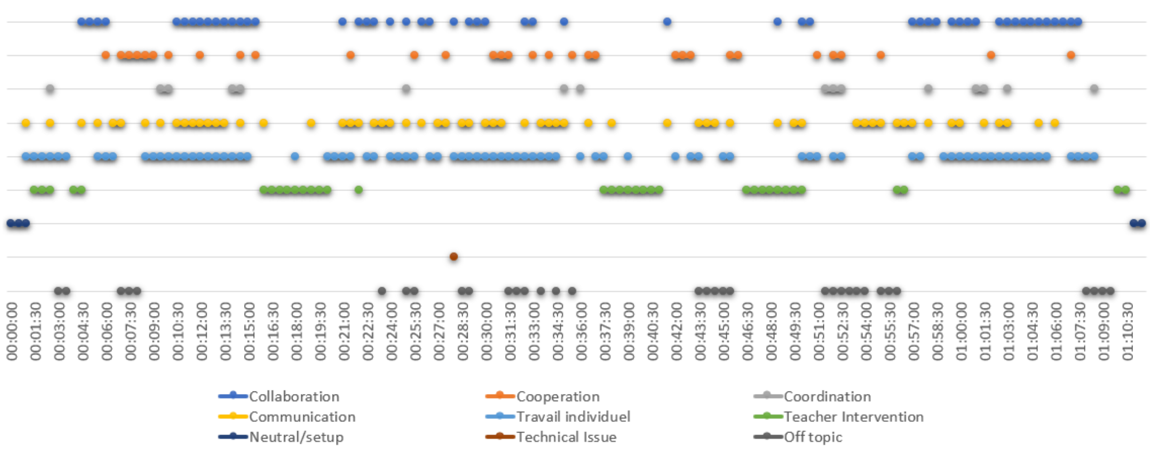



**Figure 116: PSP1S19T3S2M3 – Session B – Board-only Modality CIAO timeline**

## ANNEXE 8: $CO^2$ FRAMEWORK

### *Regulation*

| | -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|---|
| Participation | Separates himself from the group or is often absent. Does not interact even if someone speaks to him/her directly. | Mostly engaged in the group but may need to be reminded to participate. | Engages in the group's activities and responds to others. | Engages in the group's activities and helps manage them. He/She encourages the participation of others. | Engages in the group's activities and helps manage them. He/ she encourages the participation of others by making use of their skills and interests. |
| Responsibility | Does not do the work that was assigned to him/her or that they accepted to do. Does not accept to do any work. | Partially completes his/her work. | Does the work that he/she agreed to without bringing new elements. | Does the work that he/she agreed to do but brings new elements while still being in line with the group's objectives. | Does the work that he/she agreed to do, while bringing in new elements that allows the group to expand its horizons. |
| Coordination & Evaluation | Resists attempts to organize or structure work. | Does not openly resist coordination of work, but often does not follow the plan put in place by the group. | Accepts the group's plan but does not participate in its construction. | Gives ideas and assists in the coordination of the group's activity. | Evaluates the group's progress and helps structure the group's work. |

*Communication & Listening*

| | -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|---|
| Communication | Absent; Wonders around; is not present for communication. | Doesn't express his/herself well. Attempts to explain ideas, but they remain unclear. May become frustrated as a result. | Expresses his/herself well and gives supporting details. | Expresses his/herself concisely with sufficient detail so that he/she is understood. | Expresses his/herself concisely and uses alternative methods of communication to facilitate the understanding. |
| Listening | Does not pay attention to group activities or attempts to communicate. | Does not seem to listen to others all of the time. Seems distracted. | Listens to others, turns toward them to show attention. Reads what others have written/drawn/found during searching. | Listens to others and asks questions to ensure understanding. | Listens to others, asks questions. If communication is unclear, they will propose alternative communication methods to facilitate. |
| Reactions & Feedback | Does not engage in discourse, even if his/her opinion is asked. | Does not give developed responses. May be frustrated when his/her ideas are not understood or when an explanation is requested. | Feedback is often simple (yes/no) with little detail. | Developed responses to both verbal and non-verbal communication. | Developed responses that attempts to integrate multiple perspectives. |

