Écosystème pédagogique et artéfacts épistémiques :

des environnements d'apprentissage qui favorisent l'engagement étudiant

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RÉSUMÉ

Les données probantes actuelles étayent fortement l’efficacité de l’enseignement sous forme d’apprentissage actif centré sur l’étudiant. Cette démarche est une forme d’apprentissage social, permet la participation des étudiants dans des travaux de collaboration et nécessite un nouvel engagement pédagogique des enseignants. Les enseignants des cégeps du Québec adoptent de plus en plus ces nouvelles pratiques d’enseignement. Ils investissent aussi dans la construction d’espaces d’apprentissage novateurs appelés classes d’apprentissage actif (CLAAC). Les CLAAC utilisent souvent des technologies de l’information et des communications (TIC) comme les ordinateurs, les appareils personnels et les tableaux blancs interactifs. Ce mariage entre l’espace, la technologie et la pédagogie ouvre la voie à de nouvelles possibilités et de nouveaux défis. La présente étude portait sur plusieurs problématiques importantes à propos de l’enseignement qui a lieu dans les CLAAC et elle fournit des pistes et des lignes directrices pour soutenir les efforts des enseignants et la participation des étudiants.

Cette étude cherchait à répondre aux cinq questions suivantes : (1) Quels types d’enseignements sont utilisés dans les CLAAC? (2) L’engagement pédagogique de l’enseignant influence-t-il la mise en œuvre de stratégies centrées sur l’étudiant? (3) Quels types d’artéfacts les étudiants produisent-ils dans le cadre de cours enseignés dans les CLAAC par des enseignants utilisant une démarche centrée sur les étudiants? (4) Les CLAAC à forte composante technologique suscitent-elles une plus grande participation des étudiants que les classes à faible composante technologique? (5) La démarche de conception impliquée dans la production d’un type particulier d’artéfact qui pourrait être un outil d’apprentissage en profondeur efficace, selon une hypothèse formulée par les auteurs.

La recherche a été divisée en trois parties. Les première et deuxième études utilisaient des études de cas et des méthodes de recherche mixtes et portaient sur les quatre premières questions. La troisième étude utilisait une démarche de recherche fondée sur la conception (Design-Based Research ou DBR) qui consiste à concevoir et à améliorer de façon itérative une intervention éducative. Les trois études ont été menées dans trois collèges anglophones de l’île de Montréal. Toutes les données ont été recueillies dans le cadre de cours enseignés dans des salles de classe identifiées comme étant des CLAAC (à forte ou à faible composante technologique). Les participants comprenaient 19 enseignants provenant de huit disciplines : physique, chimie, biologie, mathématiques, psychologie, histoire, sciences humaines et anglais. Le nombre d’étudiants participant à l’étude est de 734 (N = 734). L’étude n° 3 a sélectionné un sous-ensemble d’enseignants en physique provenant de l’étude plus vaste, dans les trois cégeps.

L’étude n° 1 a démontré que, en moyenne, les enseignants utilisaient des démarches d’enseignement centrées sur les étudiants plus fréquemment que les démarches centrées sur l’enseignant. Plus d’enseignants utilisaient davantage de démarches centrées sur les étudiants (c.-à-d., des travaux de groupe, des travaux individuels, des discussions en grand groupe et des présentations des étudiants) plutôt que des présentations magistrales et des démonstrations. Les résultats démontrent aussi que l’engagement pédagogique des enseignants est le même, peu importe le cours, la section ou le type de CLAAC (à forte ou à faible composante technologique). Enfin, cette étude démontre que, bien que les 19 enseignants puissent être considérés comme de grands utilisateurs de méthodes pédagogiques centrées sur les étudiants, la façon dont ils orchestrent ou mettent en œuvre les activités peut être classée dans l’un des

quatre groupes suivants : groupe 1 — un grand nombre d'activités en groupe de courte durée; groupe 2 — quelques activités en groupe de longue durée; groupe 3 — activités en groupe moins fréquentes et plus courtes; groupe 4 — une anomalie représentant deux des 19 enseignants.

L'étude n° 2 a étudié l'engagement des étudiants et la production d'artéfacts. Les résultats démontrent que, dans 97 % des cours observés, les tâches centrées sur les étudiants ont généré une forme quelconque d'artéfact. Dans l'autre 3 % où aucun nouvel artéfact concret n'a été généré, les étudiants ont participé en se servant d'artéfacts qui avaient été produits précédemment (p. ex., lors des présentations des étudiants) ou ont participé à des discussions entre pairs. D'autres résultats démontrent que les artéfacts ont été produits dans un contexte : (1) espace public (n = 46) vs espace privé (n = 31); (2) en groupe (n = 88) vs de façon individuelle (n = 7), les deux types ont été produits (n = 54); utilisés une fois seulement (n = 126) vs conçus pour être réutilisés (n = 10) vs les deux une seule fois et réutilisés (n = 16); et en contexte analogique (n = 46), numérique (n = 51) et en combinant plusieurs médias (n = 55). Bien que les CLAAC à forte composante technologique présentent de nombreux avantages, nos résultats suggèrent que la technologie n'a pas d'incidence directe sur l'utilisation de méthodes pédagogiques centrées sur les étudiants.

L'analyse par théorie ancrée a produit quatre types de modèles d'engagement entre l'étudiant et l'artéfact : (1) agent ou tuteur unique; (2) scribe; (3) chacun son tour (coopération); et (4) travail d'équipe (une vraie collaboration). Les types d'engagements sont sensibles à deux dimensions : (1) le *potentiel du regroupement (*qui touche la conception de l'enseignement) et (2) l'*accès* (qui implique la démarche d'orchestration des activités).

L'étude n° 3, le projet DBR, a utilisé une méthode de coconception échelonnée sur deux semestres (F2015 et F2016) pour concevoir des devoirs et élargir l'utilisation d'artéfacts pour les cours de physique NYA. L'expérience a produit plusieurs activités intéressantes.

Les répercussions de cette étude sont les suivantes : Premièrement, il est possible d'utiliser des méthodes pédagogiques centrées sur les étudiants au niveau collégial et être quand même en mesure de voir l'ensemble du contenu des cours. En bref, les cours au cégep n'ont pas à être chargés en contenu. Deuxièmement, l'orchestration de l'apprentissage centré sur l'étudiant peut dépendre du contenu disciplinaire; nous devons donc mieux comprendre le lien qui existe entre les décisions en matière de conception pédagogique (c.-à-d., comment les activités sont conçues) et les pratiques innées d'une discipline. Troisièmement, la conception d'activités d'équipe optimales nécessite un espace d'apprentissage qui permet d'avoir accès à tous les membres d'une équipe et doit comporter des tâches complexes qui nécessitent la participation de plus d'une personne. Les enseignants doivent être conscients de la conception pédagogique et de l'orchestration des activités qu'ils conçoivent pour assurer la participation de l'étudiant. Quatrièmement, les normes et les traditions disciplinaires semblent être un aspect important de la conception pédagogique pour les activités centrées sur les étudiants. Il semble que les enseignants qui ont des modèles plus solides ont aussi plus d'antécédents de participation à des communautés de pratique centrées sur les méthodes pédagogiques comme SALTISE. Nous devons étudier la question plus en profondeur, car si ces modes de perfectionnement professionnel sont responsables de l'adoption de ces méthodes, il peut s'agir d'un modèle important qui permettra de concrétiser la réforme de l'éducation et d'en généraliser l'adoption.

ABSTRACT

Current evidence strongly supports the effectiveness of student-centered active learning instruction. This approach is associated with social learning, involve students in collaborative work and calls for a new pedagogical commitment from teachers. Quebec's college teachers are increasingly adopting such new teaching practices. They are also investing in the construction of innovative learning spaces, referred to as active learning classrooms (ALCs). ALCs often use information and communication technologies (ICTs) such as computers, personal devices, interactive whiteboards. This marriage of space, technology and pedagogy offers new possibilities and challenges. This current study addressed important issues related to the instruction that takes place in ALCs and provides insights and guidelines for supporting teachers' efforts and students' engagement.

This study addressed five issues: (1) Types of instruction is used in the ALC; (2) Impact of teacher's pedagogical commitment on implementation on student-centered approaches; (3) Types of artifacts students; (4) Engagement in High-tech ALCs and Low-tech ALCs; (5) Process of designing an extended artifact.

The research was divided into three parts. Study 1 and 2 used a case study design and mixed-methods and addressed the teacher pedagogical commitment and student engagement, respectively. Study 3 used a Design Based Research (DBR) approach, to iteratively design and improve an educational intervention. All three studies were conducted across three Anglophone colleges on the island of Montreal. All data were collected from classes taught in classrooms identified as ALCs (High-tech and Low-tech). Participants include 19 instructors (33 sections, 8 disciplines - Physics, Chemistry, Biology, Mathematics, Psychology, History, Humanities and English) and their students (N=734 students). A subset of physics teachers from the larger study were selected for Study 3.

Study 1 shows that, on average, instructors used student-centred approaches more frequently than teacher-centred approaches. More teachers, used more student-centred approaches (i.e., group work, individual work, whole class discussion and student presentations) compared to using lecture and demonstration. Findings also show that the teachers' pedagogical commitment is the same regardless of course, section, and/or ALC environment (high tech. or low tech.). Lastly, this study show that although the 19 teachers can be all characterized as high users of student-centred pedagogies, their enactments, or orchestrational patterns of activities fall into one of four types: Cluster 1, many short duration group activities; Cluster 2 few long duration group activities; Cluster 3, less frequent shorter group activities; and, Cluster 4, an anomaly representing two of 19 teachers.

Study 2 examined the student engagement and artifact production. Findings show that, in 97% of the classes observed, student-centred tasks generated some form of artifact. In the other 3% where no new material artifacts were generated, students were engaged in using artifacts that had been produced earlier (e.g., student presentations) or were engaged in peer discussion. Additional results show that artifacts were produced as: (1) public (n=46) vs. private (n=31); (2) group objects (n=88) vs. individual (n=7), both types were produced (n=54); one-time only use (n=126) vs. designed for reuse (n=10) vs. both one-time and reused (n=16); and analog (n=46), digital (n=51) and mixed media (n=55). Although High-Tech ALCs have many advantages, our findings suggest that the technology does not directly impact the use of student-centred pedagogies.

Grounded analysis generated clustering of four types of engagement patterns between student and artifact: (1) single agent/tutor; (2) scribe; (3) turn-taking (cooperation); and, (4) team-play (true collaboration). The engagement types are sensitive to two dimensions: (1) *groupness potential* (which implicates instructional design); and, (2) *access* (which implicates activity orchestration process).

Study 3, the DBR project, used a co-design approach over two semesters (F2015 & F2016) to building assignments extending the use of artifacts for Physics NYA courses. The experience produced several interesting activities.

Implications of this research are: First, it is possible to use student-centred pedagogies at the college level and still cover the course content. In short, college classes do not have to be lecture heavy. Second, orchestration of student-centred learning may be dependent on disciplinary content therefore we need to better understand the relationship between instructional design decisions (i.e., how activities are constructed) and innate practices of a discipline. Third, designing optimal Team-play activities requires a learning space that provides access to all members of a team and must involve a complex task that requires the involvement of more than one person. Teachers must be aware of the instructional design and the orchestration of the activities they design to ensure successful student engagement. Fourth, disciplinary norms and traditions appear to be an important aspect of the instructional design for student-centred activities. It appears that those teachers who have stronger patterns have also a longer history of participating in pedagogically based communities of practice - e.g., SALTISE. We need to investigate this further, if such modes of professional development are responsible for this adoption, it may be an important model that will bring educational reform to scale.

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CHAPTER 1
INTRODUCTION

Innovation in education is nothing new and has led some scholars to state: "So much reform, so little change" (Payne, 2008). Active learning classrooms (ALCs) are a recent addition to the types of learning spaces available at the post-secondary levels. This innovation is based on new ways of thinking about teaching, which in turn are grounded in social constructivists theories of learning (Lave & Wenger, 1999; Vygotsky, 1976; etc.). Quebec's universities and colleges early adopters of this innovation (Kingsbury, 2012) with dozens of new learning spaces already constructed or on the drawing boards. Over the last 10 years, colleges such as Dawson, Vanier, John Abbott and Champlain, and McGill University, in particular, have experimented with various designs of ALCs.

Research on the effectiveness of such new spaces is still in its infancy, though early results show that matching pedagogy to space is paramount (e.g., Charles, Lasry & Whittaker, 2011; 2013; Lasry, Charles, Whittaker, Dedic & Rosenfield, 2013). In other words, issues to be addressed include: how teachers design and manage the tasks students engage in; and, how space and resources allow students to engage. This study explored the impact of instructors' pedagogical commitments on their implementation of *student-centered* pedagogical approaches - also called *active learning*. It looked at the role(s) played by material and knowledge artifacts students produce and use as part of this engagement. And, it examined how these new ways of teaching in ALCs impact the nature of learning. Lastly, it explored the design process of constructing activities that can generate artifacts that are intentionally designed to be extended upon – what we call "persistent" artifacts. Results of this research provides guidelines for teachers' design of instruction and report optimal uses of these innovative ALC spaces.

Current evidence strongly supports the effectiveness of student-centered active learning instruction (Freeman, Eddy, McDonough, Smith, Okoroafor, Jordt & Wenderoth, 2014). This preponderance of evidence has led Harvard physics professor Eric Mazur to state "The evidence is irrefutable and it becomes simply unethical to continue to lecture exclusively". In contrast with lectures that leave students passively listening, student-centered active learning engages students in activities that can elicit higher-order thinking that contributes to deep learning (Bonwell & Eison, 1991). Unlike traditional instruction, the objective of student-centred approaches is the 'doing.' That is, engaging learners in meaning-making and knowledge construction, individually or jointly. Student-centred approaches are associated with social learning and often involve students in collaborative work. Such work calls for the construction of joint problem spaces (Teasley & Roschelle, 1993; Roschelle & Teasley, 1995).

As a social activity, learning produces artifacts (Engestrom, 1999). The grandfather of social learning, Vygotsky (1930/1978; 1934/1986), states that artifacts, physical or symbolic, mediate interactions between learners, and even within the learner themselves. In social settings, giving ideas an outward form means they can be shared, extended, and interlinked, in other words, it is the externalization of individual thinking (Whittaker, Brennan & Clark, 1991). Therefore, material artifacts such as concept maps, worked problems or reflective journals allow for the communication of ideas, both to self and others. Because of their mediational role, artifacts can affect the nature of the activity - i.e., how learners can engage - as well as define the goals and means of the learning (Stahl, 2002).

In sum, student-centred instruction generally calls for collaborative group work, wherein learners construct joint problem spaces. In turn, this joint work generates artifacts. To date, there is little research showing how artifacts are used in ALCs, or how the use of artifacts might be leveraged to better support new forms of learning. This study aims to fill this gap.

1.0 PROBLEM DEFINITION

Quebec's college teachers are increasingly adopting new student-centred teaching practices. These teaching practices are influenced by pedagogical commitment, also considered teacher pedagogical beliefs (Ertmer, 2005). Key factors indicating a teacher's pedagogical commitment include the nature of the work their students are asked to do, the types of technologies teachers choose to use, and the types and amounts of feedback their students receive while learning (Friesen, 2010). Roschelle and colleagues (Roschelle, Patton, Schank, Penuel, Looi & Dimitriadis, 2011) talk about the necessity for teachers to be innovators who understand how to leverage the affordances of new techno-pedagogical tools to create affective instruction as well as able to improvise teaching and learning in-situ. In particular, these authors draw attention to the processes and outcomes of the dynamic formative feedback from the students' interactions and outcomes that are part and parcel of new learning conditions. Evidence collected over the last two decades supports a strong link between pedagogical commitment and student engagement (Bransford, Brown, & Cocking, 2000; Engle & Conant, 2002; Kun, 2001, 2003; Jacobsen, Friesen & Saar, 2010). Meta-analyses of the educational technology literature show pedagogical commitment and instructional design are interdependent (Bernard, Abrami, Borokhovski, Wade, Tamim, Surkes & Bethel, 2009; Schmid, Bernard, Borokhovski, Tamim, Abrami, Wade, & Lowerison, 2009). In turn, studies report increases in students' cognitive and applied engagement when teachers use more student-centered approaches (Freeman, et al., 2014; Gebre, Saroyan & Bracewell, 2012; Prince, 2004). Taken together, these bodies of research suggest an inter-relationship between teacher pedagogical commitment, instructional design used and student engagement. What is still not well understood is the practical aspects of the instructional design, and enactment of pedagogies such as student-centred approaches, and how these might afford and/or constrain student engagement that promotes learning.

While changes are still being made on the teaching front, many Quebec institutions are investing to construct innovative learning spaces, referred to as active learning classrooms (ALCs). The number of ALCs within the Province has increased considerably since the last official report (Kingsbury, 2012). ALCs often use information and communication technologies (ICTs) such as computers, personal devices, interactive whiteboards. This marriage of space and technology offers new possibilities for learning and teaching by facilitating communication between students and teacher, inside and outside the classroom. These come with a cost to financial and human resources. For instance, an earlier study conducted by the authors focused on the impact of teachers' assignment to ALCs, the results identifying pitfalls if the teacher's pedagogical commitment didn't match the teaching environment (Charles, et al., 2013; Lasry, et al., 2013). Such issues are critical both to the decision making related to construction of new classrooms. But, more importantly, for how to support teachers who wish to use these new spaces in their decision making in regards to instructional design and *orchestration* of activities. Ultimately, the aim of both these spaces and the new pedagogies are to improve the learners' experience, which in turn involves engaging them meaningfully with the instructional opportunities and the resources within these new environments. This current study addressed these important issues and provide guidelines for supporting teachers in their use of new pedagogies and the innovative classrooms.

1.0.1 What is Student Engagement?

Early research on the topic of student engagement characterized it as an individual and psychological construct. More often than not, the focus has been on motivational aspects of learning. For instance, Brophy (1983) describe it as time-on-task, Natriello (1984) as feelings of belonging versus being disenfranchised and Newmann, et al. (1992) as the investment of effort towards the goal of learning and understanding. Also focused on the psychological, Pintrich and de Groot (1990) identified the use of cognitive, metacognitive and self-regulatory strategies as indicators of engagement. In addition, Jonassen and Carr (2000) and Richardson and Newby (2006) identify mindfulness and metacognitive awareness as critical aspects of student engagement. More recently, Fredricks, Blumenfeld, and Paris (2004) have studied aspects of cognitive engagement, and identified the use of different strategies as students learn – i.e., deep/structural strategies producing meaningful, or mastery learning versus surface/superficial strategies producing rote or performance learning. Bringing many of these ideas together, Gebre, Saroyan & Bracewell (2012) report four dimensions that account for students' success in active learning environments: (1) cognitive and applied engagement, (2) social engagement, (3) reflective engagement and (4) goal clarity.

Factors affecting Student Engagement

Over the past two decades, with the expansion of education and social-constructivism, a growing awareness of the multidimensional nature of student engagement has increased. These studies have shown the importance of the pedagogical commitment of the teacher and how the learning activities are designed (Bransford, et al., 2000; Engle & Conant, 2002; Jacobsen, Friesen & Saar, 2010). More recently, the education technology literature has documented the factors that influence the effectiveness of the use of computers in learning. These studies demonstrate that it is important to recognize that the pedagogical commitment and instructional design are interdependent (Bernard et al, 2009; Schmid et al., 2009).

1.0.2 Measuring student engagement

Recent investigations into the nature of epistemic thinking suggest that it is best observed and studied in context (in situ) (e.g., Hofer, 2004; Knight, et al., 2013; Sandoval, 2014). In particular, examination of the participation patterns as they go about the work of building and using knowledge. According to Sandoval (2014) a change in students' patterns of participation is both an indicator of a shift in their epistemic perspective as well as suggests what particular epistemic ideas existed in the first place.

This study used similar methodology involving ethnographic research design (also referred to as an action-oriented approach) to explore our students' engagement patterns as they work within the new learning environments. There is reason to believe that the context of collaborative learning is an ideal place to observe these types of interactions in their most natural setting (Knight, et al., 2013). We elaborate on this topic in the Methods section.

1.1 ACTIVE LEARNING CLASSROOMS

What are ALCs and how are they different from traditional classrooms? In these new rooms, tables designed for group work replace the rows of desks, and individual workspaces (e.g., notebooks) are replaced by wall-mounted writable surfaces (e.g., static or interactive). In ALCs the spatial layout and architecture are designed to suggest a student-centeredness to the activity - i.e., the teacher is not at the "front" of the room but in closer proximity to all students. Lastly, they are often technology-rich environments (computers, personal devices, interactive whiteboards) that allow for easy communication and networking between students and teacher, inside and outside the classroom. Examples of projects that have developed such innovative spaces include TEAL (Technology Enabled Active Learning) at the Massachusetts Institute of Technology (Dori & Belcher, 2004), SCALE-UP (Student-Centered Activities for Large Enrollment Undergraduate Programs) at North Carolina State (Beichner, Saul, Abbott, Morse, Deardorff, Allain & Risley, 2007) and ALCs at the University of Minnesota (Brooks, 2011).

The ALCs were designed to facilitate active learning. Charles and colleagues have shown that, when used with active learning, ALCs are very effective. However, if a teacher-centered pedagogy is used, ALCs could interfere with learning (Charles, et al., 2013; Lasry, et al., 2013). Research on the effectiveness of active learning pedagogies suggest that their success depends on the degree of student engagement in the learning process, that is to say in what they are required to do (Prince, 2004). And, what students are required to do depends on the design of the learning activities. Arguably, the design of such activities should match the learning objectives with the available infrastructure, including the technologies embedded into the learning spaces. What is not yet known is whether and how teachers design their activities to take up the affordances for new ways of learning offered by these new spaces.

1.1.1 Role of ICT in ALCs

Information and communication technology (ICT) plays an important role when it comes to creating learning opportunities and in facilitating the creation of other tools that contribute to the conditions necessary for learning (Barbeau, 2006; Poellhuber, 2007). For example, technology can be used to support the cognitive, reflective and social processes: the visualization of abstract knowledge (simulations, interactive models); concept maps; and the creation of shared objects for collaborative activities (knowledge networks as knowledge forums, wikis). In addition, technology enables student engagement in authentic and guided activities and thereby increases the opportunities to use scientific language and tools (Slotta, 2015). This is particularly useful given the increasing role that technology plays in enabling teachers to identify the learning environment that moves learning outside the classroom walls and increases student engagement. The question of how to link the individual and the collective and how to orchestrate between activities and artifacts produced at different levels of student engagement is one that needs to be explored further.

According to Hakkarainen and colleagues "Only when ICT- based tools in general and collaborative technologies in particular have been fully merged or fused with social practices of teachers and students, are their intellectual resources genuinely augmented and learning achievements correspondingly facilitated (Hakkarainen 2009, p 214)." He takes an "object-centered" view of human activity that he calls "trialogical." Taking a socio-cultural approach, that features learning as a phenomenon that takes place within a community of practice, Hakkarainen underscores a provocative question of how we create these classroom cultures. Does the emphasis on activity, brought on by active learning and supported by the designs of ALCs, produce this new object-centeredness? And, if so, what classroom cultures engage students in the production and visualization, reflection and transformation processes inherent in object-creation? Taking knowledge outside the heads of the individual and asking them to contribute to some joint task. Hakkarainen talks about the conceptual and material aspects of advancing ideas and knowledge building. Ideas given outward form, which allows them to be shared, and leads to the *rise-above* – the expansion of the idea – these are considered conceptual artifacts, and facilitate predicting and explaining (Bereiter, 2002). We ask the question of whether or not environments that allow for the persistence of jointly constructed artifacts would provide a space for artifacts to become true conceptual artifacts and generate more trialogical discourse, as evidenced by the transformation of the artifact.

1.2 RESEARCH OBJECTIVES

1. To better understand the types of instruction used in ALCs. We accomplish this goal by: (a) documenting the kinds of pedagogy used in ALCs; (b) examining the relationship between teachers' implementations of student-centred instruction and their pedagogical commitment. Research Question #1 and #2.
2. To document the kinds of artifacts student produce in courses taught in the different ALCs types, across the three colleges. And, to examine the ways students engage with each other during the production of these artifacts. Research Question #3.
3. To examine how different ALCs may impact student engagement during student-centred instruction. And, what factors may also be at play in determining the activities teachers use. Research Question #4.
4. To conduct a "design-based research" study (see definition), aims to develop an engaging curriculum through a set or a sequence of dynamic and transformative production artifacts. This step is guided by the thinking that it is necessary to consider optimal ways to manage and use these artifacts (that is to say, the pedagogical orchestration). Designing the learning program through the establishment of a technology artifacts at the same time facilitate the migration. In addition, we will use information technology to facilitate the migration of artifacts. Research question #5.

1.3 RESEARCH QUESTIONS

1. What types of instruction is used in the ALC?
2. Does the teacher's pedagogical commitment impact the implementation of student-centered approaches?
3. What types of artifacts do students produce for courses taught in the ALC by student-centred teachers? How do students engage during the production of these artifacts? What patterns of engagement are observed?
4. Do High-tech ALCs engage students more than Low-tech ALCs? What other factors have an impact on student-centred activities – e.g., the disciplinary filed?
5. How do students engage and learn with activities that focus on the production of persistent (or extended) artifacts? How is this learning different from other traditional learning?

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CHAPTER 2
THEORETICAL FOUNDATIONS AND RATIONALE

Social constructivist theories view learning as participation (e.g., Lave & Wenger, 1991; Wenger, 1998). Participation is defined as a social process of knowing which encompasses meaning, practice, community and identity. Over time the learning engaged in during social actions, in pursuit of a shared enterprise, results in practices that reflect the enterprise as well as the social relationships. Thereby, it is the participation in legitimate practice with others that results in learning. A key assumption is that knowledge is constructed from experiences with the world, including use of tools such as language, inscriptions, and disciplinary artifacts and practices that mediate learning (Vygotsky, 1978). The theory of *situated cognition* informs us about the process of learning and highlights the need for learning activities to be contextualized and embedded in *authentic activity* (i.e., realistic and/or typical to the domain), context and culture of the domain users (Brown, Collins & Duguid, 1989; Lave, 1988; Lave & Wenger, 1999). Student-centred instruction is built on such social constructivist theories and attempts to design for students' participation in practices that can lead to engagement in meaningful activities.

2.0 STUDENT-CENTRED INSTRUCTION

Student-centred instruction, also called active learning, is defined as designed activities that require students to engage in doing (cognitive engagement), and thinking about what they are doing (metacognitive engagement), often accomplished in social settings (social engagement) around content that is situated in an appropriately meaningful context (emotional engagement). "To be actively involved, students must engage in such higher-order thinking tasks as analysis, synthesis, and evaluation" (Bonwell & Eison, 1991, p.1).

Studies show that active learning instruction significantly decreases failure rates (Freeman et al., 2014) and increase the ability of students to incorporate their own knowledge (Prince, 2004). Additionally, evidence suggests that such approaches increase students' commitment to deeper learning processes, such as self-regulation (Azevedo, 2007), and metacognitive processes such as decision making and questioning (Lin, Hmelo, Kinzer & Secules, 1999).

While active learning pedagogies are increasingly being adopted by more teachers in higher education (Freeman et al., 2014), what counts as active learning is varied (Prince, 2004). Based on these meta-analyses, teachers who use these new pedagogies do so as what we are calling spontaneous interventions - i.e., introducing collaborative and constructivist activities that sit alongside traditional lecture (or what is considered "mini" or "interactive" lectures). In short, the reality of active learning at the post-secondary levels does not necessarily involve a re-examination or revision of entire programs or coherent curricular change. Instead, they appear to consists of these smaller investments that may or may not form a coherent pedagogical system.

As an instructional approach, active learning pedagogies frequently can be characterized by their assembly of coherent sequences of tasks which aim to achieve some defined objective - e.g., promote self-explanation and reflection, promote collaborative processes. These assembly of tasks, what we might call "scripts" or workflows, generally can be categorized into two main types:

(1) *prescribed interventions* that involve longer time commitments; and, (2) *spontaneous interventions* that involve short time commitments. Examples of the first include the well-known Problem-Based Learning (PBL; e.g., Hmelo & Barrow, 2006) approach, as well as others such as Project-Based Instruction (e.g., Barron, Schwartz, Vye, Moore, Petrosino, Zech & Bransford, 1998), Inquiry-based Instruction (Edelson, Gordin, & Pea, 1999) and Learning by Design or LBD (Kolodner, Camp, Crismond, Fasse, Gray, Holbrook & Ryan, 2003).

Spontaneous interventions, on the other hand, include the low-cost strategies such as think-pair-share, which has gained world-wide attention under the title of Peer Instruction (Mazur, 1997; Lasry, Mazur, & Watkins, 2008); and, strategies that promote reflection - e.g., minute papers (Angelo, & Cross, 1993), concept mapping (Novak, 1990). Not included in these two models are activities that extend instruction outside of the classroom - i.e., Flipped Class approaches (Tucker, 2012). Examples of these include reflective writing (Kalman, Aulls, Rohar & Godley, 2008) and "just-in-time (JiTT) teaching "(Novak, Patterson, Gavrin, Christianv & Forinash, 1999).

However, they do not have the necessary program coordination on the large scale. Moreover, a new research theme, *orchestration*, studies the coordination of these small teaching units (Dillenbourg, Jarvela & Fischer, 2009).

2.0.1 Collaborative vs. Cooperative Learning

In general, active learning pedagogies have capitalized on social interactions to foster collaboration and cooperation among participants. We define collaboration as mutual commitment by concerted individuals working together on a specific task (Roschelle & Teasley, 1995). On the other hand, cooperation is generally considered the distribution of tasks or the distribution of work (Dillenbourg, Baker, Blaye & O'Malley, 1995). Dillenbourg and Jermann (2010) report that collaboration is not a recipe to follow lightly. This requires careful design to ensure that groups engage in productive interactions, such as creating spaces for shared tasks. A collective portfolio is an example (Driver, Asoko, Leach, Scott., & Mortimer, 1994; Roschelle & Teasley, 1995).

2.1 OBJECT-ORIENTED ACTIVITY

Activity Theory is consistent with the socio-cognitive and socio-cultural conceptions of learning. It describes socially based actions and the development of practice, which in turn produces social outcomes (Engeström, 1993; 2001; Leont’ev, 1974, 1981, 1989; Nardi, 1996; Vygotsky, 1978). From this perspective, activity is described as transformation, therefore, it refers to “doing in order to transform something” (Barab & Plucker, 2002).

According to the theory, activity is comprised of four triangular relationships. First generation activity theory focuses on mediated action (Vygotsky, 1978) – the top portion of the triangle. Second generation activity theory focuses on activity as human practice (Leont'ev, 1981) – the bottom portion of the triangle. The Activity Theory model highlights six factors that interact to produce the system’s outcome (see Figure 2.1). These factors include the following: the subject (who is involved in carrying out the activity), the tools (the means of carrying out the activity), the object (the reason the activity is being carried out), which in turn are influenced by the rules (the cultural norms and standards that govern the performance of the activity), the community (the context or environment of the activity) and the division of labour (who is responsible for what when carrying out the activity – roles).

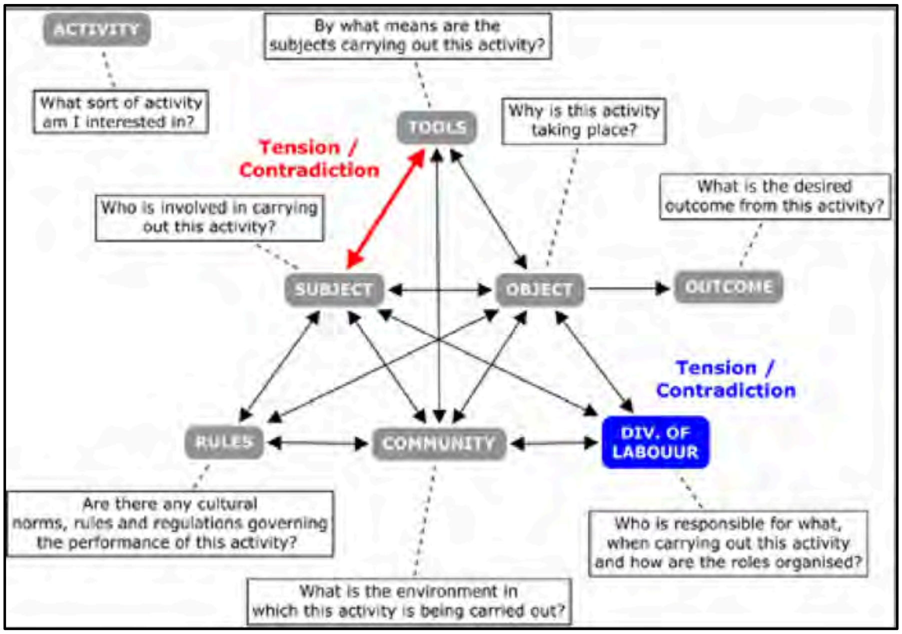

Figure 2.1 Description of the relationships within Activity Theory triangles. Figure from http://phdblog.net/tag/activity-theory/

Third-generation activity theory, which we will focus on in this current study, offers a theoretical and methodological approach to describe and examine the complexities generated by the interaction of human learning across at least two activity systems (Engeström, 2009). In other words, learning at the level of the collective (group and class) is influenced by the contributions of multiple individuals. The resources/tools used by the individual represent their own activity system, which comes together with the resources produced by the collective. The overlapping space where the outcomes of the two activity systems overlap (see Figure 2.2). This process helps to account for the transformations and creations of new forms of activity that are the result of the crossing boundaries or boarders (Gutierrez, Bien, & Selland, 2011). An example of this would be the creation of artifacts that are the outcome of one system but taken up by another as a resource. For instance, the entry in a student's reflective journal that is taken up by the teacher to create a collective document that represents the students' point of view – the example we have used before.

We are interpreting these Activity Triangles as an epistemic framework, that is to say a representation of the all the elements required to complete an activity-object. The subject (individual or group) interacts with the Rules (the classroom culture the teacher brings from their own pedagogical commitment), the Community (or rather what the community brings: the classroom environment), the Tools (resources: physical and virtual, private and collective) and how tasks are distributed, to produce the activity artifact, or the target Object. This study used this framework and these elements as a first iteration in identifying the elements important in this study.

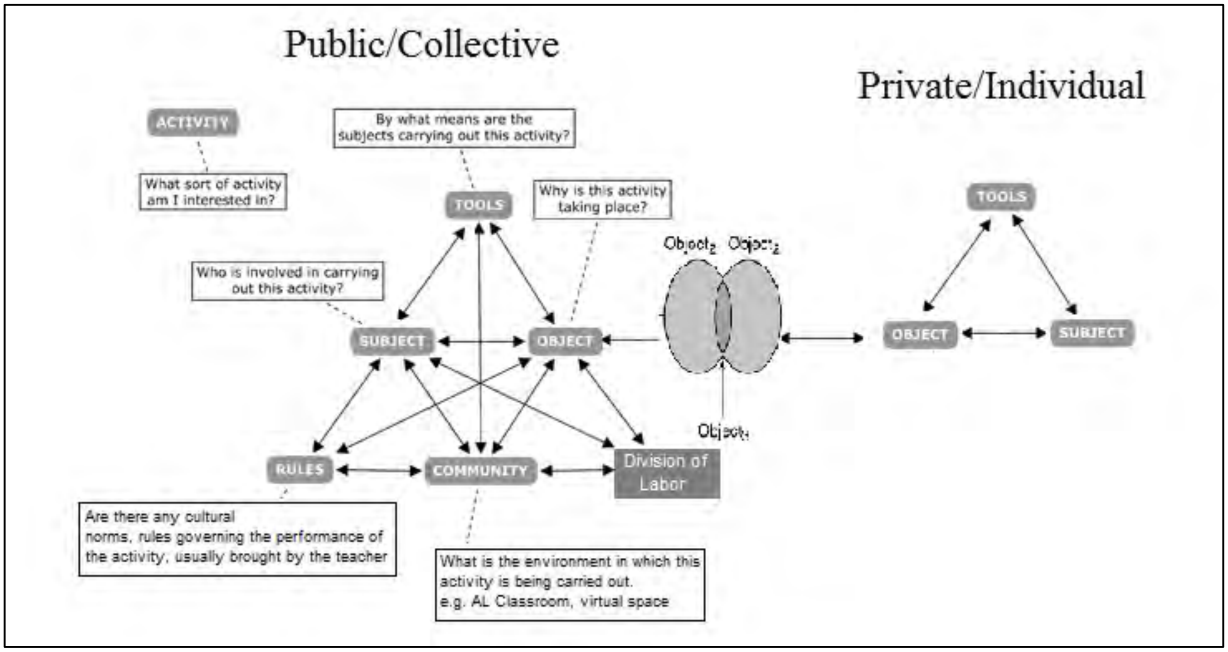

Figure 2.2 A representation of Activity Theory triangles, showing how epistemic elements combine into a system. Both group and individual activities can produce objects that further interact to produce a third transformed object.

2.1.1 Epistemic and dynamic artifacts

ALCs have created a new type of learning environment that unites learning pedagogies and technology. Teachers may develop meaningful activities that allow students to work together or individually to produce knowledge artifacts. In turn, these artifacts take on a new form, sometimes aggregated, sometimes transformed by iterative review process, when reused by the same people. Integrated technology for ALCs plays a role in helping these artifacts to move from one form to another.

The individual log entries of a reflection journal could, for example, be grouped to create a common learning document that shows the major misconceptions of the class, while preserving the anonymity of the students. This new aggregated artifact can then be used in the classroom, by the teacher to tackle issues, or by students as a focal point for other activities. To give another example, a concept map could be created collectively on a whiteboard by a group of students, and then be reviewed by a second group. The teacher might even give as homework to students individually to review this collective concept map.

This recycling process would then produce a new artifact, different from the first, with a new meaning for the participating students. A dynamic learning artifact similar to these that have identified by James D. Slotta and colleagues (Peters & Slotta, 2010; Slotta, 2015; Tissenbaum, Lui & Slotta, 2012). This new educational resource exists only in the context of active learning classes for this type of pedagogy. Important questions arise from these observations. What is the significance of these dynamic learning artifact in an ALC? How, from this product and this process, can we create an educational solution to the problem of student engagement? Could such an artifact assess the individual learner as well as the group? What does this type of education mean for the teacher? How should it coordinate the development of such artifacts in a time frame and within the learning ecosystem (public and private spaces)?

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CHAPTER 3
OVERVIEW OF RESEARCH METHODS

This research was divided into three studies, and used a mixed-method design, which allows for the collection of both qualitative and quantitative data. The data were collected throughout 4 academic semesters, 2015 fall, 2016 winter, 2016 fall, and 2017 winter.

Study 1: documented the pedagogical practices of the teachers whose courses were conducted in ALCs across the three colleges.

Study 2: examined how students engaged and produced artifacts that use the affordances for learning designed into different types of ALCs (high-tech and low-tech).

Study 3: examined the design of instructional interventions focused on development of extended or persistent artifacts.

3.0 RESEARCH DESIGN

Study 1 and 2 used a case study design (Merriam, 1998, Yin, 2009) and mixed-methods of data collection. The data corpus includes: classroom observations collected through ethnographic methods (field notes, video/audio recordings), teacher interviews, collection of student and teacher artifacts.

Study 3 used a *Design Based Research* (DBR) is a methodological approach that allows researchers to work with teachers to produce learning interventions. DBR consists of iterative cycles of implementation and testing to ensure an adaptation of the theory to the real conditions of the educational context. The method must take into account the real opportunities and limitations of the educational context in which the intervention will be implemented. In fact, DBR uses mixed methods of data collection to ascertain a base understanding of the work in question. In doing so, the findings of studies using DBR are directly applicable to the local environment and help to plan the general principles for creating subsequent educational interventions.

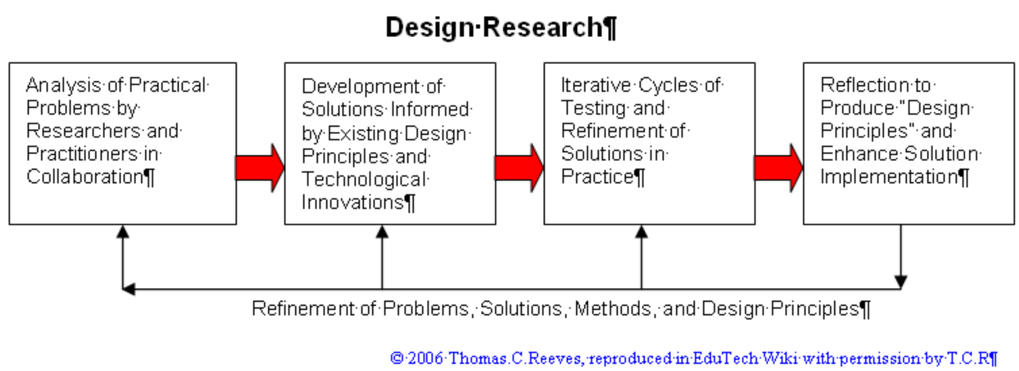

Figure 3.1 Description of processes involved with design-based research.

The quasi-experimental design built into the DRB project was used to examine specific aspects of the production process and how they influence the product and its use: migrating to collective from individual artifacts compared with migrating to individual from collective artifacts; public going to private artifacts; static artifacts to dynamic artifacts (see Table 3.1).

Table 3.1 Description of the five treatment sections – i.e., student numbers, institution, instructor and instructor's experience with active learning, and classroom setting.

Section	T1 (hon)	T2(reg)	T3(hon)	T4(reg)
Student #s	n=23	n=26	n=31	n=18
Institution	College1	College 1	College 2	College 2
Classroom setting	Hi-tech	Hi-tech	Mid-tech	Hi-tech
Teacher	T1	T2	T3	T4

3.1 PARTICIPANTS AND SETTING

Study 1 and 2 used a purposeful sampling approach to recruit a total of 19 instructors across the three institutions, representing 33 course sections across 13 courses, and eight disciplines - Physics, Chemistry, Biology, Mathematics, Psychology, History, Humanities and English. The class sizes of these sections ranged from 15 to 40 students. The study includes only data from students who gave consent (N=734 students). The majority of these participants were in their first year of study and between the age of 16-19. Student profiles were representative of their respective college's demographics. Study 3 selected a subset of physics teachers from the larger study, and from all three colleges.

Caveat. The population of teachers who teach in ALCs across the three colleges may not be representative of the all college teachers because, generally, these individuals have selected to teach in these new spaces. Additionally, each college has developed a learning community to support the training and development of teachers who use these new learning spaces. One of the colleges, in particular, has created a strong community with over 100 teachers who regularly participating in training and professional development activities.

The study was conducted across three Anglophone colleges on the island of Montreal. All data were collected from classes taught in classrooms that have been identified as active learning classrooms. Characteristics of the ALCs fall into two types: (1) high-tech (e.g., interactive writable board and desk computers); and, (2) low-tech (e.g., wall-mounted white boards). All institutions had both types of rooms. The detailed features of learning spaces across three colleges are listed below. A total of nine active learning classrooms (ALCs) were involved, the distribution across institutions and the specific features presented in Table 1.

3.1.1 Features of AL classrooms

The features of learning spaces where observed classes took place are different. Generally speaking, all the three colleges have 2 types of active learning classrooms, one with high technology (e.g., interactive writable board and desk computers), and the other equipped with low technology (e.g., wall-mounted white boards). Under the umbrella of two types of rooms, however, the ones within the same category still differ to a certain degree in terms of their layout and infrastructure. The detailed features of learning spaces across three colleges are listed below.

Table 3.2 Features of Active Learning Classrooms across three colleges.

College	Type of ALCs	Layout and infrastructure of teacher's working space	Layout and infrastructure of student's working space
C1	High Tech	Teachers have a working podium and one working smart board, which are located at the front of the class.	Students sit around 6 tables, each with an additional smart board in front. All the student tables are in a circular manner. Students sat in groups. The class is arranged in a circular fashion.
	Low Tech	Teachers have a working station and a smart board located at the front of the class. There is also a projector at the back of the classroom.	White boards on the remainder of the walls around the room. Each student table sat in front of a collection of white boards, Students sat in groups. The class is arranged in a circular fashion.
C2	High Tech	Teachers have a working podium at the center of the room, and one working Smart Board on the front wall.	Five additional Smartboard on the remainder of the walls around the room. Each student round-sized table sits in front of Smartboards. There are also 3 desktop computers on each student table, one of which has control over the smartboard.
	Low Tech	A working podium for teachers sits in front of the room, and a whiteboard and a projector screen also locate on the front wall.	Students sit in lines at movable tables. A collection of whiteboards is on walls around the room. Sometimes an equipment cart with laptops is available for students as well.
C3	High Tech	Teachers have a whiteboard located at the front of the room, and a Smartboard at a corner next to the teacher whiteboard.	Three additional Smart Boards placed at the remainder of corners around the room are available for student usage. A collection of whiteboards also is on the remainder of walls of the room. Each student has his/her own movable table, and every four or eight tables placed in two lines form a group. A collection of mini whiteboards is also available for students to easily pick up from either the edge of a table or a board stand.
	Low Tech	Teachers have a multi-functional podium and a Smartboard, which are located at the front of the room.	A collection of white boards is on the remainder of walls around the room. Students sit in lines at static tables. A few hand-size mini boards available.

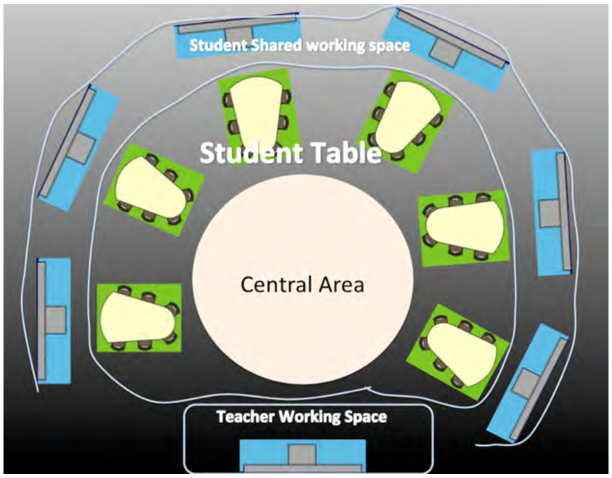

Figure 3.2 Layout of tables and technology in high-tech ALC classroom found in College #1.

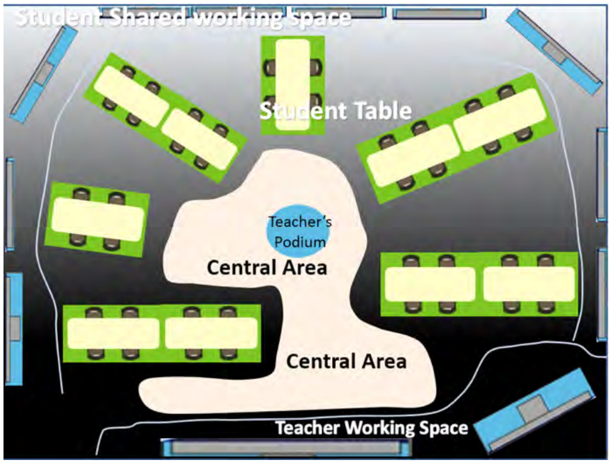

Figure 3.3 Layout of tables and technology in high-tech ALC classroom found in College #2.

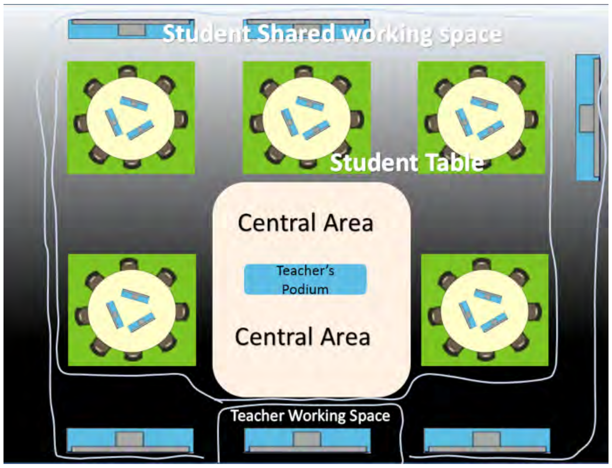

Figure 3.4 Layout of tables and technology in high-tech ALC classroom found in College #3.

3.1 DATA COLLECTION

3.1.1 Instruments used for Studies 1 and 2

Data collected for Studies 1 and 2 included the following: student artifacts, teacher interviews and surveys; and, most importantly, the classroom observations protocols. We describe each of these data sources below.

<u>Student artifacts data</u>

Artifacts generated by students were collected from activities conducted both within the class period and from online assignments. Generally, these data were obtained from photographs or screen shots of the students' publically displayed work; and/or directly from students who were asked to save their work at the end of the class activity. This copra includes a wide variety of representational types and formats – e.g., calculations, drawings, written text (see examples in Chapter 5).

<u>Teacher questionnaires</u>

1) *Teacher Artifact Production Survey* (TAPS) was designed by the authors (see Appendix B1). Its purpose was to understand how teacher generated instructional materials are (or can be) transformed into learning objects (i.e., dynamic artifacts) used by students. The survey consisted of 25 questions divided into 2 parts. Part 1 collects demographic information and whether or not technology plays a role in your course. Part 2 will ask the following: (1) the purpose of your instructional materials (i.e., artifacts) and how they are used; (2) the types of instructional materials you typically design for your lessons; (3) when and how these materials are made available; (4) the types of student-generated materials your activities might result in (i.e., artifacts produced by students), and how these are used.