***Teamwork***

| | -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|---|
| Communication | Does not engage in the work or works on tasks alone before coordinating with others. Unreliable, may be resistant. | Agrees to do work when asked. Will sometimes take on roles. May dominate the group (does not share). | Agrees to work on his/her tasks. Takes on those tasks that are most interesting to him/her. | Makes efforts to divide work equally amongst group members. Takes on roles but leaves space for others to contribute. | Willing to adapt and take on needed roles (interchangeability) according to the group's needs. Divide's the work equally and does his/her part of the work. |
| Listening | Pursues his/her own interests and objectives. | Struggles to reconcile the group's objectives with their own objectives. | Agrees to the group's objectives but does not contribute to them. | Contributes to the definition of the group's objectives. | Contributes to the definition of the group's objectives while trying to balance between the needs of all members. |
| Reactions & Feedback | Refuses to engage in team-building activities. Actively attempts to distract the group. | Pursues social conversations to the detriment of the group's collaborative work. | Participates in team building activities but does not initiate them. | Suggests team-building activities and engages in them at appropriate moments. | Encourages and suggests social interactions which favor team building. Able to refocus the group when they are off topic. |

### *Social Intelligence*

| | -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|---|
| Interpersonal Conflict Resolution | Is the source of interpersonal conflicts in the group. | Ignores interpersonal conflicts and does not attempt to resolve them. | Attempts to resolve conflicts, but with difficulty. | Attempts to resolve interpersonal conflicts and succeeds in bringing the group back to work. | Encourages diverse viewpoints and resolves conflicts within the group. |
| Emotional Needs Responsiveness | Does not recognize the emotions of others or exacerbates the situation. | Recognizes others' emotions but does not respond to them. May not see the emotions as valid. | Recognizes others' emotions, but the response is very brief, not addressing the root or attempting to adapt to them. | Recognizes others' emotions and attempts to respond to them. Recognizes good ideas and encourages others. | Recognizes others' emotions. Thanks others for contributing. Makes attempts to encourage individuals as well as the group. |
| Shared Talk Time | Cut others off when speaking several times. | Cut others off occasionally, but even if he/she realizes it they will continue talking | Cuts others off, but realizes/ apologizes and lets the person finish | Does not cut others off, shares discussion time | Does not cut others off, shares discussion time, proposes a strategy to divide talk-time equally among group members. |

***Constructive Conflict***

| | -2 | -1 | 0 | 1 | 2 |
|---|---|---|---|---|---|
| Maintaining Shared Notions | Doesn't pay attention to what others are doing; does not realize when differences occur; continues working on his/her own ideas | Notices divergence but does not make efforts to resolve the conflict. | Proposes solutions to ensure maintenance of shared notions from time to time. | Enters constructive dialogue with others and can accept being wrong. | Integrates others' opinions into his/her solutions; guides the constructive dialogue in the group; Successfully repairs divergence |
| Debate | Does not contribute to debate | Arguments are unclear, poorly constructed and undetailed. Arguments may be counterproductive. | Reasoning is clear and developed but struggles to respond to other's challenges. | Clear, detailed arguments. Debates without issue. | Clear arguments supported by examples. Helps / supports others defend their ideas. |
| Open Mindedness | Attempts to impose his/her opinions. Judges others' suggestions quickly and in such a way that it may cause interpersonal conflict. | Is resistant to new ideas/approaches; Rarely asks for others' opinion. Judges ideas quickly. | Accepts others' opinions but does not ask for them. Generally open to new approaches. | Asks for others' opinions; does not judge others' ideas before they are completely expressed. | Asks for other's opinions. Does not judge other's ideas but asks questions to understand them in order to better integrate or provide feedback. |