The TAPS was administered twice. First it was used as interview questions with eight instructors, an average of two from each of the three colleges, at the end of the 2016 fall semester. The aim of those interviews was to gain additional insight into the purpose of the class artifacts from the perspective of instructors. Also, in 2017 winter semester, it was administered as a survey to teachers whose classes had been selected for observation previously. A total of 20 surveys were collected.

2) *Post-secondary Instructional Survey* (PIPS; Walter, Henderson, Beach & Williams, 2016), introduced earlier, is a 32-item survey intended to assess a teacher's commitment to different approaches of teaching and learning - 24 items measure pedagogical commitments and 8 demographic information (see Appendix B6). It consists of 11 items describing what instructors expect from students' engagement in regard to their instruction and learning are based on the Faculty Survey of Student Engagement (FSSE), developed as a complement to the National Survey of Student Engagement (2001); 13 that address real in-class teaching context, based on a critical analysis of literature and the integration of critical elements from two class observation protocols - i.e., the TDOP (Teaching Dimensions Observational Protocol; Hora, Oleson, & Ferrare, 2012) and RTOP (Piburn & Sawada, 2000). The 24 items are described as a Likert scale measure with each answer framed as a pedagogical decision. Proper face, content, and construct validities were made while developing PIPS, and the overall instrument reliability of PIPS, a=0.800, was reported (Walter et al., 2016). The PIPS was administered during the 2016-2017 academic year to a cross-

section of teachers who taught in ALCs, at the three colleges. A total of 28 surveys were collected.

3.1.2 Classroom Observation Instruments and Protocol

Studies 1 and 2 collected data across five academic semesters: winter 2015 (W15), fall 2015 (F15), W16, F16, W17 (see Table 3.3). These data consist of classroom observations (field notes and video recordings) collected using an ethnographic approach. They represent two types of scenarios: (1) observations of the instructor's pedagogical patterns; and (2) observations of the groups interactions. For scenario 1, field notes were always collected, and sometimes included video recordings. For scenario 2, field notes and video & audio recordings were collected. In the case of scenario 2, they also reflected specific observations about the groups during the collaborative portion of the activity.

All field notes used an observational protocol that was developed by the research team and used previously – a schema identifying details of the activity engaged in, who was involved (e.g., at which social plane), and what kind of artifact was produced (see Appendix B4). The protocol is similar to the COPUS (Smith, Jones, Gilbert & Wieman, 2013) but contains more details because of the nature of this particular research question and the cohort of instructors who already use active learning approaches. We performed a comparison of these instruments as a way of validating our protocol (see Appendix B5). Scenario 2 observations also included specific observations about the groups during the collaborative portion of the activity.

All video/audio recordings were made using GoPro cameras and digital recorders. Scenario 1 observations, two cameras from two vantage points were used – i.e., each camera mounted either at the front or back wall of the classroom to capture maximum information about the teacher's perspective and his/her interactions with student groups. Scenario 2 observations, cameras were also positioned at the work tables of selected groups. Generally, this consisted of two cameras per group – one mounted on a wall and the other held by a researcher to manually adjust the camera angle, as needed.

Procedure used for classroom observations

Instructors were recruited at the beginning of each semester, before the start of classes when possible. Communications with the instructor included a clear explanation of the purpose of the research and what was involved in the classroom data collection, including timing for the video recordings. All instructors included in the study agreed to these conditions and consent was obtained the associated consent form. A minimum of three classroom observations, in close sequence, were scheduled for each instructor to ensure the data accurately reflected their teaching practice. Some instructors who were the subject of multiple years of observation had higher observation numbers, the maximum being 20 observations.

Students were recruited from the class sections of the associated instructors. The research team followed the protocol outlined in the application to the Research Ethics Board (REB) of each college. This protocol included the following: in coordination with the instructor, a member of the research team spent 5-10 minutes of in-class time introducing the research project and distributing consent forms. Generally, forms wer2e returned the following class but sometimes required several reminders. Whenever appropriate, data were collected only from students had given consent. In cases where it was impossible to do so, or doing so would reveal students' decisions, those individuals were removed from data to be analyzed. See Appendices (A1, A2, A3) for copies of consent forms.

Table 3.3 Summary Table of the data collected through 2015 Winter to 2016 Winter

Year/ Semester	Colleges	# of teachers	Observa-tions	# of sections	# of class	Field of Study	Course	Classroom type
2015 F	C1	7	DT1 (16) DT2 (8) DT3 (7) DT4 (4) DT5 (11) DT6 (8) DT7 (1)	9	55	Physics, Chem. Socio., Psych.	*Physics/ NYA;NYC *Chemistry/ NYA;DW *Knowledge/ *Cultural Psy/	high tech (49), low tech (4), lab (1)
	C2	3	VT1 (8) VT2 (6) VT3 (6)	3	20	Physics, Biology, Chem.	*Physics/ NYA *Bio/NYA *Chemistry/ NYA	high tech (6), low tech (14)
	C3	2	JT1l (7) JT2 (9)	4	16	Physics	*Physics/ NYA; NYB; NYC	high tech (8), low tech (8)
	Total	12		16	91			
2016 W	C1	6	DT6 (6) DT7 (5) DT8 (8) DT9 (5) DT10 (9) DT11 (8)	7	41	Socio. Psych. History, Biology	*Biology/NYA *Knowledge/ Food/ *Psychology/Cult ural Psy; Experimental Psy *History	high tech (22) low tech (18) trad. classrm (1)
	C2	4	VT1 (4) VT2 (6) VT4 (2) VT5 (2)	4	14	Biology, Physics, Math, English	*Biology/NYA *Physics/NYC *English *Calculus	high tech (10) low tech (4)
	C3	1	JT2 (2)	2	2	Physics	*Physics/NYB	low tech (1) high tech (1)
	Total	11		13	57			high tech (34) low tech (23)
2016 F	C1	1	DT1 (4)	2	4	Physics	*Physics/NYA	high tech (38)
	C2	2	VT1 (3) VT6 (2)	2	5	Physics	*Physics/NYA	high tech low tech
	Total	3		4	9			
Total		**19**		**33**	**157**			

3.1.1 Instruments Used for Study 3

Data collected for Study 3 included student interviews, conceptual tests (FCI) and tests designed to assess the students' content knowledge. We describe these instruments below. It also included classroom observations during the implementation of the designed activities. The procedure used was the same as described above.

Student interview

Two sets of student interviews were conducted during the global study: (1) focus group consisting of 2-3 students, post intervention #2; and (2) individual student, post intervention #3. Both sets of interviews focused on designed activities of the respective interventions. Each interview session took approximately one-hour and conducted by a senior member of the research team (see Appendix B3).

Force Concept Inventory survey

We used the *Force Concept Inventory* (FCI; Halloun & Hestenes, 1985; Hestenes et al., 1992) as pre-posttest to assess student's conceptual understanding in their introductory physics courses. It is commonly known that students may not have a complete conceptual understanding of the physics described in Mechanics courses (kinematics and dynamics) even when they can solve those problems (Kim & Pak, 2002). The FCI is a 30-item multiple choice test. Constructed on years of research, it is designed to elicit deep conceptual understanding by providing learners with answer choices that include distractors compiled from the most prevalent misconceptions held by novices. Therefore, learners cannot rely on computations or memorized algorithms, instead, they need to understand the concept to identify the correct answer from the distractor answers. The FCI is one of the most validated concept assessments and most widely used instruments in physics education research (McDermott & Redish, 1999).

3.2 DATA ANALYSIS

3.2.1 Quantitative Approaches Used

Standard quantitative and statistical methods of analysis (ANOVA, MANOVA, correlational analyses) were used to analyze data including student artifacts, teacher and student interviews, and student performance (in-class activities) and outcome data (conceptual tests (FCI) and class tests).

3.2.2 Quantitative Approaches Used

<u>Interaction analysis</u> (Jordan & Henderson, 1995) were used to analyze the student engagement patterns. Interaction analysis is based on ethnomethodology (Garfinkel, 1974; Heritage, 2013). Its assertion is that order emerges from the interactions of participants. This approach looks at the ways participants engage with each other to accomplish their objectives, i.e., work with each other. This approach was used to answer RQ#3 and elaborated on in Chapter 5.

<u>Qualitative methods</u> (Corbin, Strauss, & Strauss, 2014) were used in the analyses of these data. These include using both emergent and a priori codes to sort the data. The process is described below.

Development of Coding Schema

Classroom observational data scenarios – (1) observations of the instructor's pedagogical patterns; and (2) observations of the groups interactions. For scenario 1, field notes were always collected, and sometimes included video recordings. For scenario 2, field notes and video & audio recordings were collected.

How is the coding scheme developed: the initial observational protocol and coding schema were created by the research team for previous research (Charles et al., 2013) and adapted for this new study (Fall 2014). This new protocol was tested during the Winter 2015 semester. A comparison between the initial coding scheme and COPUS is also documented in a word file). Eight types of in-class activities are included in the new version of coding scheme based on initial scheme and COPUS (how is the COPUS doing), which are Teacher Presentation, Teacher Demonstration, Student Presentation, Group Activity, Individual Activity, Whole Class Discussion, Non Instruction, and Other (short presented as TP, TD, SP, GA, IA, WCD, NI, and O, respectively). The eight codes are used during preliminary analysis, however, in practice, not all of the eight codes were applied for every session.

Coding procedure

Each class session was coded into the following categories: (1) teacher-centered (lecture/demo); (2) student-centered (group/individual/whole class/student presentation); and, (3) other (administrative work). Coding schema presented in Table 3.1. Actual time spent in each activity was then calculated and recorded for each teacher.

Table 3.4 Codes identified and used for analysis of the classroom observation data.

Lecture		Student work				Other	
Teacher presentation	Teacher Demonstration	Group Work	Individual Work	Whole class discussion	Student presentation	Administration	Other

There were 25 sections where each one has 8 codes (i.e., Teacher Presentation, Teacher Demonstration, Student Presentation, Group Activity, Individual Activity, Whole Class Discussion, Non-Instruction, and Other) to indicate what kind of activity the teacher/student are working on. Calculate the time length (in min) for every activity documented in field notes (using the starting time point of the latter activity, e.g., 9:10am, minus the starting time point of the former activity, e.g., 8:45am, which gives the time length for the former activity, 25 min in total). Please note that the latter activity and the former activity should be two distinct activities (e.g., TP Vs. GA). If multiple instances are documented in the field note and coded as the same activity (e.g., all coded as TP), then all the instances are considered to be the parts of one activity. Then put the length of time under the same code category (e.g., if the code is TP, then only put the time length under TP row) within its corresponding section (if it is the 3rd activity happening during this class, then should put the time length in the 3rd section of the spreadsheet). Therefore, each section only can be filled in with 1 code (i.e., only 1 activity for one section). All the activities should be filled in the excel spreadsheet (see Figure 3.5)

Segment#		09.10.15	09.29.15	10.01.15	10.06.15	10.08.15	10.20.15	10.22.15	10.27.15
1	TP		19		8				
	TD								
	SP								
	GW								
	IW								
	WCD								
	NI	4		8		8	6	3	5
	Other								
2	TP	2					2		1
	TD								
	SP								
	GW		38		9	2			
	IW							2	
	WCD			3					
	NI								
	Other								
3	TP		4	5	4	5		1	
	TD								
	SP								
	GW	4							30
	IW								
	WCD						9		
	NI								
	Other								
4	TP	9							15
	TD								
	SP				2				
	GW		4			4	36	1	
	IW								
	WCD			6					
	NI								
	Other								
5	TP			2	1	2	4	2	
	TD		1						
	SP								
	GW	31							7
	IW								
	WCD								
	NI								
	Other								

TP	Teacher Presentation
TD	Teacher Demonstration
SP	Student Presentation
GW	Group Work
IW	Individual Work
WCD	Whole Class Discussion
AD	Administration
O	Other

Figure 3.5 Example of the preliminary analysis excel spreadsheet.

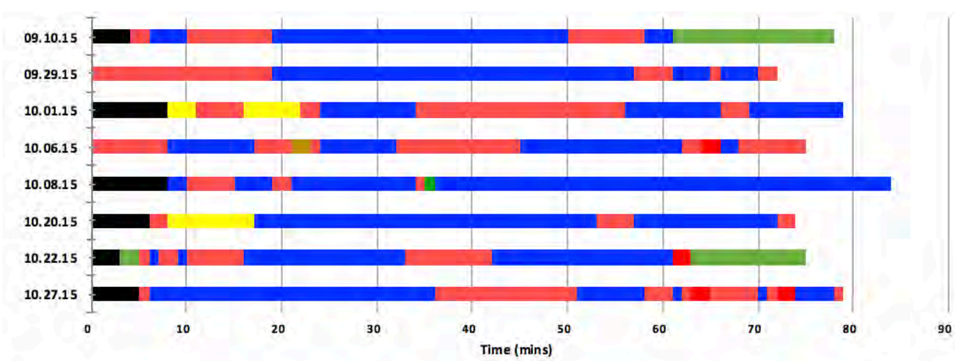

Figure 3.6 Example of the time sequence display of teacher activities.

The time-display chart is generated based on the filled-out spreadsheet. All activities are color-coded. A color-index is attached with the spreadsheet. All the activities are horizontally spread out in the chronology order. Therefore, the length of the bar shows the time duration devoted to the activity, and the color of the bar shows the category of the activity. All the different color bars also reflect the activity sequence of the class.

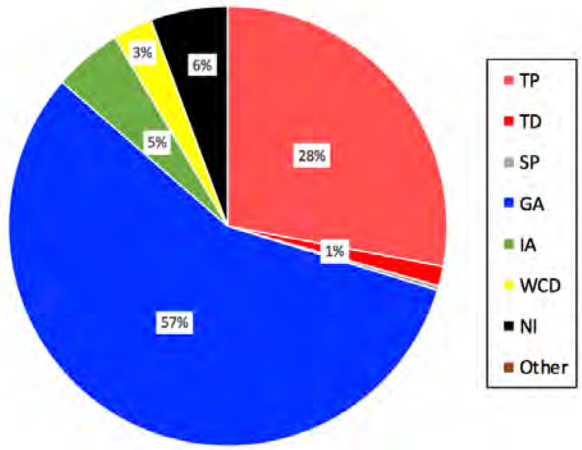

Figure 3.7 Example of the Pie chart (proportion display)

The proportion pie chart display is produced based on the excel spreadsheet as well. Instead of displaying the real sequence and the length of time for all the learning activities in one class, the purpose of the proportion display is more to standardize the data so as to easily make fair comparisons among different teachers with various numbers of sessions. For each session, the length of time for the same activity is added up so that the total length of time of the eight activities is calculated. The length of time for one section is averaged based on the eight learning activities (i.e., the eight codes) across all the sessions within. Still the eight activities are color coded using the same color index. Then the average length of time of the eight in-class activities for this section is proportioned and represented by their percentages.

3.2.3 Data Analysis for Study 3

Data for Study 3 were analyzed using both quantitative and qualitative methods. In particular, we used Spider Graphs as a way of understanding the relationships of the concepts as they changed over the longitudinal implementation. Specific details provided in Chapter 6.

3.3 SUMMARY OF METHODS

The table below (Table 3.5) provides a summary and easy way to navigate the research questions and different methods used throughout the report.

Table 3.5 A summary table that organizes the layout of the report by chapter, study, research question, data collected and analyses used.

Chapter	Study	Research Question	Data Collected	Analysis
Chapter 4	Study 1	RQ#1. What types of instruction is used in the ALC?	- Classroom observation	- Emergent coding - Descriptive statistics - MANOVA
		RQ#2. Does the teacher's pedagogical commitment impact the implementation of student-centered approaches?	- Classroom observation - Teacher surveys	Cluster analysis
		RQ#4 Do High-tech ALCs engage students more than Low-tech ALCs? What other factors have an impact on student-centred activities – e.g., the disciplinary filed?	- Classroom observation	MANOVA
Chapter 5	Study 2	RQ#3a. What types of artifacts do students produce for courses taught in the ALC?	- Student artifacts - Teacher interviews	Descriptive statistic
Chapter 6	Study 2	RQ#3b. How do students engage during the production of these artifacts? What patterns of engagement are observed?	- Classroom observation - Student interviews	Interaction analysis (using Studio Code software)
Chapter 7	Study 3	RQ#5. How do students engage and learn with activities that focus on the production of persistent (or extended) artifacts? How is this learning different from other traditional learning?	- Classroom observation - FCI - Student artifacts - Quizzes - Final tests	- DBR - Descriptive statistics - Qualitative analyses - Spider graph - ANOVA - Linear regression

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CHAPTER 4
RESEARCH QUESTION 1 & 2

Student-centered instruction, is defined as designed activities that require students to engage in doing and thinking about what they are doing (Bonwell & Eison, 1991). It capitalizes on social interactions and engages students in group work; and, calls for teachers to change their instructional practices (e.g., Henderson et al., 2010, 2011). The latter being particularly challenging (Garet, Porter, Desimone, Birman, & Yoon, 2001). Investigations conducted by Lund and colleagues show that their sampling of 73 faculty (M=3.7 observations each), from established post-secondary institutions in the United States, still are a long way from adopting such evidence-based pedagogies in any numbers (Lund, Pilarz, Velasco, Chakraverty, Rosploch, Undersander & Stains, 2015; Lund & Stains, 2015). This chapter addressed the issue of identifying the types of activities teachers in this study used and how these may or may not be claimed to be student-centered approaches. In the remainder of the chapter we address the other research questions as to the influence of these pedagogical commitments on activities that students are asked to engage in, and the artifacts they produce, as a result of this engagement.

Research Questions Answered

1. What types of instruction is used in the ALC?
2. Does the teacher's pedagogical commitment impact the implementation of student-centered approaches?
4. Do High-tech ALCs engage students more than Low-tech ALCs? What other factors have an impact on student-centred activities – e.g., the disciplinary filed?

4.0 METHODS USED FOR RQ#1 & 2

The data corpus analyzed herein were collected from classroom observations of 33 unique course sections, representative of 19 teachers, from the three colleges in question. This purposeful sampling of teachers in ALCs represents eight disciplines, which we categorize later into STEM and Social Sciences. Each course section was observed over several class sessions (*M*=8.3 observations/section) to ensure representativeness of the pedagogical commitment being used in that course, making for a total of 157 observations. The observational protocols used in this process are described earlier (see Chapter 3). Qualitative methods were used to code these data along the lines of the different variables of interest. We elaborate on the coding process below.

4.1 RESULTS OF RQ#1

4.1.1 Assessing Instructors Pedagogical Commitments

Our findings show that on average, instructors used student-centred approaches more frequently than teacher-centred approaches (58% of time spent in active learning, with a Q1-Q3 range 52% to 67%). This is based on 19 teachers, representing 33 course sections, and observed for an average of 8.3 times per teacher, total observations (N=157). Furthermore, while Stains (Stains, Pilarz & Chakraverty, 2015) has identified 20% of instructional time as the threshold for active learning, we find that all 19 teachers examined devoted more than the 20% of their instructional time to active learning. Additionally, more teachers, used more student-centred approaches (i.e., group work, individual work, whole class discussion and student presentations) compared to using lecture and demonstration as their main teaching approach (see Figure 4.1 & 4.2).

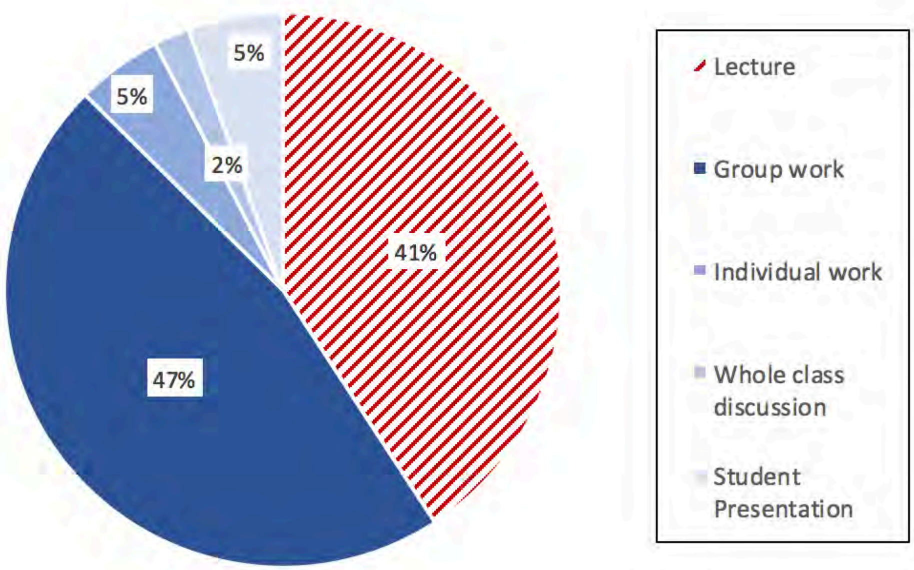

Figure 4.1 Average percentage of time spent in activity types characterized as Student-centred and Teacher-centered, n= 33 sections (or 19 teachers), over N=157 observations.

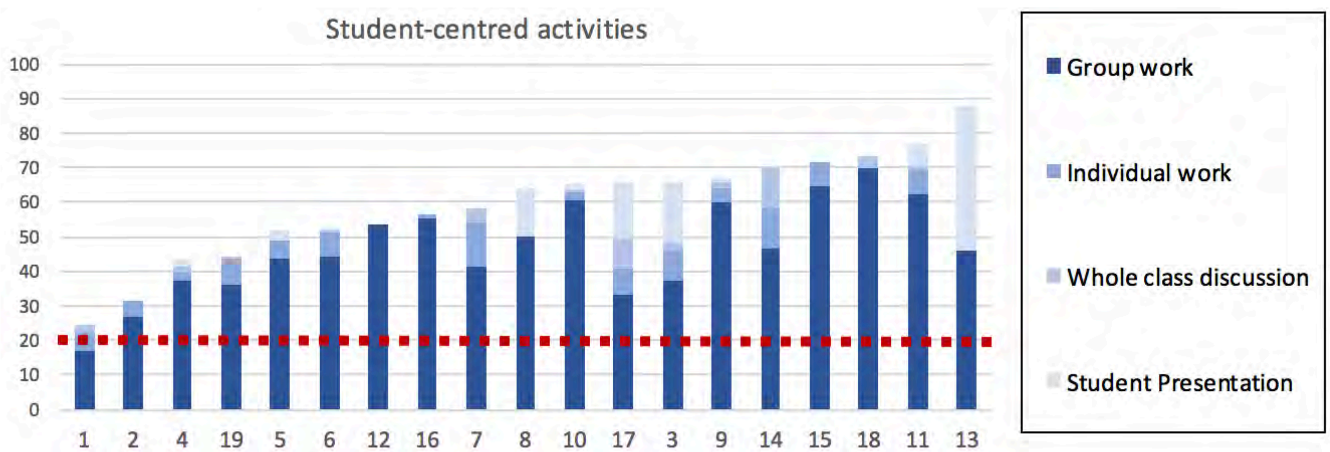

Figure 4.2 Comparison of the 19 instructors' student centered activities within their observed classes. The horizontal line at represents the 20% threshold of active learning identified by Stains. Note that all 19 instructors examined were above this threshold.

The boxplot in Figure 4.3 shows that the average percentage of time these 19 teachers (33 unique course sections) spent engaged in student-centered activities was, M=54, SD=21, Median=56.6. If we compared this figures to other research, this cohort is particularly student-centred. For instance, studies show averages of 95% teacher-centered instruction among university STEM educators (Lund, Pilarz, Velasco, Chakraverty, Rosploch, Undersander & Stains, 2015). And, even when teachers receive professional development training these numbers remain above 60% - a reduction from 95% to 60% after workshops with a return to 80% after two years (Stains, Pilarz & Chakraverty, 2015).

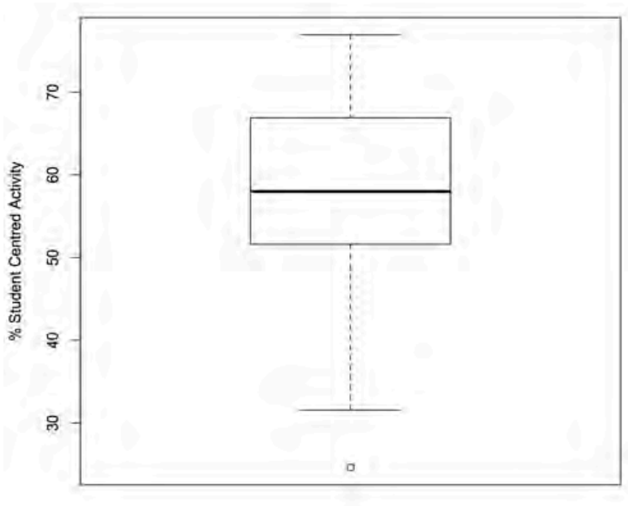

Figure 4.3 Box & whiskers of % Student-centered approaches used for the 19 cases. Distribution of % classroom time allocated to student-centered activities by 19 teachers, range 24% to 76%.

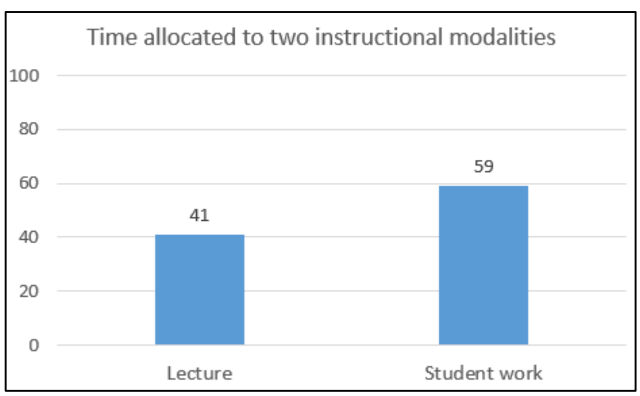

Figure 4.4 Averaged over the 19 teachers (representing 33 unique course sections), % of class time allocated to the two instructional modalities – i.e., teacher-centered, student-centered– averaged over total observations.

We prepared the observational data for each teacher, the percentage of class time spent on teacher-centered activities (lecture/demo) versus the various student-centered activities (group work, individual, whole-class discussion, student presentation). A MANOVA was performed over each observation to detect any contextual differences in pedagogical pattern. In all but one teacher, no significant ($p > 0.05$) contextual dependence was found. The average (over teachers) of the fractional time devoted to these activities is shown in Table 4.1, while the distribution of factional time devoted to student-centered activities is illustrated in Figure 4.2. The latter highlights that despite significant differences, more than half of these teachers devoted more than half of their class time to student centered activities, most of which was in the form of group work. This is consistent with our sampling of teachers who have shown a commitment to active learning pedagogy.

Table 4.1 Percentage of total class time teachers allocate to different types of activities.

	Teacher-centered activity	Student-centered activities (SCA)				
Average # of observations	Lecture	Group work	Individual work	Whole class discussion	Student Presentation	Total
8.3	40.81	46.63	4.98	2.07	5.51	59.19

These data all confirm that, on average, this sample of teachers used less than 40% of their time in teacher-centered activity. This is in clear contrast to Lund and colleagues (Lund et al., 2015) whose sample of 73 teachers spent an average of 81% of their time in lecture mode. Furthermore, while the student-centered approach used by our current sample ranged from a low of 24% to high of 76%, the majority use this approach over 50% of the time observed. Thereby, we make a reasonable claim that our cohort of teachers can be categorized as having clear student-centered pedagogical commitments.

Impact of Pedagogical Commitment on Students Activities

While implied in the analysis above, teachers operationalize this pedagogical approach in the following ways – group, individual, whole class or presentation modes (see Figure 4.5). The clear majority of time was spent in group activities (47%), followed by individual work (5%) and student presentations (6%).

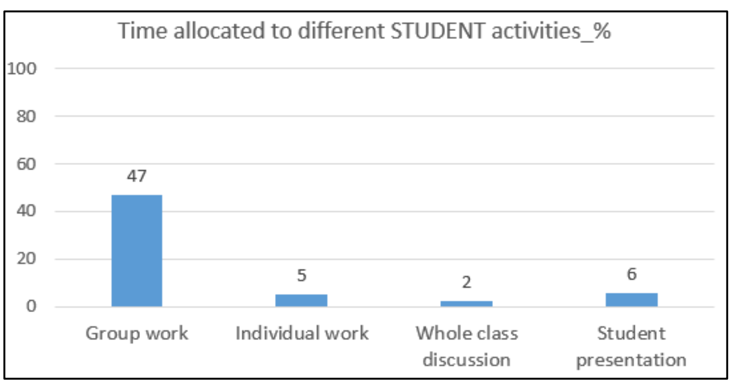

Figure 4.5 Distribution of classroom time allocated to different modalities of student activities – group, individual, whole class, or presentation.

4.1.2 Stability of Teacher's Pedagogical Committee

Another finding shows that, importantly, the pedagogical patterns within individual teachers is a stable attribute. That is, the teachers' pedagogical commitment is the same regardless of course, section, and/or ALC environment (high tech. or low tech.). A MANOVA analysis was performed within the observations of each teacher to determine whether contextual differences (i.e., course and/or type of learning space, cohort) led to differences in teaching pattern (operationalized as fraction of class time devoted to: lecture, group work, individual work, whole class discussion and student presentation). In all but one case, there were no statistically significant differences related to these contextual factors. The one exception, teacher 4, only differed in the fraction of class time spent on individual work between different courses; i.e. this appears to be a small, but significant, difference attributable to the nature of the course.

4.2 RESULTS OF RQ#2

4.2.1 Impact of Pedagogical commitment on student-centred approaches

Findings show that although the 19 teachers can be all characterized as high users of student-centred pedagogies, their enactments, or orchestrational patterns of these activities, fall into one of four types (see Figure 4.6). This means that even within student-centred teachers, decisions related to enactments are guided by pedagogical commitment and other factors. We attempt to tease out these other factors.

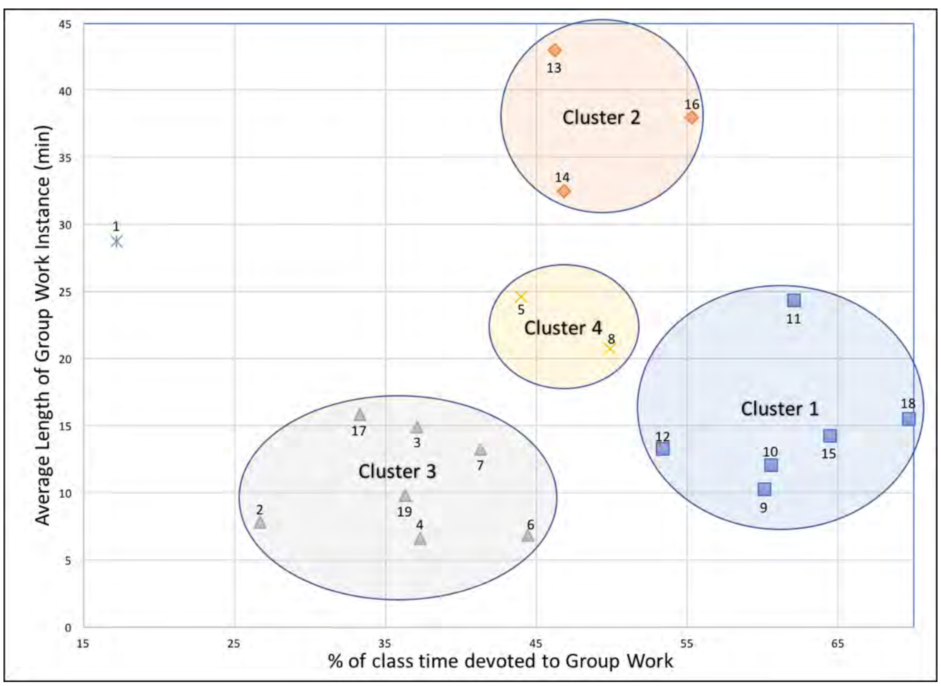

Figure 4.6 Cluster analysis revealing four clusters of student-centred pedagogy organized by % of group work and average length of group work assigned within class session. Cluster 1: very frequent but short activity sessions. Cluster 2: moderately frequent but long activity sessions. Cluster 3: moderately frequent but short activity sessions. Cluster 4: moderately frequent and moderately long activity sessions.

Teachers in Cluster 1, were generally observed as designers of many short duration activities, ending (or interrupting) them after 10-15 minutes to provide feedback at the class-level. Observations of teachers in Cluster 2 revealed longer group activities where walked through the classroom to provide feedback to individual groups. Cluster 3, gave shorter activities but less frequently. These activities were sometimes short problems (as in Cluster 1) other times they were interrupted with a class level explanation. Unlike other groups, Cluster 3 appeared to be made up of teachers who had less experience with student-centred instruction or were teaching in disciplines with lots of content to memorize (e.g., biology, history). Cluster 4 was a bit of an anomaly, as it consisted of two teachers who used student-centred learning for some time but often taught in ALC environments that presented physical challenges.

The rate at which learning artifacts were produced by a group had a significant relationship to the teacher's cluster membership (Figure 4.7). This is not unexpected, as the clusters were, in part, partitioned by the fraction of class time devoted to group work: more time spent doing group work leads to more group work artifacts being generated.

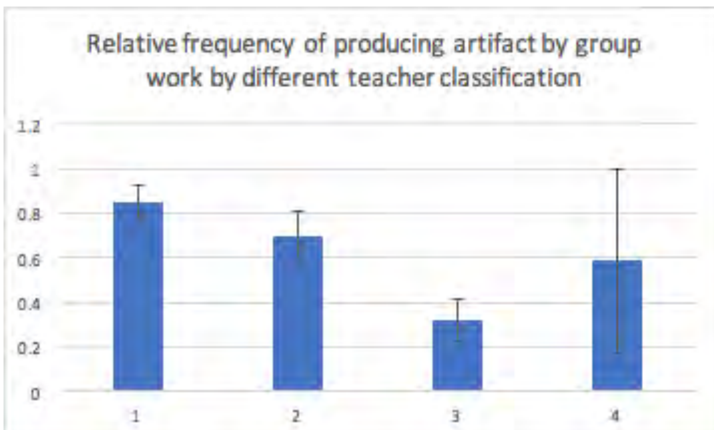

Figure 4.7 Relationship between cluster membership and frequency of artifact production.

These four clusters not only represent possible differences in teacher's orchestrational decision-making but may also implicate different types of artifact production and students' engagement. That is, the types of feedback teachers will give (class level or group level) might be impacted by the Cluster 1 vs Cluster 2 orchestration. So too the types of artifacts that can be produced (short problem solutions vs. extended or multi-component artifacts). Interestingly, Cluster 2 (long duration and group level feedback) also meant that the artifact being worked on had more potential to expand differently for each group. Additionally, the type of artifact activity designed by Clusters 1 and 2 teachers appears to have been constrained by the nature of the discipline and its cultural practices. For instance, Cluster 1 was made up of more teachers from physics and math disciplines - e.g., problem solving traditions. Cluster 2 was made up of more teachers from creative disciplines - e.g., meaning construction and divergent thinking.

4.3 RESEARCH QUESTIONS #4

Do High-tech ALCs engage students more than Low-tech ALCs? What other factors have an impact on student-centred activities – e.g., the disciplinary filed?

4.3.1 Methods Used For RQ#4

Using the observational data collected and coded in earlier, we examined whether the ALC features might influence these allocations of time to these student-centered activities (Figure 4.8); and whether the disciplinary fields might be an influence (Figure 4.9).

4.3.2 Results RQ#4

Findings show no significance of the type of ALC environment on the type of student-centred activities observed. A MANOVA (Table 4.2) confirms no statistical difference for the type of ALC (high-tech vs. low-tech) on the percentage of time teachers allocate to the different student-centered activities, df=2, F=.366, p=.94. These results support early research that showed classroom spaces did not impact learning, rather teacher's pedagogical commitments are paramount (Lasry et al. 2013; 2014). Therefore, going forward, we eliminated this variable of physical space as one of the factors to be considered.

On the other hand, the field of study (STEM/Science vs. Social Science) appears to be statistically significant (see Figure 4.9). A MANOVA produced a statistical significance for the percentage of time teachers allocated to student-centered activities, F=10.68, p>.000. We elaborate on this further on. Lastly, as anticipated, there is no interaction between discipline and ALC type.

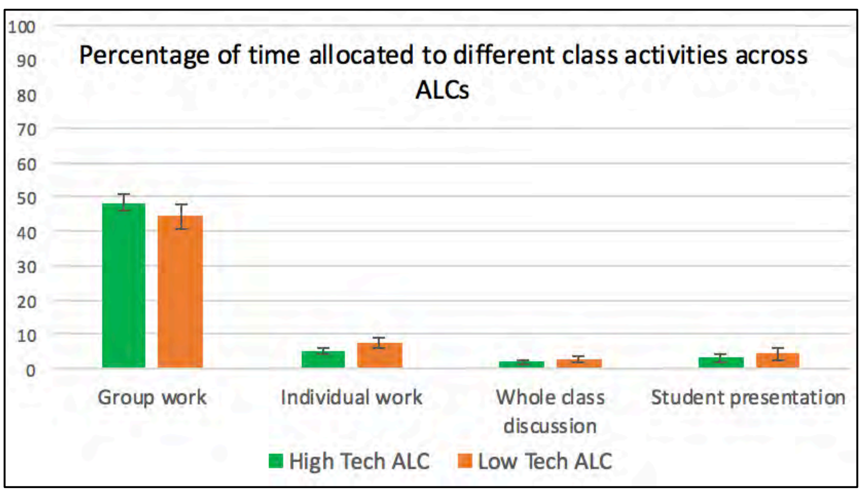

Figure 4.8 Percentage of student-centred activities by type of ALCs.

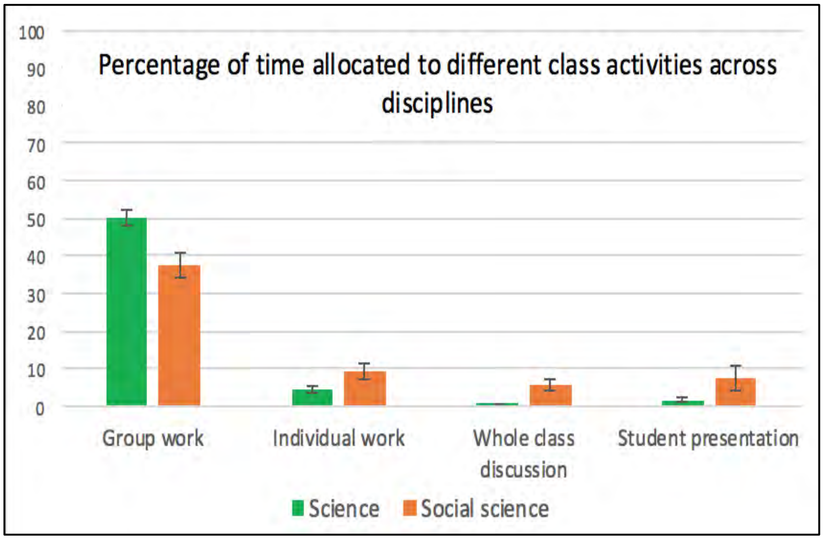

Figure 4.9 Percentage of student-centred activities by field of study.

Further examination of this relationship shows a significant difference for these activity types by disciplinary field. Based on these results, STEM teachers spent a greater percentage of time engaging students in group work (47%) compared to social science teachers (35%) with, F=9.637, p< .01 (Table 4.3). On the other hand, social science teachers allocated a greater percentage of time to individual activities (8.5% vs. 4%), F=5.219, p< .05; and, whole class discussion (5.4% vs. 0.7%), F=24.823, p<.001. Not surprisingly, student presentations were not significant because they make up such a small percentage of the data.

Table 4.2 Impact of ALC type and Disciplinary field of study on % of time teachers spent in student-centered activities.

Independent Variables		df	F	Significance
			39.324	.000
Discipline		1	10.678	**.000**
Type of classroom		2	.366	.938
Discipline * Type of Classroom			.415	.798

Table 4.3 Effect of Disciplinary field of study on % of time teachers spent in student-centered activities.

Dependent Variables		df	F	Significance
Group Work	4591.811	1	9.637	**.002****
Individual Work	441.504	1	5.219	**.024***
Whole Class discussion	639.892	1	24.823	**.000****
Student presentation	541.595	1	3.598	.060

Significance at *p<.05, **p<.00

4.3.3 Summary

Confirmed with our previous work that ALC features do not play a significant role in teachers' decision making of the class activities. In another word, the features of classroom do not have impact on teachers' pedagogical commitment to the class revealed in their implementation of class activities. A new finding from this current project suggest an important role of disciplinary filed in teachers' class orchestration. Science teachers tend to use more group work activities than social science teachers, whereas the latter shows devoting more time in individual work activities than the former.

4.4 CONCLUSIONS AND IMPLICATIONS FOR RQ#1

Teachers in this study show us that it is possible to devote over 50% of class time to student-centred activity and still cover the course content. In short, college classes do not have to be lecture heavy. The largest percentage of that student-directed time involves group work.

Orchestration of student-centred learning may be dependent on disciplinary content and the types of activities they call for (e.g., math & physics: problem solving; history & sociology: essays). There is a need to better understand the relationship between instructional design decisions (i.e., how activities are constructed) and innate practices of a discipline.

4.5 REFERENCES

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CHAPTER 5
RESEARCH QUESTION 3

As a social activity, learning produces artifacts (Engestrom, 1999). The grandfather of social learning, Vygotsky (1930/1978; 1934/1986), states that artifacts, physical or symbolic, mediate interactions between learners, and even within the learner themselves. In social settings, giving ideas an outward form means they can be shared, extended, and interlinked, in other words, it is the externalization of individual thinking (Whittaker, Brennan & Clark, 1991). Therefore, material artifacts such as concept maps, worked problems or reflective journals allow for the communication of ideas, both to self and others. Because of their mediational role, artifacts can affect the nature of the activity - i.e., how learners can engage - as well as define the goals and means of the learning (Stahl, 2002). This chapter addressed the issue of the types of artifacts students produced during their courses in the ALCs. Also addressed is how students engaged with each other while creating these artifacts.

Research Questions Answered

3a. What types of artifacts do students produce for courses taught in the ALC by student-centred teachers? How do students engage during the production of these artifacts? What patterns of engagement are observed?

5.0 METHODS USED FOR RQ#3a

Data from the 157 of classroom observations were coded for the types of artifacts students produced and used during their in-class time. These consist mainly of in-class but also include those that started or continued outside of class (often online). Types of artifacts included written products (i.e., text-based statements, mathematical equations, etc.) and visual products (i.e., excel graphs, drawings, concept maps, photographs (also photos that digitize their text or drawings), video, etc.). Sometime they were produced with analog media (pen and paper, dry eraser, scratch cards (e.g., iFAT)), other times they were digital media (photos, video, specialized software (e.g., Notebook, Tracker, Excel), web-based tools (e.g., Visual Classrooms & SMART Amp), simulations).

5.1 RESULTS OF RQ#3a

5.1.1 Artifacts Produced During Student-Centred Activities

Findings show that, in 97% of the classes observed, student-centred tasks generated some form of artifact: problem solutions, research notes, idea maps, equations, drawings, and so on. In the other 3% where no new material artifacts were generated, students were engaged in using artifacts that had been produced earlier (e.g., student presentations) or were engaged in peer discussion (e.g., Peer Instruction, debate).

To better understand the range of artifacts produced over the total observations (N=157) we organized them (see Table 5.1) by the following: nature (public/private/mix, group/ individual/ mix, 1-time use/reused/mix) and by medium used (analog/digital/mix). The Table shows that more artifacts were produced as public (n=46) vs. private (n=31); but, on even more occasions, both types of artifacts were generated (n=75). More artifacts were produced as group objects (n=88) vs. individual (n=7), but in approximately 30% of instances, both types were produced (n=54).

Table 5.1 Summary of all artifact types produced during the observed classes (N=157), note no artifacts were produced for n=5 instances.

<table>
<tr><th></th><th>Public</th><th>Private</th><th>Group</th><th>Individ.</th><th>1time use</th><th>Reused</th><th>Analog</th><th>Digital</th><th>No artifact</th></tr>
<tr><td>One type solely</td><td>46</td><td>31</td><td>95</td><td>7</td><td>126</td><td>10</td><td>46</td><td>51</td><td rowspan="2">5</td></tr>
<tr><td>Mix of types</td><td colspan="2">75</td><td colspan="2">50</td><td colspan="2">16</td><td colspan="2">55</td></tr>
</table>

Public vs. Private Artifacts

Generally, more artifacts were produced as mixed modes of Public and Private during individual sessions (see Figure 5.1). Most group artifacts were generated in public spaces - i.e., whiteboards or SMART boards (see Figure 5.2). Sometimes they were intentionally shared (as part of a jigsaw or musical table activity where groups switched artifacts). Other times, their ambient nature made these artifacts implicitly shared as part of the new classroom culture where students feel comfortable examining what and how other groups are progressing (see Figure 5.3, right side). Fewer artifacts were generated as private to the group - e.g., web-based group software (see Figure 5.4). Individual artifacts were produced to a lesser extent. When part of a mixed modality activity, the individual artifact typically was a starting point of group activity - e.g., 2-stage exams, photo and physics notation activity (see Figure 5.3).

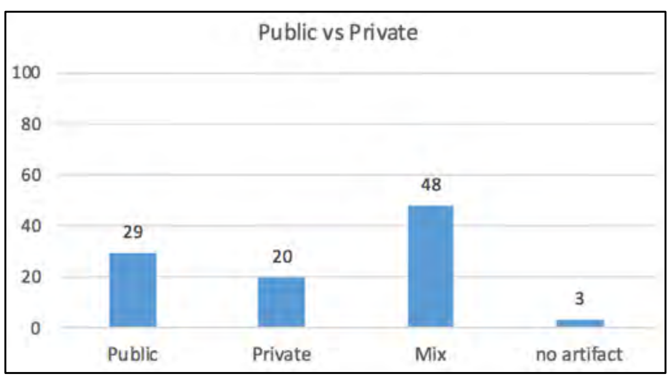


Figure 5.1 The percentage of Public, Private, and Mixed types of artifacts produced during class sessions in the ALCs.

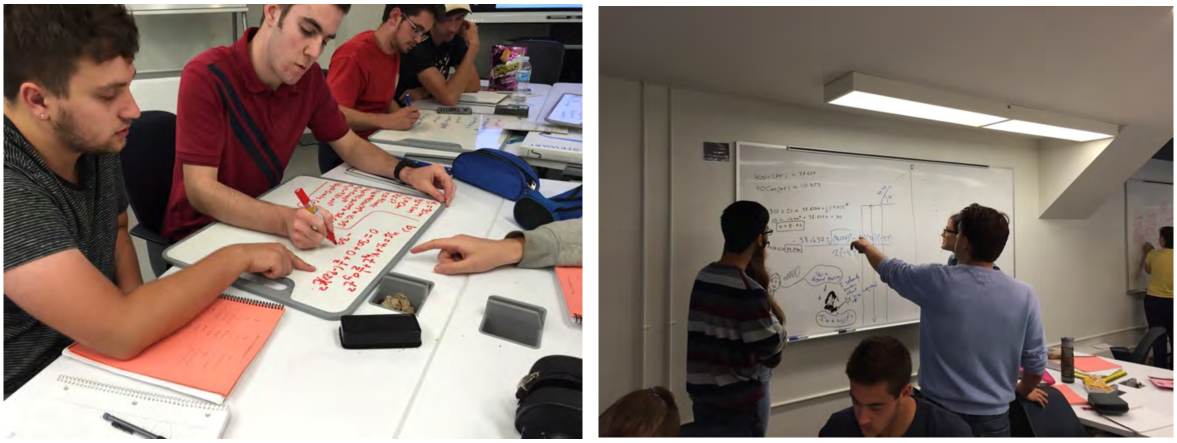
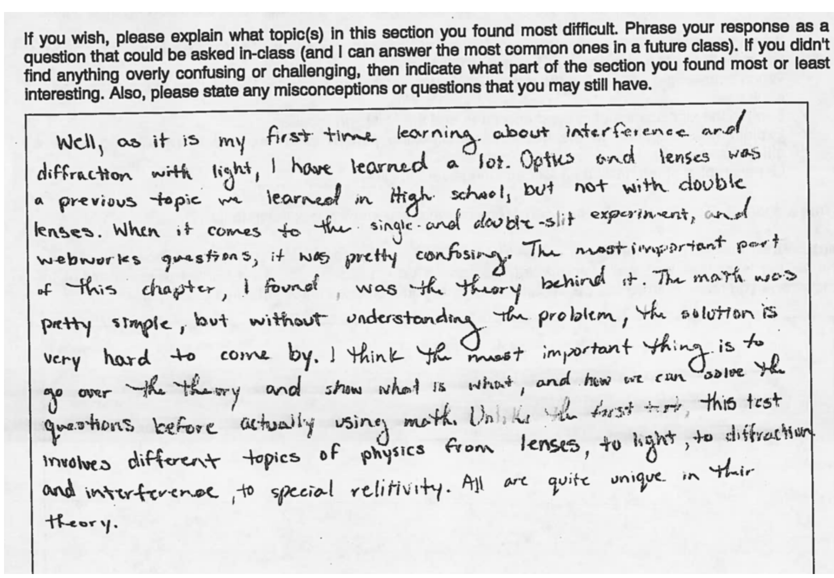


Figure 5.2 Example of private group (left) and public group (right).

Figure 5.3 Example of individual private (left) and group private (right) artifacts. In this case, the individual private artifacts are brought into a group private artifact that is part of a 2-stage exam.



If you wish, please explain what topic(s) in this section you found most difficult. Phrase your response as a question that could be asked in-class (and I can answer the most common ones in a future class). If you didn't find anything overly confusing or challenging, then indicate what part of the section you found most or least interesting. Also, please state any misconceptions or questions that you may still have.

Well, as it is my first time learning about interference and diffraction with light, I have learned a lot. Optics and lenses was a previous topic we learned in High school, but not with double lenses. When it comes to the single-and double-slit experiment, and webworks questions, it was pretty confusing. The most important part of this chapter, I found, was the theory behind it. The math was pretty simple, but without understanding the problem, the solution is very hard to come by. I think the most important thing is to go over the theory and show what is what, and how we can solve the questions before actually using math. Unlike the first ~~test~~, this test involves different topics of physics from lenses, to light, to diffraction and interference, to special relitivity. All are quite unique in their theory.

Figure 5.4 Example of private artifact, a reflective writing submitted to the teacher alone.

Group vs. Individual Artifacts

Generally, more artifacts were generated in a Group mode of production during individual sessions compared to the mixed (32%) and individual (4%) modes (see Figure 5.1). In other words, most artifacts were produced by group work.

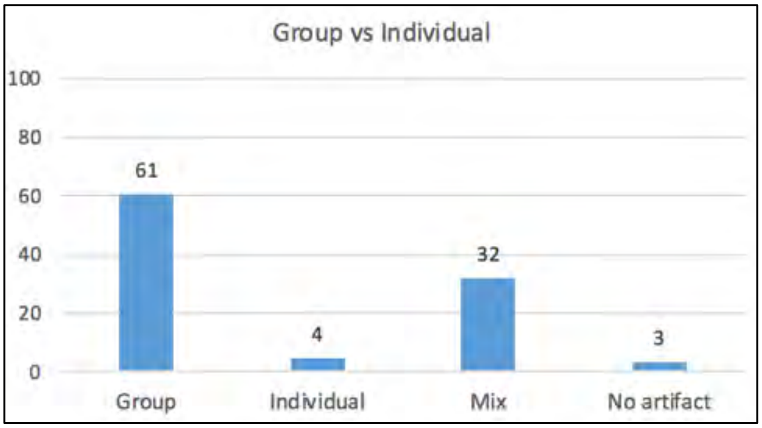


Figure 5.5 The percentage of Group, Individual, and Mixed types of artifacts produced during class sessions in the ALCs.

One-time vs. Reused Artifacts

Most artifacts were produced for one-time only use (n=126), with a small number being designed for reuse (n=10). In a few instances, there were both one-time and reused artifacts generated in the same session (n=16). In other words, one-time use (80%) or reused (7%). A small percentage (10%) fall into the Reused or persistent category (see Fig 5.6). In those cases, the reused artifacts were generally objects that were brought into class and reworked; whereas the one-time use artifacts were some type of individual quiz.

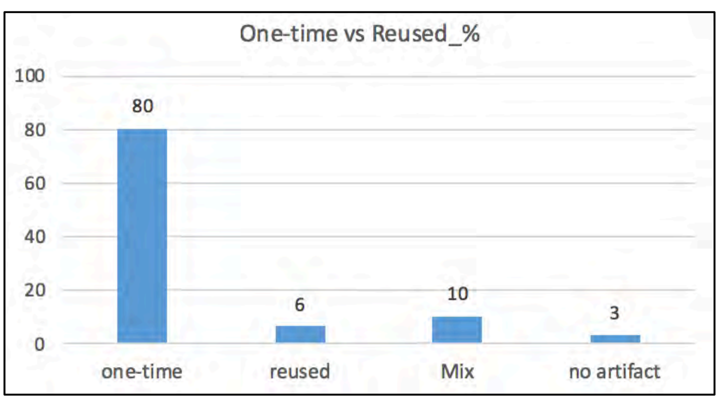


Figure 5.6 The percentage of One-time, versus Reused or Mix use artifacts produced during class sessions in the ALCs.

One example of reused artifacts was in a Visual Arts course that brought together researched ideas (Figure 5.7). Over time and several iterations, these ideas were analyzed and synthesized to develop thematic groups. Another example was designed activities for a physics course that used photos of real life examples (Figure 5.8). Students were asked to annotate photos, with arrows and symbols that led to equations and further abstraction of the motion.

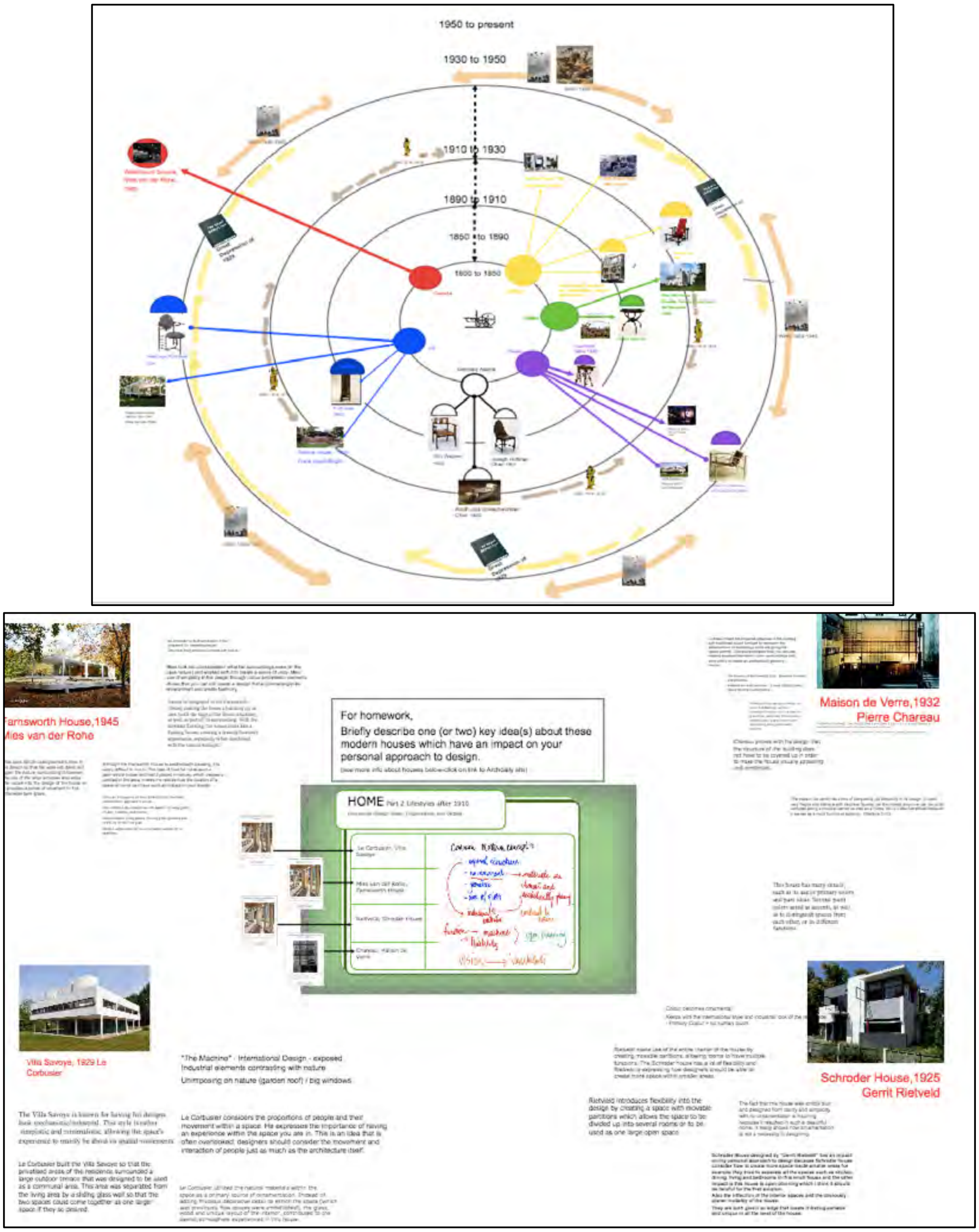


Figure 5.7 Two examples of "extended-use" artifacts from a Visual Arts course produced in SMART Amp. The artifacts were produced over 2-3 weeks by groups of 4-5 students.

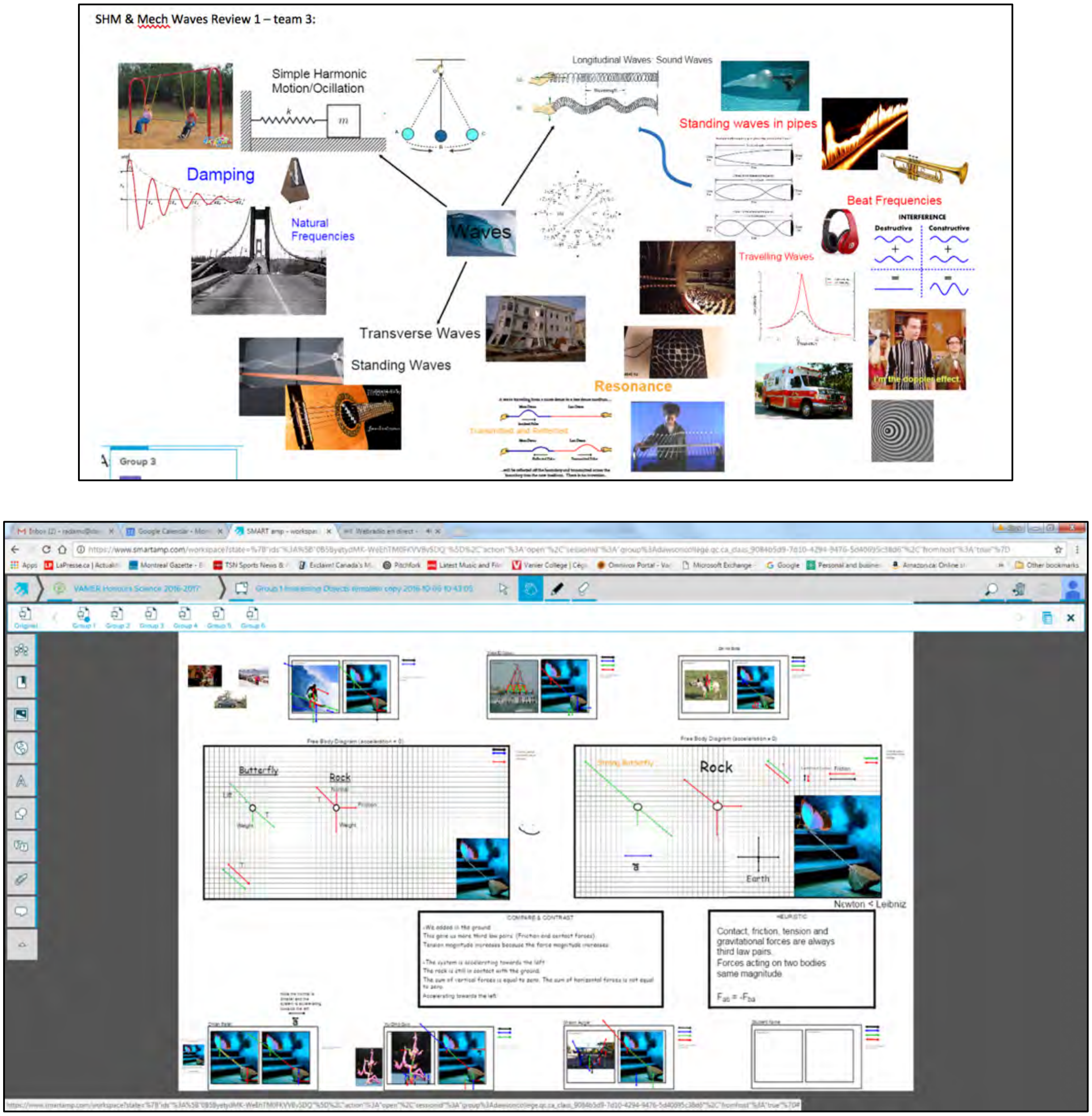


Figure 5.8 Two examples of "extended-use" artifacts from physics courses produced in SMART Amp. Groups of 4-6 students were involved in building this shared artifact over 3 class sessions.

Analog vs. Digitally Produced Artifacts

The medium used was equally distributed between analog (n=46), digital (n=51) and mixed media (n=55). Analog examples include: reflective journals; one-minute papers; individual and group quizzes (2-stage exams; iFAT cards), mini-whiteboard drawings, whiteboard products - e.g., drawings, text, problem solutions; poster-board drawings; etc. Digital examples include: software files - e.g., SMART Amp documents, Excel graphs & tables, photos & drawings, output from specialized software (e.g., Tracker), etc.

Table 5.2 Description of the types of artifacts produced as Analogy, Digital and Mixed media.

	High Tech	Low Tech
Analog technology ONLY	In this history class, students are asked to free write something on their notebook, based on a topic provided by the teacher.	In this chemistry class, students are provided with questions and are asked to answer on a static platform, either paper worksheet or wall-mounted whiteboard, individually or with some peers together.
Digital technology ONLY	In this biology class, teacher provides a problem set to students, students work on the set of questions in groups using desktop computers or wall-mounted Smart Board.	In this physics NYC class, students work on a concept-map activity in groups using Smart Amp, an online platform which allows each group has their own working place on an almost endless canvas. For the entire class session, students use their own personal devices or the school portable laptops to get access to the online working space.
Analog + Digital technologies	In this physics NYA class, student work activities can be divided into two parts. First part is that students solve some problems in groups, which of the questions presented on Smart Board. The second part is that students are assigned to an in-class quiz which administrated by worksheet.	In this psychology class, students first work in group to generate a solution for a problem. The solution is presented on whiteboard. Then for another student artifact-production activity in the same class, students use iPads brought in the class by their teacher. They work on a term-project through an online platform, Smart Amp.

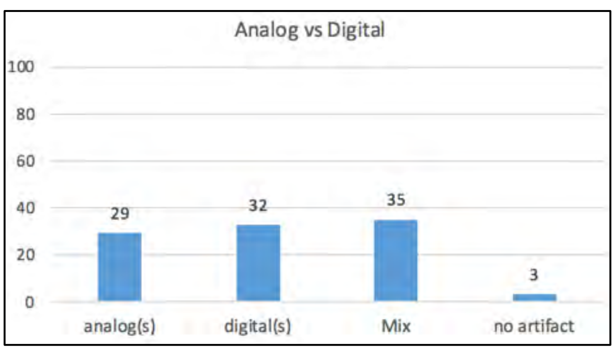


Figure 5.9 Percentage of Analog and Digital artifacts produced during ALC class sessions.

Types of analog artifacts included writing on whiteboards, and worksheets. It also included paper products that could be shared by being tacked to the whiteboards. In Figure 5.10 the students are generating a concept map with sticky notes. In Figure 5.11 the students are displaying drawings produced as part of an in-class activity for Industrial Design.

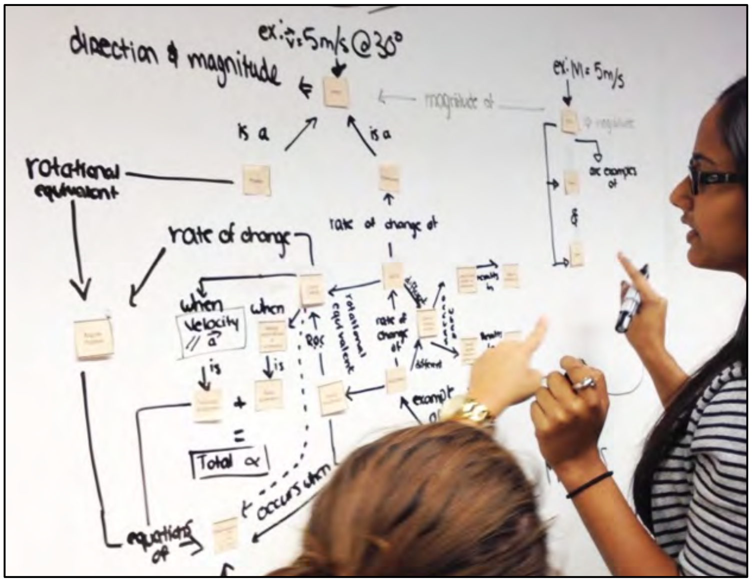


Figure 5.10 Students creating concept map.

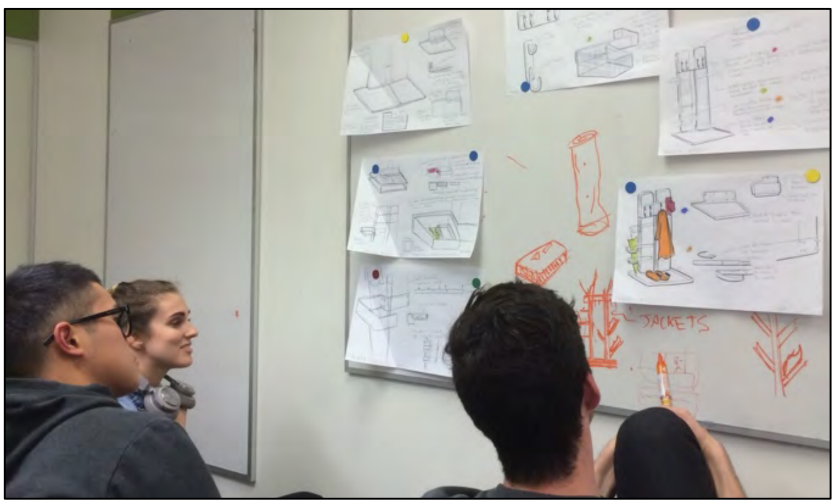


Figure 5.11 Students reviewing drawings.

Digital artifacts consisted of products brought into the classroom on lap-tops (see Figure 5.12) or produced on other software (e.g., SMART Notebook) and brought in as a document to be worked on by the group. There were also products that were produced digitally on the SMART boards in those high-tech ALC that had SMART boards for each student groups (Figure 5.13). In those cases, the artifact was both public and shareable both in an ambient manner as well as through the networking capacity of the classroom technologies.

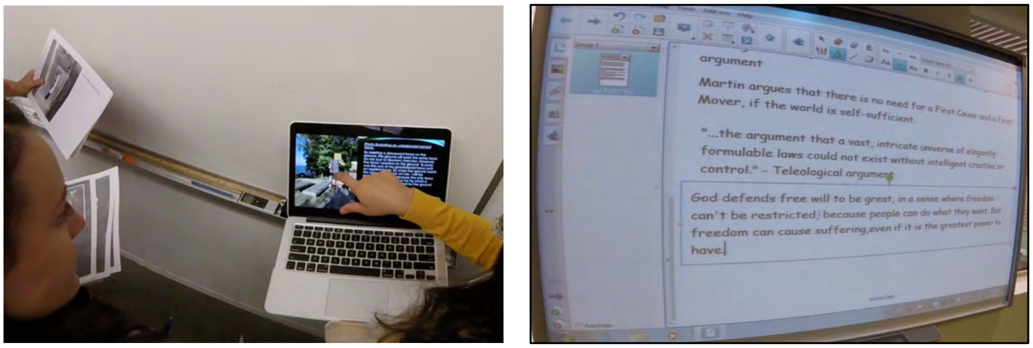


Figure 5.12 Example of digital media – laptop (left) and SMART Notebook file (right).

Figure 5.13 Example of digital media where SMART boards were being used interactively.

5.1.2 Summary of Artifacts

Artifacts existed along several of these dimensions. In fact, they can be described as Public and Group Analog or Private and Group Digital, and so on. With that, we summarized them in the following Table (see Table 5.3) as a way to show these intersections.

Table 5.3 Summary of the artifact by nature and medium.

Artifact Medium	Nature of Artifact	
	Public (Group)	Private (Individual & Group)
Analog	Whiteboard products - e.g., drawings, text, problem solutions; poster-board drawings; etc.	Reflective journal; one-minute papers; individual and group quizzes (2-stage exams; iFAT cards), mini-whiteboard drawings etc.
Digital	SMART board files - e.g., drawings, problem solutions, photo & text assemblies, etc.	Software files - e.g., SMART Amp documents, Excel graphs & tables, digital photos & drawings, output from specialized software (e.g., Tracker), etc.

5.2 TEACHER'S BELIEF ABOUT THE ROLE OF ARTIFACTS

Interestingly, teachers have very different intentions for these artifacts. Some value the process of artifact production, viewing it as a way of giving students practice with the doing. Others, value both the process and the product itself. We categorized the latter comments into two categories: (1) artifacts as "boundary objects" that generate purposeful discourse among students; and (2) artifacts as "starting point" that ensures students can think individually before getting into the social learning context. Here are examples of such statements.

Artifact as boundary object

T4: *I don't know if it's artifact production or problem solving, but I know just the simple act of discussing a topic, giving them a question, having them work in groups of 4 on the whiteboards together, is great… they're asking me questions, they're looking at each other and helping each other, uh they're integrating the concepts that we've just talked about.*

T11: *To plot them in excel and get trend lines… one kid was surprised that a sixth order polynomial gave a much better fit than a second order polynomial, "what does that mean? Does that mean that the acceleration isn't constant?" That's exactly what it means. "Oh!!" And they were starting to do all these different polynomial fits, and they were interested in acceleration now - snap, crackle, pop! And they would go back to their calculus class and say "how many derivatives can we do? Can we go on forever?" Here's a sine function go nuts right.*

T2: *break the ice on a concept, make sure we're getting rid of misconceptions, um making sure we know how to calculate the math, sometimes that's involved, or we know how to draw these structures, but no I don't collect.*

T6*: um there are certain topics where concept maps would work super nicely, and I also use them at the end of a big chunk of units of the course, where they link the different concepts that we've seen in this course in a big concept map, in this unit in a big concept map.*

Artifact as starting point

T9 & T15: *Our quizzes are the same, the [students] get started individually, and then at some point we [say] "okay, now it's group time"... It's like the peer-tutoring idea. [Students] start thinking on their own, and then after a little while you say now you can discuss.*

What is interesting to note is that regardless of the original media, students have begun to document and produce digitized copies of their in-class work. And, in some cases, the teacher too has begun to ask students to do so. For instance, this comment by one of the teachers:

T7: *take a paragraph or so and translate it into modern English. Basically, paraphrase it, and make it clear. And I've always done that… But for years it was that, and then write everything out by hand. Now it's on the smart board and it gets shared. And this is one of the things that I don't just leave it up to them sending it to each other by Mio, I compile it into a Word document as a Word document so for sure they have access to it, and I put it in documents for them to have.*

Importance of Shared Artifacts

The majority of artifacts were produced in public and as shared objects. That is, the majority of work was group work on writeable surfaces such as whiteboards (dry eraser or interactive). To a lesser extend individual artifacts were also produced, generally as the starting point of another activity. For instance, one teacher talked about always asking students to write their own explanations before starting a group project.

T7: *I absolutely insist that they write their answers down before sharing with the group, because this is something that allows for most possible answers, whereas if you're just shouting out answers, the first on that gets said tends to block other possible answers. So right it down, when it's there, so that's really important.*

T9 & T15*: I mean our quizzes this semester… Every time it's the same, they get started individually, and then at some point we're like "okay now it's group time". So I think the idea of having them start something, it's like the peer-tutoring idea. They start thinking on their own, and then after a little while you say now you can discuss.*

5.3 REFERENCES

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CHAPTER 6
RESEARCH QUESTION 3b

Joint action involves more than communicating content but also coordinating joint process. When coordination of process is involved common ground is negotiated on a moment by moment basis. Clark and Brennan (1991) state that a process of “grounding” is required for the updating of common ground. Two factors shape the process of grounding – purpose, and medium of communication. The process by which participants come to mutually agree on the purpose of the communication is considered “grounding criterion.” These authors state that “technically, then grounding is the collective process by which the participants try to reach this mutual belief.” (p. 129). Grounding changes with purpose. According to Grice (1975), generally, participants in communicating attempt to establish “collective purposes.” Techniques used for grounding a conversation will change depending on the purpose and on the content. As such, it the outcome of the engagement, the artifact, and the process of its construction becomes an important object and phenomenon to examine. In this chapter, we explore how we might do so by examining the artifact’s construction as our object of analysis.

Research Question Answered

3b. How do students engage during the production of these artifacts? What patterns of engagement are observed?

6.0. METHODS & RESULTS RQ#3b

Activity theory allows us to consider all the interactions within an ecosystem. According to Yamagata-Lynch (2010):

> *Object-oriented activity refers to mediational processes in which individuals and groups of individuals participate driven by their goals and motives, which may lead them to create or gain new artifacts or cultural tools intended to make the activity robust. In this process, there is no guarantee that the activity will become robust. In fact, at the conclusion the activity may collapse and become unsustainable. (p.17).*

Using Activity-Theory as a metaphor, we examined the interactions of students with the artifact and identified different patterns of engagement. A grounded approach was used to examine the 144 video recorded sessions. The coding process revealed four student-engagement types: Single agent, Scribe, Turn-taking, Team-play. Each of these are described in Table 6.1 (below). This first stage of analysis was followed by a deeper level process that examined the actual construction process and how the artifact emerged through these interactions. We describe this process more fully in the next section.

Table 6.1 Classification of types of engagement during group activity, using access and contributions to the shared artifact as the unit of analysis.

Engagement Types	Who is accessing the artifact (direct contact)	How are contribution to the artifact being made
Single agent/ tutor	1 individual	- artifact emerges through the solo player with group members confirming or checking on the work - e.g., checking of calculations.
Scribe	1–2 individuals from group	- artifact emerges through directions that contain information and solutions - e.g., more knowledgeable student(s) contribute and direct the construction.
Turn-taking (cooperation)	>2 group members take turns in serial fashion	- artifact emerges as an assembly of components in cooperation but not much negotiation or integration of the parts - e.g., players do their part then leave the game.
Team-play (true collaboration)	majority of group participating, often simultaneously	- artifact emerges through contributions that flow back and forth between members of the group with a seemingly shared goal - e.g., players monitor progress and contribute to game until the end.

The engagement types are described along two dimensions: (1) *groupness potential* (which implicates instructional design); and, (2) *access* (which implicates activity orchestration process). *Groupness potential*, is mediated by: (1) the nature of the task - if it is too easy then one person can do it; if it asks students to perform simple tasks like assemble information, students will not do more; (2) the students' prior knowledge - if the solution is familiar there will be little challenge and one person can complete the task; if the tasks has known algorithms then it can be accomplished without negotiation of meaning, even if that takes time. *Access*, on the other hand, appears to be mediated by: (1) the physical constraints (and technology) of the joint problem space; (2) the nature of the input device(s); and (3) the nature of the teacher's orchestration - we have seen student engagement type change when teachers ask students to stand up and get to the board.

6.2 RESULTS RQ 3b

6.2.1 Interactions Leading to the Emergence of the Artifact

A small number of videos representing the different types of engagement were selected from the corpus of 144 group videos and coded using Studio Code. The codes aim to indicate the construction of the artifact. Developed by the authors, the methods start with an assumption that the artifact construction has a "trajectory" that is established by the goal of the activity. This goal interacts with the prior knowledge and nature of the tasks, which impacts the possible contributions of other participants. The actions taken by the initiator of the artifact sets the artifact on this course. The general process of how the artifact emerges and progresses revealed by momentarily displayed bars (see Figure 6.13., row name: artifact progressing). The turquoise striped bars indicate a contribution made by the teacher by a teacher intervention. Then, a detailed examination of the same artifact construction process is performed (see Figure 6.14.). The solid colour bars indicate different students who might move into and out of this construction role. Again, the turquoise striped bar indicates indirect teacher adding or repairing to the student artifact, which always right after or in the same time with a teacher intervention. The course of artifact construction following the "established trajectory" is represented on the top row (row 2; and 11). All other contributions are considered additions (e.g., new knowledge) or repairs (e.g., corrections) to this initial trajectory and identified as secondary inputs and placed on the subsequent (rows 3-6; and 13-16). The discourse surrounding the production of the artifact is identified by the code of "negotiation" (row 8; and 18). The teacher's intervention is also identified, when applicable (row 10; and 20).

Three Types of Engagement

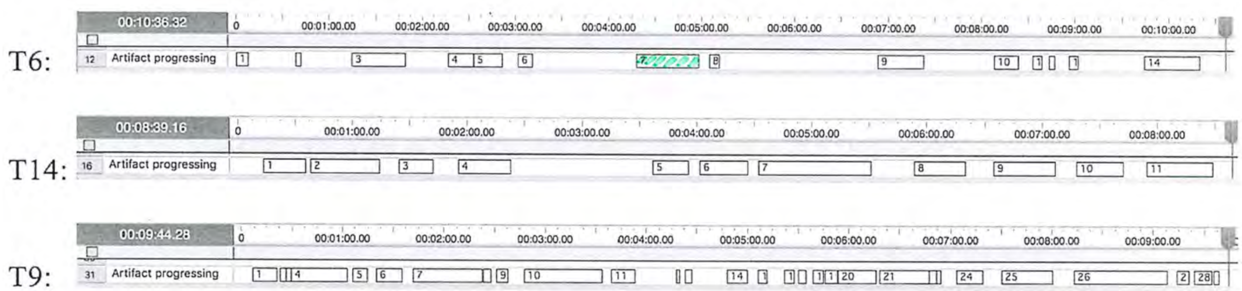


Figure 6.13 Timelines for three groups from three different classes. Each timeline represents a different engagement type: Scribe (top–T6), Turn-taking (middle–T14), Team-play (bottom–T9).

We present the coded timeline data displays for three of the four types of engagement observed (see Figure 6.13). It shows a comparison of three coded timelines representing three different engagement types. The big difference between these types are the ways in which the artifact emerges. In sample T6 (Scribe), the artifact emerges slowly and discontinuously, and each contribution is unevenly distributed in terms of the length of working time (row 12). Compared to sample T14 (Turn-Taking) where there is a continuous building of the artifact which emerges and develops with large blocks indicating long period of working time. Sample T9 (Team-Play), is an example of an artifact that emerges quickly and continuously where lots of long and short blocks interweaving with each other.

Closely looking at the process of artifact construction, sample T6 (Scribe) shows that the artifact emerges heavily from the input of "scribe" (row 2), and the only few contributions made from other team members are significantly short comparing to those of scribe's. However, in sample T14 (Turn-Taking) reveals the artifact development from a back and forth between the direct construction (row 2), and contributions from others in the group - direct additions to the artifact (row 3) and indirect additions (row 5). In fact, row 5 is very active meaning that others in the group played an important role in directing the construction of the artifact. Sample T9 (Team-Play), displayed constant contributions from all members of the group who build, add and repair the artifact, both directly and indirectly, which indicated by the relatively even distributed colors across row 11 to row 16.

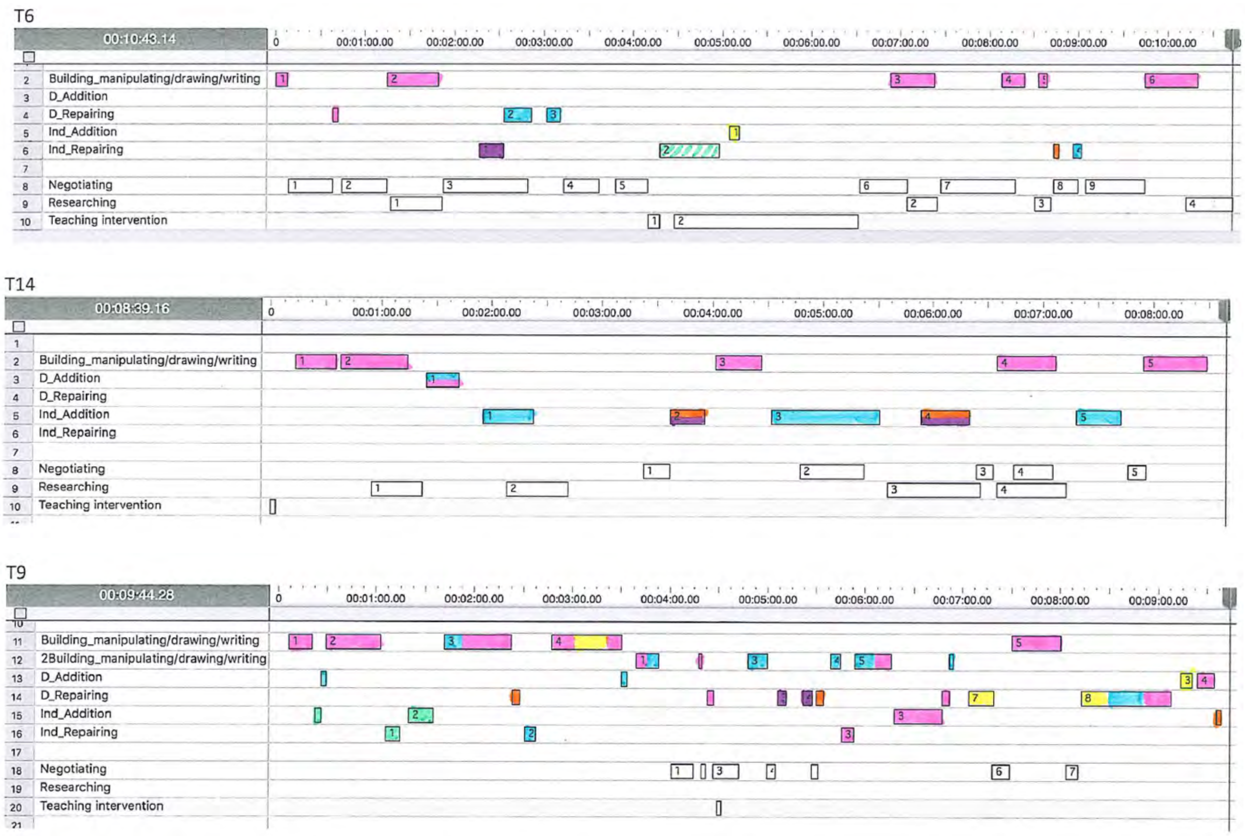


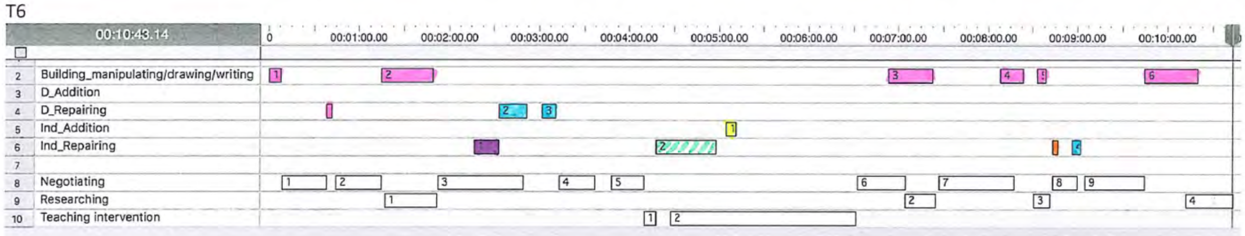
Figure 6.14 Coding window for three groups from three different classes. Each coding window represents a different engagement type: Scribe (top – T6), Turn-taking (middle – T14), Team-play (bottom – T9).

Comparison of Scribe Type Engagement Generating an Artifact

Figure 6.15 shows a comparison of two Scribe type engagements over a 10-minute period. In the T6 example of Scribe type engagement, the main building of the artifact is generated by one student (pink). This artifact does not emerge easily, note the slow development and long gaps between the construction phases (row 2; segment 2 and 3). In this instance, the intellectual work is being done almost exclusively by others in the group during the negotiation phase (row 8; segments 1-9). Additionally, the other students are engaged in researching (row 9; segments 1-4) which leads to the construction of the artifact (row 2; segments 3-6). While this example of Scribe shows some evidence of the artifact engaging students this engagement is not focused on the artifact and would be best described as a weak artifact mediation – perhaps equivalent to Chi's description of Active engagement versus Constructive or Interactive (Chi & Wylie, 2014).

In the T7 example of Scribe type engagement, the main building of the artifact is generated by two students working together as scribes for their group (pink & turquois; row2 only; segments 1, 2, 3, 4). Its construction is continuous for the first nine minutes of the activity. The main contributions are being generated by the negotiation (row 8) and additions made by the two students (orange & purple; row 5 & 6; segments 1, 2, 3). In addition to the negotiation and meaning-making, which occurs to a greater extent at the beginning of the artifact construction, there is also researching (row 9) that goes into the construction of the artifact (row 2; segment 3). This type of Scribe shows a higher level of engagement around the artifact construction.

T6



T7

Figure 6.15 Comparison between two Scribe types of engagement (T6 & T7). T6 is an example of a slow paced discontinuously constructed artifact. T7 is an example of a fast-paced continuously constructed artifact.

Comparison of Team-Play Type Engagement Generating an Artifact

Figure 6.16 shows a comparison of two Team-Play type engagements over a similar time period. Example T9, described earlier, shows how an artifact emerges quickly and continuously (see rows 11 & 12), with the help of indirect contributions from members of the group (row 15 & 16). Very important in the last minutes of the artifact construction in the direct repairs to the artifact (row14; segment 8) where three students are involved. Example T16, also emerges quickly and continuously but, notably, there is a parallel construction of two simultaneously emerging artifacts (rows 21 & 22) in addition to the additions and repairs being made directly (row 24 & 25), with very little indirect construction. Both these samples are good examples of what Chi refers to as interactive engagement (Chi & Wylie, 2014). What is different between these two T9 and T16 examples, however, is the amount of negotiation that takes place in T16. This suggests that while the Team-Play engagement is clear, there is something very different about what it takes to construct the artifact. What we know about these two groups is that the T16 students were less confident in their solutions and likely had less prior knowledge of how to solve the problem. Therefore, the early negotiation is a critical part of their understanding how to build the artifact. T9, on the other hand, were made up of students who had a high level of prior knowledge and seem to only need to negotiate with each other about some smaller aspect of the artifact (approximately four-minute mark). This leads us to consider whether there is some type of tacit agreement between students who have a greater degree of common ground therefore do not need to have the same amount of discussion to construct the artifact.

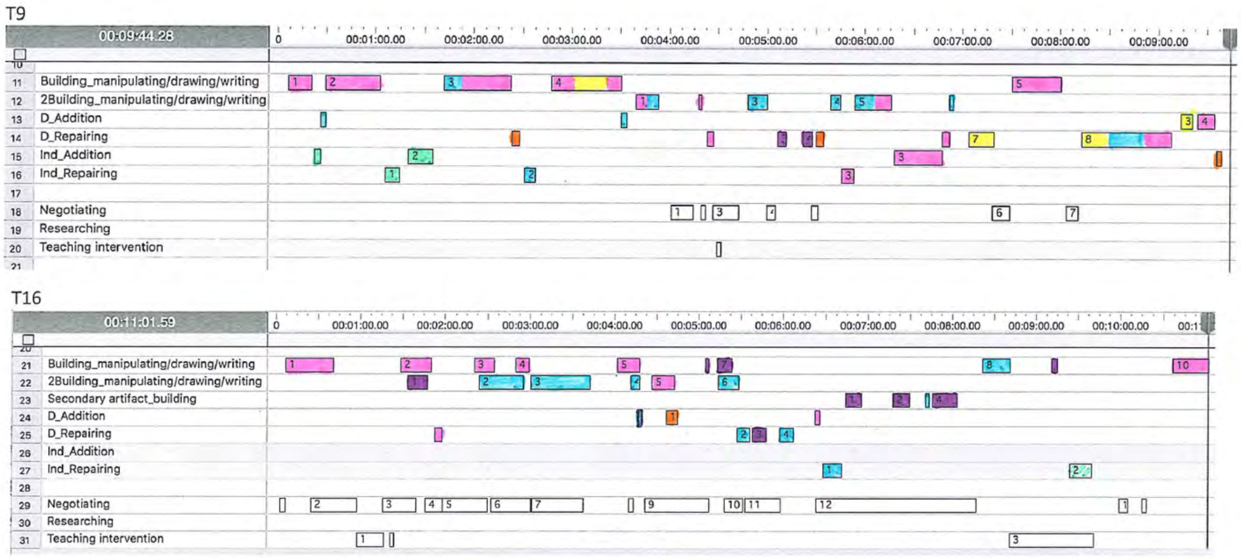


Figure 6.16 Comparison between two Team-play types of engagement (T16 & T9).

6.3 SUMMARY

As teacher-researchers, we claim that the team-play engagement type is the most satisfying because of the clear evidence of student engagement. Such "interactive" types of knowledge construction are supported by the literature as being more likely to promote learning for all participants (Chi & Wylie, 2014). The data, however, show that each engagement type can also be accomplished at a shallow or deep level, which can add greater levels of meaningfulness for more members of the group task. In the scribe mode, only one student physically constructs the artifact. Yet, the artifact emerges as a result of group negotiation including frequent corrections or "repairs". In the Team-play mode, students construct simultaneous artifacts within the same space and engage in lots of negotiation. In fact, a secondary artifact is built to allow for further explanation of ideas. This brief snapshot provides an example of how a deep level of even a scribe engagement can benefit more participants.

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CHAPTER 7
DESIGN BASED EXPERIMENT

It is claimed that physical objects, which can be touched and manipulated "can continue to exist across time and space, and they can continue to exist as physical objects even when not incorporated into the flow of action (Wertsch, 1998, pp. 30–31)." Such thinking, in concert with reflections on the role of artifacts as tools for mediation (e.g., Vygotsky, 1978; Engeström, 1999; Cole, 1979; Hakkarainen, 1999), has lead us to recognize the importance of the extended or persistent artifact. This transforming object can go from material to psychological to cultural. Few have looked at this topic as it relates to classroom learning (e.g., McDonald, Le, Higgins & Podmore, 2005). We created this Design Based Research (DBR) to explore the possibility of designing such an object which is both tool and artifact. In order to better understand the role of reused (or persistent) artifacts, this study engaged in a DBR project that used a co-design approach to building several assignments that called for teachers to extend the use of both primary and secondary artifacts. This DBR project consisted of two phases that span two semesters: (1) Phase 1 in the Fall 2015; and, (2) Phase 2 in the Fall 2016. Each phase had several iterations, in keeping with the DBR method. We describe this two-year project in brief below.

7.0 METHODS - DESIGN BASED RESEARCH PROJECTS

Design Based Research (DBR) is a methodological approach that allows researchers to work with teachers to produce learning interventions. DBR consists of iterative cycles of implementation and testing to ensure an adaptation of the theory to the real conditions of the educational context. The method must take into account the real opportunities and limitations of the educational context in which the intervention will be implemented. In fact, DBR uses mixed methods of data collection to ascertain a base understanding of the work in question. In doing so, the findings of studies using DBR are directly applicable to the local environment and help to plan the general principles for creating subsequent educational interventions.

In this instance, the quasi-experimental design built into the DRB project was used to examine specific aspects of the production process and how they influence the product and its use: migrating to collective from individual artifacts compared with migrating to individual from collective artifacts; public going to private artifacts; static artifacts to dynamic artifacts (see Table 3.1).

7.1 PHASE 1 - FALL 2015

Phase 1 of the DBR project started in the Fall 2015 with the recruitment of six teachers from the Physics departments, representing all three colleges. Along with members of the research team, made up of two physics instructors and two pedagogical designers, the recruited teachers set out to design three activities for the Physics NYA course. Note that the actual design team consisted of the four individuals with feedback from the six participating teachers.

The topic of Newton's Laws was selected because of their importance in understanding motion. In addition, the topic generally is introduced mid-way through the semester (between weeks 5-10) therefore provided sufficient time for the design team to work together. A total of four activities were designed: Activity 1 (Dynamics); Activity 2 (Newton's 3rd Law); Activity 3 (Energy); Activity 4 (Momentum). For the full set of documents produced for these see Appendix C1, 2, 3, and 4. Implementation and data collection summaries shown in Figure 7.1.

#1_Dynamics							
Cohort	**Teacher**	**Room**	**In-class artifacts**	**Pre/after-class artifacts**		**Video**
Hon	T11_hon	Low-tech	✔	✔	✔	✔
	T9_hon	High-tech	✔	✔	✔	✔
Regular	T11_regular	High-tech	✔	✔	✔	✔
	T15_regular	High-tech	✔	✔	✔	✔
	T16_regular	High-tech	✔	✔	✔	✔

#2_Newton's Third Law						
Cohort	**Teacher**	**Room**	**In-class artifacts**	**Pre/Post-class artifacts**		**Video**
Honors	T11 - hon	Low-tech	✔	✔	✔	✔
	T9_hon	High-tech	✔	✔	✔	✔
	T10_hon	Low-tech	✔			✔
Regular	T9_regular	High-tech	✔	✔	✔	✔
	T15_regular	High-tech	✔	✔	✔	✔
	T16_regular	High-tech	✔			✔

#3_Energy						
Cohort	**Teacher**	**Room**	**In-class artifacts**	**Pre/Post-class artifacts**		**Video**
Honors	T11	Low-tech	✔	✔	✔	✔
Regular	T4	High-tech	✔	✔	✔	✔

#4_Momentum						
Cohort	**Teacher**	**Room**	**In-class artifacts**	**Pre/Post class artifacts**		**Video**
Honors		Low-tech	✔	VC shared artifact	Post photos & FBDs	✔
				Reflective Writing (RW)	Post RW; Post teacher feedback	✔

Figure 7.1 Summary of the four implementations designed for Phase 1 (Fall 2015), including the sections, type of students, teachers, type of ALC. The checkmarks indicate the data collected.

Data Collection & Procedure

Each activity was implemented and documented using an ethnographic approach to the observational data collection (video recordings, collection of the artifacts). These data were catalogued, and the videos were reviewed along with the observer notes and teacher feedback (informally collected). Decisions for the iterations were based on three criteria: (1) the degree to which the activity allowed students to produce an artifact; (2) the degree to which that artifact production generated student engagement within the groups; and, (3) the degree to which the artifact could be extended and reused for future activities.

7.1.0 Activity 1 (Dynamics)

Activity 1 was divided into three parts – pre-class, in-class and post-class. Its objective was to support students' learning the dynamic's concept: direction of acceleration = direction of net force. In addition, students would have practice with the following: drawing and interpreting motion diagrams; calculating graphical summation of vectors; manipulating coordinate axes to suit a scenario; constructing appropriate free-body diagram and labelling; and, applying dynamic friction to a sliding object.

Part 1 asked the students to engage in a pre-class activity that included a warm-up exercise involving some typical physics questions (see Figure 7.2). It was followed by the in-class activity (see Figure 7.2).

Suppose that you are asked to solve the following problem: Chadwick is pushing a piano across a level floor (see the figure). The piano can slide across the floor without friction. If Chadwick applies a horizontal force to the piano, what is the piano's acceleration? To solve this problem you should start by drawing a free- body diagram.Hint 1. How to approach the problem: You should first think about the question you are trying to answer: What is the acceleration of the piano? The object of interest in this situation will be the object whose acceleration you are asked to find.

Figure 7.2 Excerpt from Activity #1 part 1, the pre-class exercise.

The in-class activity asked students, working in groups of 4 – 6, to correctly label the following vectors (n, f, w, F net, a, v) for three different conditions - box sliding down rough incline at constant speed; at constant acceleration; sliding up incline, slowing to a halt. Activity #1 was capped off with a post-class activity that asked students to compare the different conditions (each group's condition being different) and comment on the common thread (Figure 7.3). For this part of the activity, students were asked to upload their pictures from stage 3 and, at home and individually, rank these 6-7 pictures in order of (i) increasing normal force, (ii) increasing acceleration. This post-class activity was completed in the online discussion platform Visual Classrooms. Lastly the student, as individuals, were asked to reflect on the series of exercises they had engaged in (see Figure 7.4).

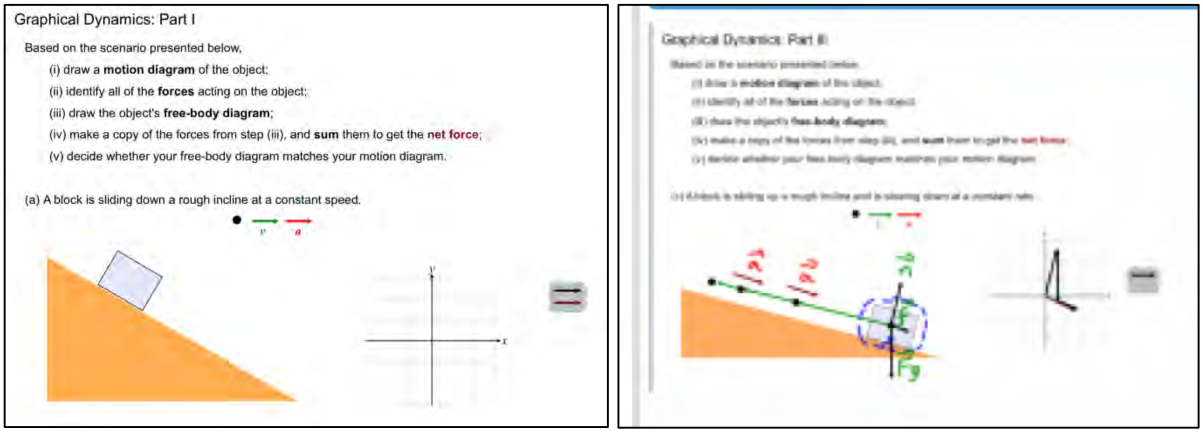


Figure 7.3 Example of comparison exercise students contributed to as a post-activity #1 exercise.

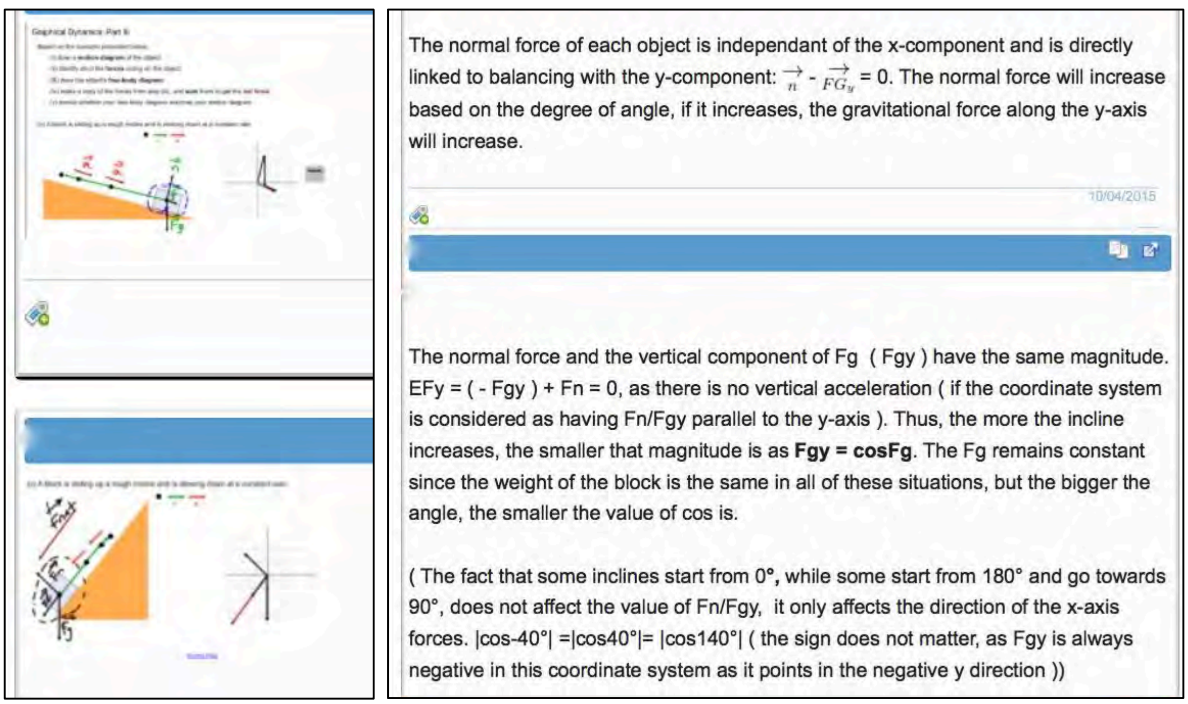


Figure 7.4 Example of comparison exercise students contributed to as a post-activity #1 exercise.

7.1.1 Methods for Analyzing Activity 1

In order to assess whether or not the in-class activity was successful the artifacts produced by the groups were analyzed and graded. For the purpose of this report we selected two sections that could be readily compared because of their similar populations – T9 and T10 both honors physics but taught by different teachers using in different types of ALCs. The comparison allowed us to understand whether or not the environment or the teacher might be responsible for differences to the artifacts production process, and to the learning potential of the designed activity.

Process for Constructing Artifact Rubric for Dynamics Activity

For the purpose of comparing the artifacts between the sections, and within the section, only the common tasks were included [only the object going down the slope]. The series of artifacts were shown to several experts [physics instructors] who picked out the salient points while comparing and contrasting the artifacts, both intra- and inter-class. A gradated series of cases/codes was developed for each section of the artifact [the FBD and the vector sum]. The focus was on the correct physics, and a putative grade was given for each code. This allowed a total grade to be easily calculated for each group.

Table 7.1 Comparison of section's T9 and T10 averaged class grade on Activity #1 artifact.

Artifact score	Class section	
	T9	T10
Average	7.7	7.4
SD	1.3	1.8

Additional codes were allocated for non-physics differences: for use and orientation of an axis [since the classes used axes differently] and for on- and off- task graffiti. All codes were observed in all classes, but there were no significant differences between the two groups in terms of the physics scores. There were differences in other aspects between the groups. The artifacts were analyzed and given a grade, the average

7.1.2 Assessing the Group Learning in Activity 1

We selected six groups, three from each of the two sections (T9-1, T9-4 & T9-6; T10-1, T10-3 &T10-4), as representative of the types of engagement that were commonly seen during the production of the artifacts for Activity #1. See Figure 7.5 and 7.6 for examples of the classroom and engagement context. The video data of their discussion during the construction of the artifact was analyzed using discourse analysis approach.

Overview of the data

Several of the groups struggled with a common misconception: for an object to be in motion there must be a force making it move in the direction of motion. In other words, students misunderstand that the net force is in the same direction as the *velocity* [direction of motion] rather than the Newtonian understanding that the net force is in the same direction as the *acceleration* [the direction of change of velocity]. Both classes showed examples of this.

The easier case is of the box sliding down the slope. Students accept that it is the component of the weight that pulls the object down the slope. However, group T9-4 still held the misconception that there must be an extra force pulling down. They included this extra force on the free body diagram and constructed their vector sum with this extra force. This was immediately apparent on their artifact and the teacher noticed by looking at it. The teacher came over and prompted some discussion about the physics of the situation. The students then corrected the problem.

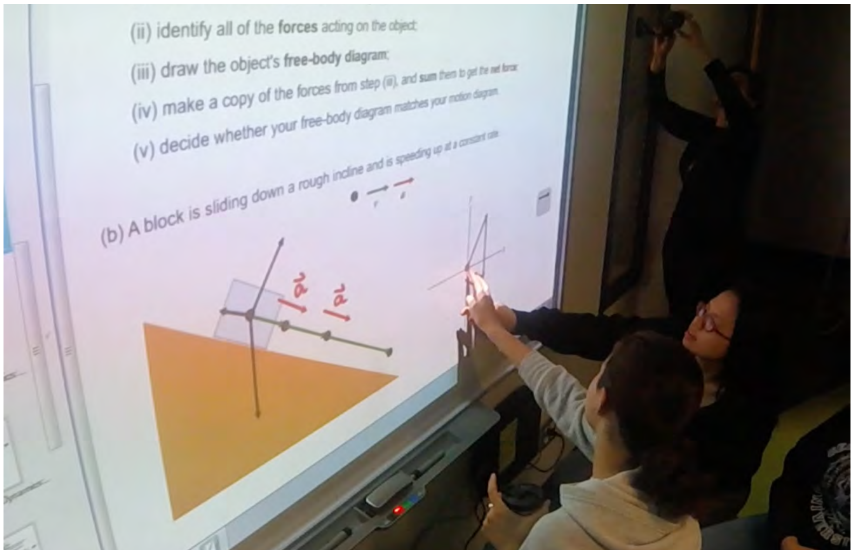


Figure 7.5 Students in T9-1 constructing their group's artifact for Activity #1.

The conceptually more difficult case is of the object going up the slope. Several groups struggled with: what is making the object go up the slope? Indeed, initially there must have been some sort of force [a kick or push] to make it go up the slope, but the misconception is that this force must still be present for the entirety of the motion. When this force is no longer present, the net force, and therefore the acceleration will be down the slope, causing the object to slow down. Many of the groups immediately got this subtlety in particular T10-4, and it didn't warrant significant discussion for these groups. However other groups T10-3 explicitly mention an acceleration and/or net force up the slope.

For group T10-3, the group started off on the wrong foot: even their motion diagram is indicating an acceleration up the slope, so everything that follows is also wrong. Interestingly, one student does realize something is wrong when doing the vector sum task. This part does get corrected on the basis of this recognition, while leaving the FBD incorrect. The teacher notices a problem with the artifact, and comes over, prompts discussion and then the FBD is also corrected.

T10-1 has a similar problem, and the first part of the problem is nominally correct. The group stumbles on the block going up part of the problem, making incorrect statements about the directions of the acceleration for the two cases. The group isn't completely on the wrong track, but reject the correct answer and consequently get stuck. In this case, the teacher did not notice and/or was unavailable and the class finished before the problem was resolved.

One group had time and space to explore around the topic

T10-4 was actually quite a successful group who quickly converged on the correct answer, leaving time for exploring. This did include off-task doodling, but one interesting interaction involved the vector sum task. A property of vectors is that the order of addition does not matter (commutative). So, for the vector sum task, whichever way the vectors are added (tail to tip) the result should be the same. This group went through a process of drawing a vector sum correctly, erasing it, then redrawing the sum with a different order of vectors, which is also correct. The group seemed to recognize that each iteration was correct and therefore didn't elicit much conversation.

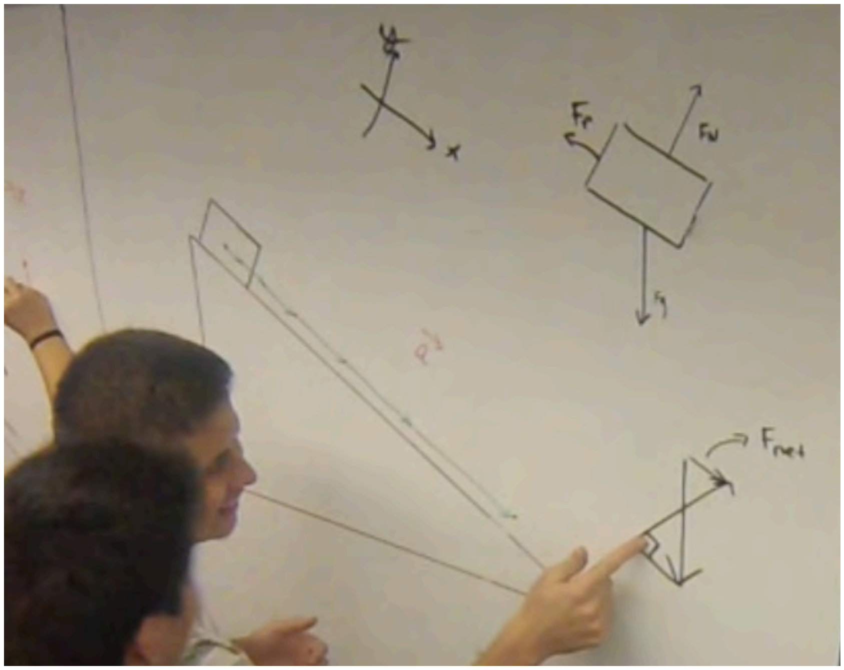


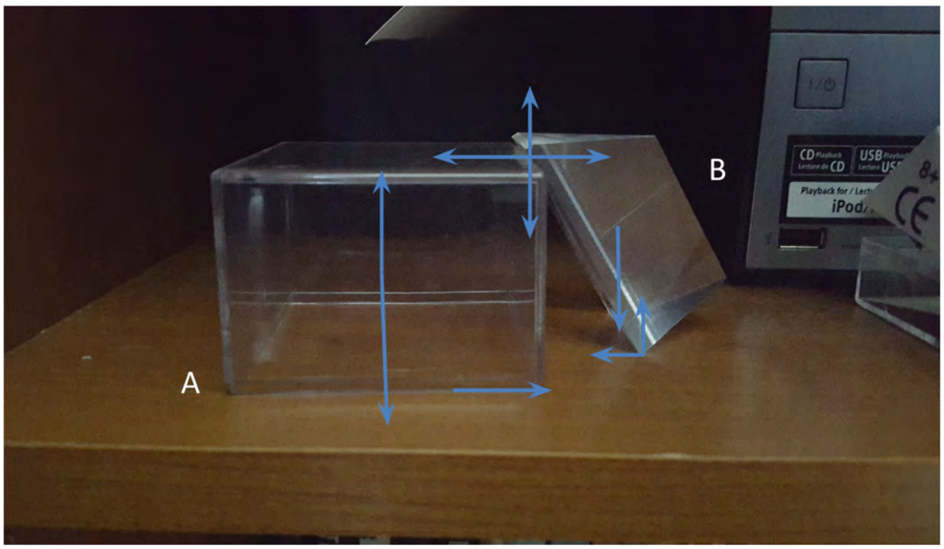
Figure 7.6 Students in T10-4 completing the vector sum task for Activity #1.

7.1.3 Evaluation of Activity 1

On average, Activity #1 achieved the goal of promoting learning. In particular, the assessment of the student artifacts show that, on average, the groups understood the activity and made correct decisions in the required calculations. In regard to the Activity's DBR goal of producing artifacts that could be extended, these three exercises provided students with the opportunity to generate three different but related artifacts, each on a different social plane. Part 1, the pre-class artifact was an individual production. Part 2, the in-class artifact was a group production. Part 3, the post-class artifact was a class-level production. While all were relatively well received the purpose of the artifacts themselves was lost. There was no reason for the students to meaningfully reuse these objects or to build on them. Therefore, we set about designing the next round of artifact producing activities as part of this DBR project.

7.1.4 Activity 2 (Newton's 3rd Law)

Activity #2, similar to Activity #1, was divided into three parts. As the iteration of Activity #1, the co-design team set about to improve on the artifact's purpose and create an intentionality for its reuse. The content objectives for Activity#2 were to have student practice: isolating interacting objects for a Newton's Third Law analysis; constructing a pair of linked free-body diagrams, and to correctly identify action-reaction pairs; and, applying Newton's Third Law to both static and dynamic interacting objects. Part 1 was a pre-class exercise that introduced the students to Newton's Third Law. Each student was asked to photograph two static interacting objects and to construct the associated pair of free-body diagrams. These were then submitted through Visual Classrooms group space (see Figure 7.7). Part 2, the in-class activity, made explicit use of these photos and free-body diagrams and expanded on by a sequence of collaborative activities (Figure 7.8). Part 3, the post-class exercise, asked each student to rework their original diagrams. In Visual Classrooms, student groups collaborate to regulate and to correct each other's work. The final product was a group submission of two free-body diagrams per student, along with several written statements detailing the shifts in thinking that led to it. The project was assigned a group grade by the instructor in order to encourage active collaboration.



Name	Force
A1	Floor normal
A2	Prism normal
A3	Floor friction
A4	Prism friction
A5	Weight

Name	Force
B1	Block friction
B2	Floor normal
B3	Floor friction
B4	Block normal
B5	Weight

Figure 7.7 Example of students' contribution to the pre-class Activity #2 exercise.

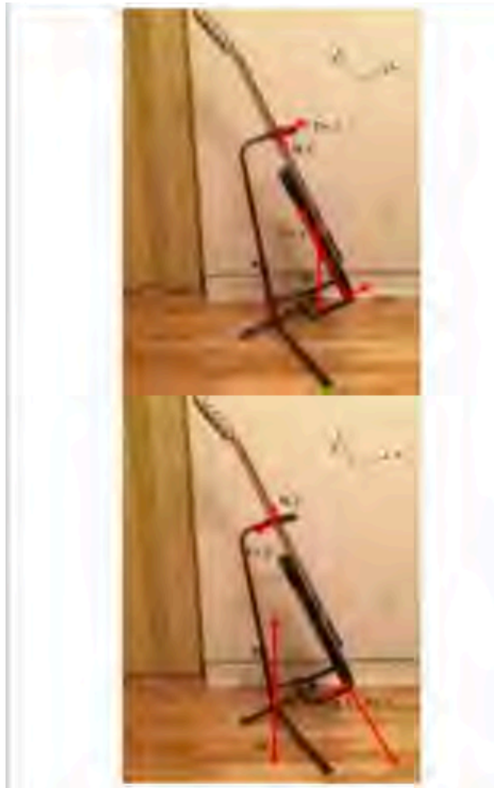


Figure 7.8a Example of the in-class exercise for Activity #2. Extension of the pre-class individual artifact, brought into class and forming the basis of discussion and further elaboration.

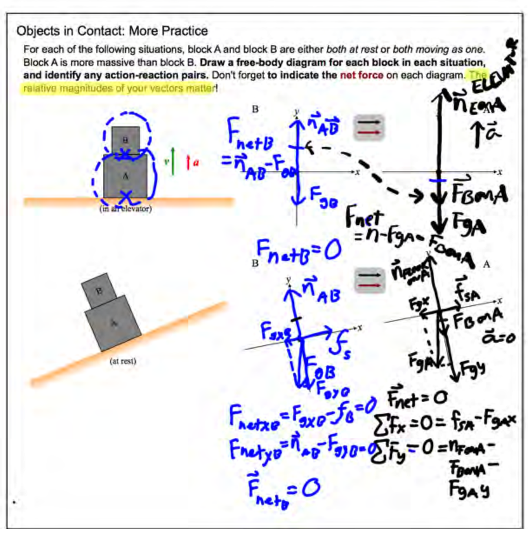
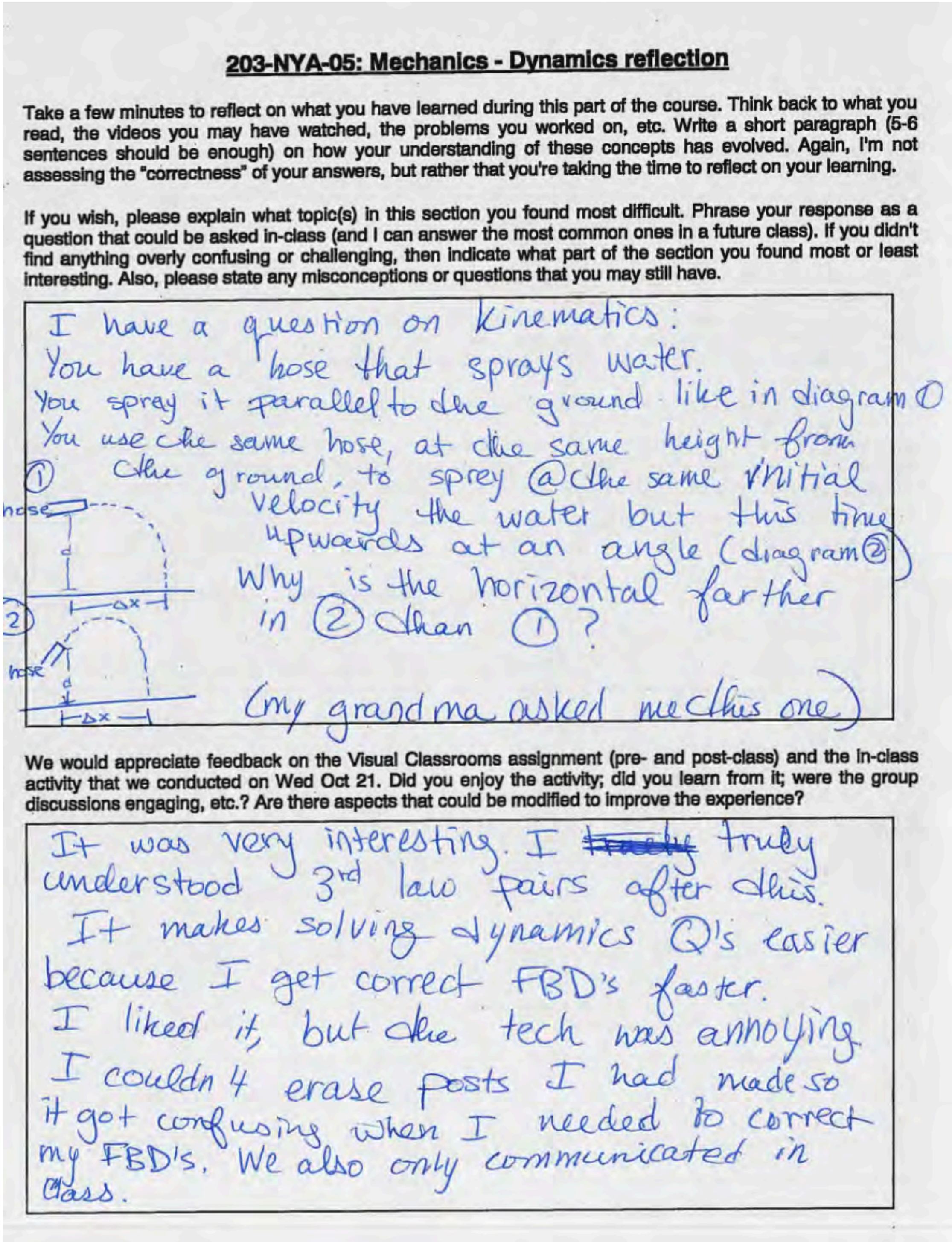


Figure 7.8b Example of the in-class exercise for Activity #2.



203-NYA-05: Mechanics - Dynamics reflection

Take a few minutes to reflect on what you have learned during this part of the course. Think back to what you read, the videos you may have watched, the problems you worked on, etc. Write a short paragraph (5-6 sentences should be enough) on how your understanding of these concepts has evolved. Again, I'm not assessing the "correctness" of your answers, but rather that you're taking the time to reflect on your learning.

If you wish, please explain what topic(s) in this section you found most difficult. Phrase your response as a question that could be asked in-class (and I can answer the most common ones in a future class). If you didn't find anything overly confusing or challenging, then indicate what part of the section you found most or least interesting. Also, please state any misconceptions or questions that you may still have.

I have a question on Kinematics:
You have a hose that sprays water.
You spray it parallel to the ground like in diagram ①
You use the same hose, at the same height from
① the ground, to sprey @ the same initial
velocity the water but this time
upwards at an angle (diagram ②)
Why is the horizontal farther
in ② than ①?

(my grandma asked me this one)

We would appreciate feedback on the Visual Classrooms assignment (pre- and post-class) and the in-class activity that we conducted on Wed Oct 21. Did you enjoy the activity; did you learn from it; were the group discussions engaging, etc.? Are there aspects that could be modified to improve the experience?

It was very interesting. I ~~[illegible]~~ truly understood 3rd law pairs after this.
It makes solving dynamics Q's easier because I get correct FBD's faster.
I liked it, but the tech was annoying. I couldn't erase posts I had made so it got confusing when I needed to correct my FBD's. We also only communicated in class.

Figure 7.9 Example of students' reflections submitted as Post-activity exercise, after activity #2.

7.1.5 Evaluation of Activity 2

On average, Activity #2 also achieved the goal of promoting learning as seen by the quiz results. Once again students were provided with the opportunity to generate three different but related artifacts, each on a different social plane. This time Part 1, the pre-class artifact, was an individual production but also included group discussion as part of the Visual Classrooms environment. Part 2, consisted of both the extension of the individual artifact which allowed students to continue the discussion of their individual artifacts (see Figure 7.8a). As well, it included the production of other artifacts that were more typical worked out physics problem, based on the same principles, but typical physics problems (see Figure 7.8b). In regard to the Activity's DBR goal of producing artifacts that could be extended, these three exercises were not truly successful. Once again there was the problem of not having a real reason for students to return to the original photos and free-body diagrams, meaning there was no genuine reuse these objects.

7.2 SUMMARY OF PHASE 1

While there were two more attempts to modify the design of the activity, these were not fully implemented (see Appendix C3 & C4 for Activity #3 and Activity #4 respectively). This first phase of the DBR project showed the difficulty in constructing meaningful activities that require extending the artifacts beyond the simple first level transformation. That is, take a photo and annotate it with physics notations (i.e., create a free body diagram). It also showed the difficulty of the co-design process which, out of necessity, calls for content experts and pedagogical design experts to work together as equals.

7.3 PHASE 2 - FALL 2016

Phase 2 of the DBR project took place in the Fall 2016. This time around the challenge was focused more closely on designing an activity wherein an artifact could be revised, transformed and evolved meaningfully. That is, there is an authentic need to reuse the artifact, which, in turn, plays an important role in the learning. In addition, this time around we focused on working more closely with the teachers who would be implementing the activity, giving them a greater sense of ownership. Therefore, when the activity needed to be adapted, it was done so *in situ,* and with full support of the design team. This, we believe, is a critical move in the co-design process and resulted in several further adaptations to the activity that allowed the students to engage more deeply with the artifacts being produced.

7.3.0 Activity 5 (Interacting Objects – Newton's 3rd Law)

Design-Based Objectives of Activity 5

This time around, we designed the *Interacting Objects Activity* intervention (see Figure 7.10). The intension of this activity was to promote the development of a persistent artifact that students would continue to transform over several weeks. In doing so, the final artifact would allow us to examine the impacts of the following variables: (1) individual vs. collective; and (2) private (group spaces) vs. public (group spaces). The latter variable unavoidably is often confounded with technology choices: the online private group environment (e.g., SMART Amp) vs. the in-class public environment (digital multi-touch whiteboards or dry eraser whiteboards).

#5 Interacting Objects								
Cohort	Teacher	Room	In-class artifacts	Reflective writing	In-class assessment	After-class quiz	Delayed test	Video
Honors	T9_01	H-tech	✔	✔	✔	✔	✔	✔
	T11	L-tech	✔	✔	✔	✔	✔	✔
Regular	T9_10	H-tech	✔	✔	✔	✔		✔
	T8	H-tech	✔					✔

Figure 7.10 Summary of the implementations designed for Phase 2 (Fall 2016), including the sections, type of students, teachers, type of ALC. The checkmarks indicate the data collected.

Learning Objectives of the Activity 5

The focus was placed on one concept, Newton's Third Law. Perhaps the easiest law for students to state on demand - i.e., "every action has an equal and opposite reaction" - but is actually difficult to interpret and easily confounded with other concepts. Correct interpretation and implementation of the third law is therefore an important marker of a student's journey from non-Newtonian to Newtonian thinker. Additionally, this time around the design team engaged the participating teachers more fully, one teacher in particular.

In particular, students often confuse specific cases in which forces are equal and opposite due to Newton's second Law [$\sum\vec{F} = m\vec{a}$] with cases of Newton's third Law. For example, an object simply sitting on a table has two forces acting: a normal force up, and the weight [the gravitational force] down. These forces are indeed equal and opposite, because the object in this non-accelerated situation has zero net force, and the forces must balance. They are equal and opposite, but not because they represent an action-reaction force pair. Rather, the normal force is acting as a force of constraint preventing the object from accelerating and, consequently, must be opposite in direction to, and equal in magnitude, the weight in order to satisfy both Newton's First and Second Laws. If the object was accelerated, say upwards in an elevator, there would have to be a net force up, and the forces would no longer be equal and opposite: the normal force would be greater.

In addition, an expert would point out that the normal force and weight are products of two different interactions on the object: the normal force is an electromagnetic interaction with the surface the object is sitting on, but the weight is a gravitational interaction with the mass of the earth. The forces therefore represent two different interactions and two different types of forces acting on a single object. In contrast, Newton's third Law describes a *single* interaction (action-reaction) between *two separate* objects.

This misconception of confusing second and third force-pairs is particularly stubborn, as evidenced by results from the Force Concept Inventory literature.
A less stubborn, but still important-to-overcome, misconception about Newton's third Law is that it does not apply between objects that are accelerating, or moving differently. It always applies.

Specifics of the Conceptual Artifact 5

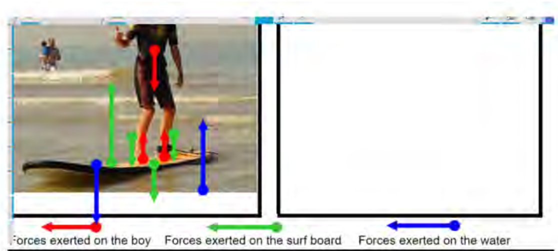
The learning objectives for this activity were for students to develop their own expert heuristic that would allow them to correctly distinguish between equal-and-opposite force-pairs due to Newton's Second or Newton's Third laws. This heuristic should include a deeper definition of Newton's third law than is normally described: incorporating the one interaction two objects concept, and that one interaction implies one type of force only. In addition, the heuristic should be robust for accelerating cases.

7.3.1 Materials Designed for Activity 5

Activity 5, Interacting Objects (Newton's 3rd Law) consisted of four components: (1) pre-class writing activity and photograph; (2) in-class exercise analyzing and annotating photographs from the group (using SMART Amp); (3) in-class exercise development of a heuristic based on the common solutions to the analyzed photos; and (4) post-class comparisons.

Pre-Activity Writing: Students were asked to describe their understanding of Newton's Third Law. The goal of this task was to elicit their prior knowledge. The competency had been covered at high school, although not at the required depth for college, meaning that students were able to give the "action-reaction" definition, and give a short example.

Selection of a real-world pair of interacting objects: This task was similar to other activities earlier in the semester in which connections were made with real-world examples by students finding photos or video, either from their own device cameras, or from the internet. One goal is to lower barriers between the real world and the classroom by bringing their out-of-classroom experiences into the classroom. The instructions constrained the task, e.g. only two interacting objects, situation in equilibrium [static case]; to make the task more focused and also to allow comparison with other students' work.



Isaac Newton stated in his third law that for every action, there is an equal and opposite reaction. It entirely relates to my image and the forces that are acting on the surfer, plank and water. At the moment of the picture the three elements were static. Therefore, we can conclude that the sum of the force acting on: the surfer, the board, and the water underneath are respectively zero (if this wasn't the case there would be movement). For the surfer, his weight pulls him down, so the normal of the board equalizes it in the opposing direction. For the board, its weight and the normal of the surfer pull it down, so the normal of the water equalises the sum of these forces in the opposing direction. For the water, the contact force (normal) of the board + the surfer pulls down, and the normal of the water (or the ground if you want to go further) equalizes this downward normal force in the opposing direction.

Figure 7.11 Example of a student's personal annotation of their photo and their explanation of the forces represented in the free body diagram.

Free Body Diagram of Static Case: In this component, individual students drew free body diagrams of the interacting objects. The goal here first was to model the situation and take a sometimes-complex situation and simplify it for analysis. This is a skill that had been covered previously in the course, so the task also activated prior knowledge from the course. This work was done in the area provided on the group workspace, which provided axes and vector arrows to scaffold the work.

Free Body Diagram of Accelerating Case: In class, the group chooses one example from the individual submissions. The group discusses and cleans up this chosen case. The next step is where the real learning occurs. The students take their static case, and imagine accelerating it along one axis. For instance, the two interacting cars are put in an elevator accelerating upwards. The free body diagrams must now change, because now there must be a net force in the direction of acceleration. Forces that were equal and opposite because of Newton's second law [because the net force was previously zero] are now *not* equal and opposite, and therefore they cannot be a Third Law force-pair. True action-reaction pairs may change in magnitude but they will continue to be equal and opposite to one another, and they will continue to act on two separate objects.

This activity is quite challenging for students as it has an element of productive failure. Students are forced to grapple with the nature of the force-pairs and often get it wrong initially as their conceptions are "stress tested". However, the provided workspace is the same as for the static case, allowing for students to dig in quickly and to not worry about the workspace infrastructure. The space was designed for students to quickly compare and contrast the accelerated and non-accelerated scenarios.

Writing the Heuristic: Students are asked to do an explicit compare and contrast of the two cases and write a heuristic to describe their new understanding of Newton's third law. This task was designed to allow for the recording of any rise-above ideas that would consolidate the learning. It is this heuristic that would be the evidence of learning and also the take-away for the students.

7.3.2 Assembling the Group-level Artifact

<u>Phase 1 of Activity 5</u>

Selection of photographs showing interacting objects. Students choose lots of fun photos, many of them showing funny animal and insect photos (see Figure 7.12). These would form the basis of the ongoing reused artifact that would progress from individual to group to class artifact.

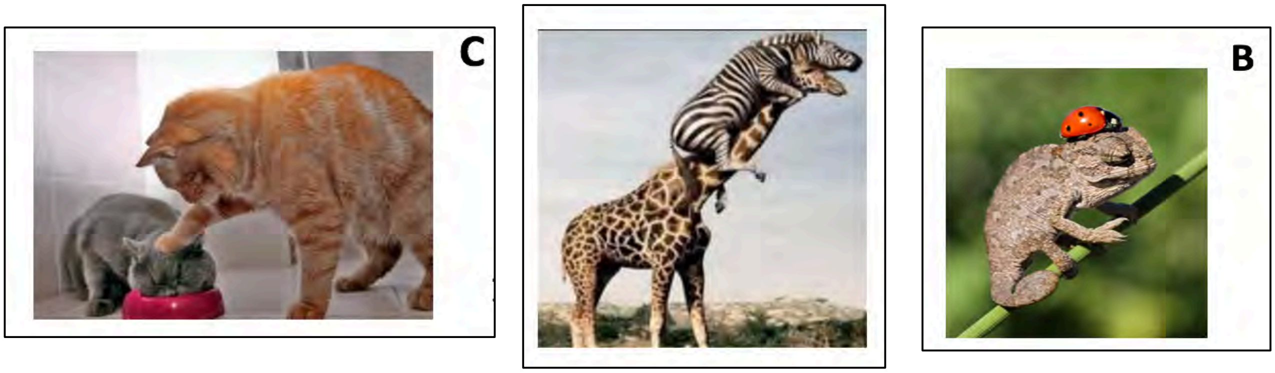


Figure 7.12 Examples of the individual activity and photos produced by students in the pre-class activity.

Phase 2 of Activity 5

First attempts at drawing the free body diagrams on the individual photos produced some misunderstanding and overly complex free body diagrams (see Figure 7.13). Most students didn't understand how to simplify the real-life scenarios into single points.

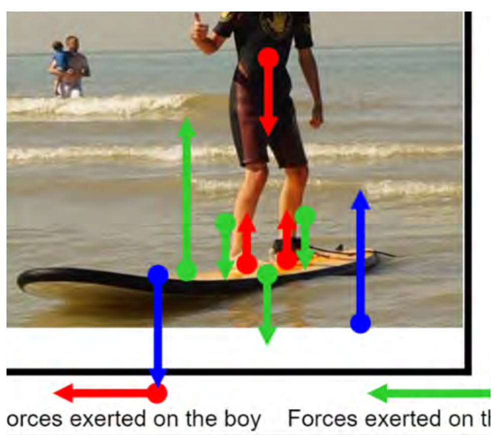
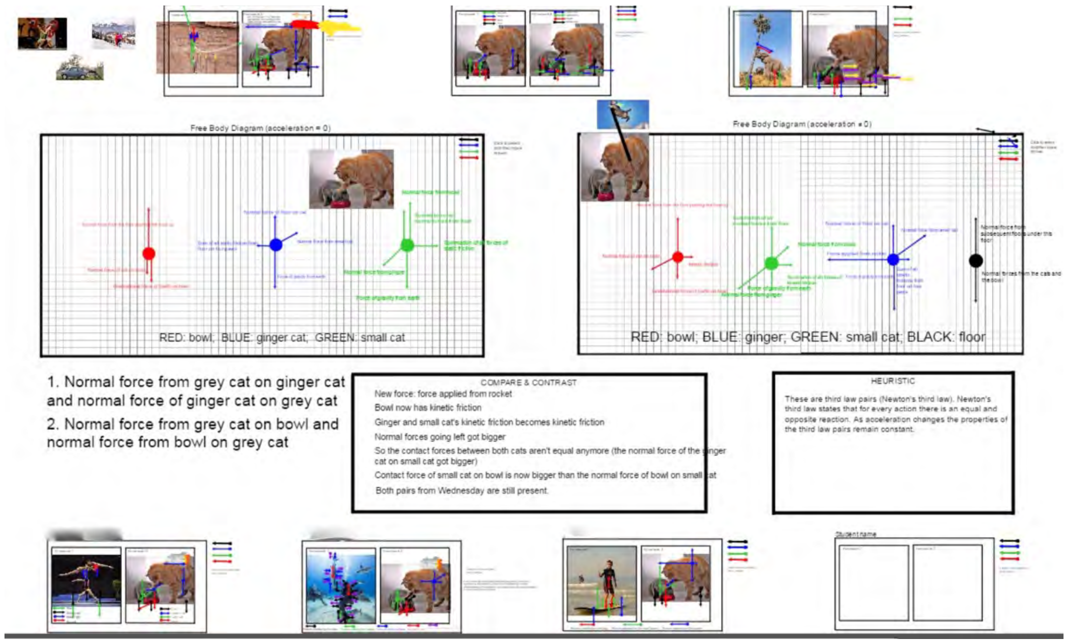


Figure 7.13 One student's efforts at annotating their interacting objects photograph with force vector representations.

However, the group effort shows that when working together, and with the help of the teacher, the students were able to construct an accurate representation of the forces emanating from the interaction of the two bodies as single points (Figure 7.14). Additionally, this figure shows their first attempts at writing a comparison between the two conditions, acceleration =zero and acceleration = non-zero, as well as their group's heuristic.



<u>**Figure 7.14** Group's effort at annotating their interacting objects assignment and working collaboratively to identify and compare the zero and non-zero acceleration cases. This one also includes their first attempt at a heuristic.</u>

<u>Phase 3 of Activity 5</u>

The first two phases of Activity 5 proved to have several main weaknesses with regards to the learning goals – i.e., understanding how to represent the interacting forces. While this conceptual difficulty was an important consideration, this design for the assignment was successful with regard to the reuse of the artifact. Finally, there was a genuine reason to return to the initial objects, and to reconsider how they had been annotated. And, because of the online group collaboration platform, SMART Amp, students could work together on their group canvas both at home and in the classroom. In short, having this new environment made it seamless to transport artifacts into and out of the classroom.

<u>The *in situ* adaption of Activity 5</u>. The need to make this activity work brought about an adaption to its initial implementation script. Three of the four sections choose to solve the problem of students' misunderstanding of how to annotate the real-life images by demonstrating of the solution as the final stage of the activity. However, one teacher chose to continue the activity into yet another couple of classes. He accomplished this by reframing the problem by adding the scaffolding of the simplified block to represent the real-life images (see Figure 7.15). He then gave the students another opportunity to work on the activity and redraw their free body diagrams and compare with each other. This extra time also allowed him to have the student focus their attention on the group heuristics (see Figure 7.16). In fact, the students were asked to vote on which ones most effectively captured the rule of thumb learned by doing the activity and the comparison between the static and accelerating cases.

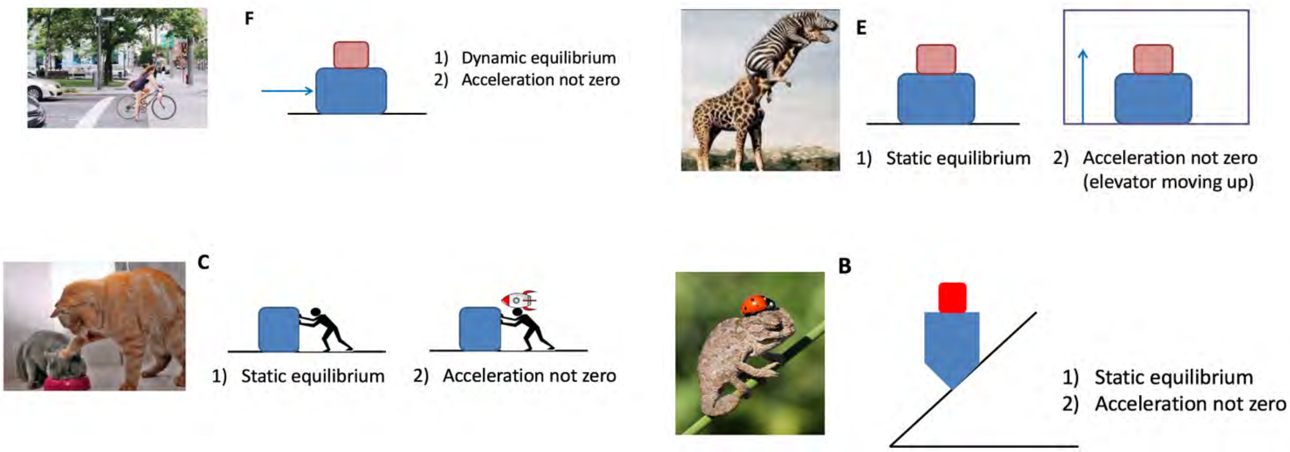


Figure 7.15 Scaffolded images with classical physics block representation, these were inserted into the class-level SMART Amp canvas page.

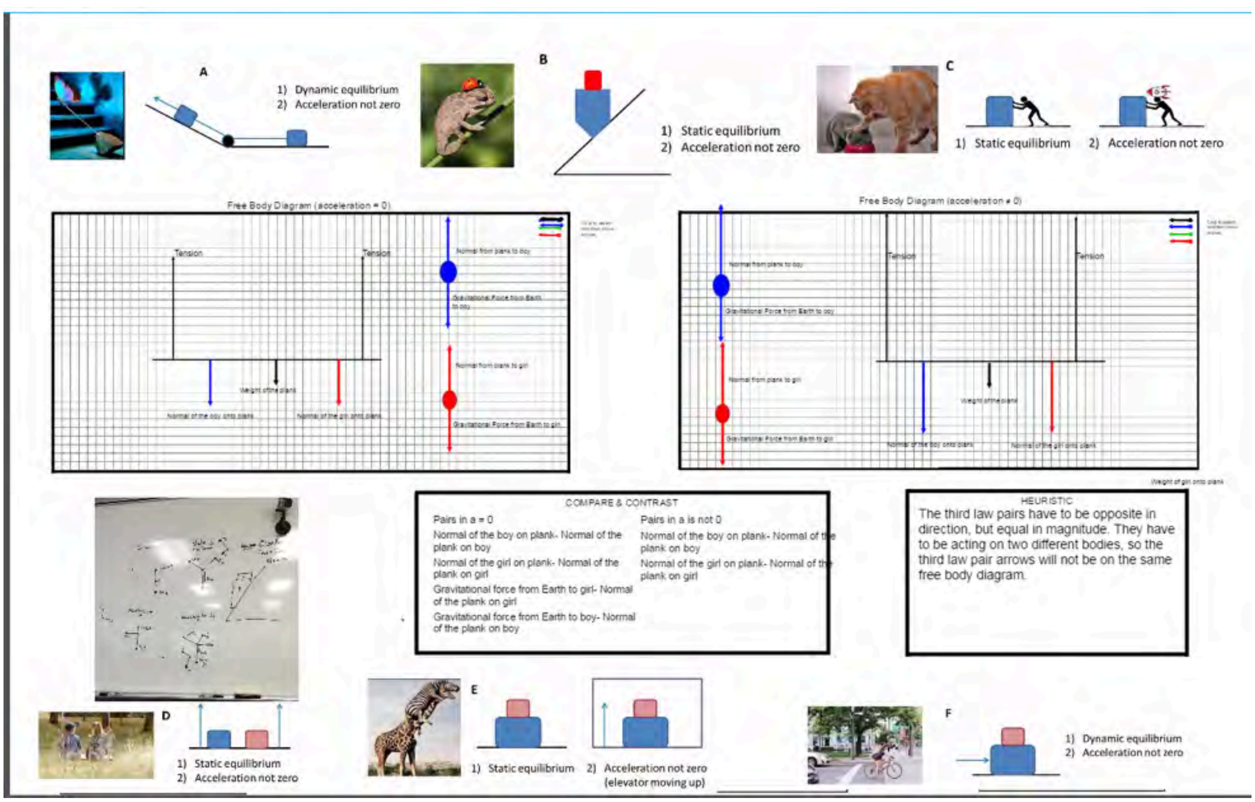


Figure 7.16 One group's free body diagram annotations using the scaffolded canvas, along with their whiteboard elaborations (photo insert) along with "compare & contrast" and "heuristic."

Examples of the group heuristics that were voted on by the class as part of the adaptation of the Activity 5 (see Figure 7.17). Note that the heuristic that received 13 votes was very well done.

There is an equal and opposite reaction for every action. ie. object sitting on table: object exerts a force on table, table exerts a force opposite in direction and equal in magnitude on object. These types of pairs are called **Third law pairs**.

Third law pairs are defined to be acting on 2 objects. It is possible to have equal and opposite forces acting on one object, but this is <u>not</u> a third law pair.

Even though the change in state of a system (ie. system state transforms from dynamic equilibrium to accelerating) may appear as if it has affected the presence of a third law pair, it didn't. If one drew FBDs of bodies in 2 different states and found that the number of third law pairs changed, he has made a mistake and must look over his work.

It is possible that a change in acceleration of a system affects the presence of a *non third law* pair. This entirely depends on the direction of the new acceleration. If the orientation of one of the new acceleration's vector components share a common axis with one of the pair's vector components, the presence of this pair will change. (ex: object in elevator; weight and normal from elevator on object is a pair; elevator begins to accelerate in the same direction as the normal's orientation; normal's magnitude changes; no longer a pair)

Pulleys and other apparatuses that change the way a system presents itself may hide a third law pair from one's eyes. Pulleys and similar machines <u>do not</u> affect the presence of a third law pair; it merely makes it harder to find.

13

Here are rules for identifying Newton's 3rd law pairs:

-For a tension that connects two bodies, the first body will be subject to a tension that is equal and opposite to the tension applied on the second body (in their respective FBDs).

-When two bodies are in contact, a force exerted by the first body onto the second will be met by a force, of equal magnitude but opposite direction, citing from the second body onto the first.

-In cases where a pulley is involved, the pulley does not affect the third law pairs (as it only <u>looks like</u> certain forces might not be a pair because of their apparent direction).

8

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1) Friction laws: (i) If a frictional force exists between bodies, it always faces the direction opposing the motion. (ii) The force of friction is defined by μ*N. μ represents the coefficient of friction (static or kinetic) between the surfaces and N represents the normal force of the body that applies it. (iii) Friction exists as a third law pair between two studied bodies.

2) Tension laws: (i) The mass of the string should be massless which tells us it is only used to connect two bodies. (ii) Tension does not always exist as a third law pair between two bodies (Directions may not be exactly opposite even though their magnitudes are the same). A set of bodies is called a system and it should accelerate at the same rate, given they are on the same plane.

3) Normal laws: (i) when studying two specific bodies, they apply a force on each other which acts as a third law pair. The way the blocks are positioned when they interact does not matter as the normal will be perpendicular to the applied surface.

4) General laws: (i) If the system is in static equilibrium, the acceleration is = 0. The force of static friction opposes the direction of the tendency to move. (ii) If the system is in dynamic equilibrium, the acceleration = 0. The force of kinetic friction opposes the direction of the movement.

6

- Third Law pairs must <u>always</u> act on two different bodies.
- <u>Every</u> force involves the interaction of two objects.
- Forces <u>always</u> come in pairs.
- It is <u>impossible</u> to identify Third Law Pairs on a single body.
- The magnitude of the forces acting on the first object equals the magnitude of the forces acting on the second object, but they are opposite in direction. All of this happens simultaneously.
- "For every action, there is an equal and opposite reaction." *F12 = - F21* *(<u>NO exceptions</u>)*
- Force pairs remain equal if and only if the weight of the objects don't change.
- Two objects that push on each other exchange momentum as well, s. t. the total momentum of the system remains constant.
- The *Momentum Conservation Principle* says that the momentum lost by the first object is gained by the second object (eg. during a collision). This also relates to the equal reaction that Newton stated with his 3rd law.

5

The third law pairs have to be opposite in direction, but equal in magnitude. They have to be acting on two different bodies, so the third law pair arrows will not be on the same free body diagram.

2

Any force applied from body a on body b has an equivalent and opposite force from body b on body a

1

Figure 7.17 Examples of the group "heuristics" that were voted on by the class.

7.4 ASSESSING ACTIVITY 5 - FALL 2016

The implementation of the extensive Activity 5 (Interacting Objects) was examined with several assessments: (1) the quality of heuristic that individual students and groups wrote; (2) the accuracy and improvement in the annotations of their artifacts; (3) the correctness of their answers to class quizzes on the topic of Newton's 3rd Law; (4) their ability to identify complete heuristics (vote for the "best" heuristic); (5) performance on final exam; and, (6) maintain their understanding, delayed test after 3 months.

7.4.1 Methods for Assessing the Student Learning in Activity 5

<u>Research Design & Participants</u>

Using a quasi-experimental design, we examined changes in understanding of the concepts related to Newton's 3rd Law both within class and between sections. The primary focus of this study is on the students in the class section (n=35) that worked on the adapted and extended project – teacher T11 who used a low-tech ALC. Most of the work was accomplished at the group level, with six groups made up of 5-6 students each.

Data Analysis

Because the data collected include both group and individual work, the unit of analysis used in this study is both the group and the individual. In order to understand the learning and possible conceptual change that could take place we needed to use a *semantic analysis* methodology. Semantic analysis is a process borrowed from linguistics that allows the researcher to reveal the syntactic structures hidden within a piece of writing, be it a phrase, clause, sentence or paragraph, to their language-dependent meaning. Using this technique required us to start by developing a coding schema based on the analysis of an expert's explanation – i.e., what should be the semantic relationships between the component concepts. Our team of expert physics teachers made this task easier. Using a jointly agreed upon explanation for the Newton's 3rd Law heuristic, we identified the key components and their semantic relationship to form the basis of the coding schema (see Table 7.2). This was used to score the heuristics produced for Activity 5: (1) first group heuristic (Heuristic1 or H1); and, (2) revised group heuristic (Heuristic 2 or H2). We present excerpts of the analyses used to generate these results because of the complexity of identifying changing conceptual knowledge.

Table 7.2. Heuristic coding rubric for Heuristic 1 (H1) & Heuristic 2 (H2) for Activity 5.

Scored Concepts
A - 3rd Law force pairs are "equal and opposite" M - 3rd Law force pairs are equal in magnitude O - 3rd Law force pairs act in opposite directions
B - 3rd Law force pairs must act on two bodies
C - The presence of acceleration may change the magnitude of the 3rd Law force pairs but it does not result in the addition or reduction of the number of force pair, given the same object-to-object contact
D - 3rd Law force pairs must be of the same type. (*e.g.*, both normal, both friction, *etc.*)
E - Concept is incorrect (either 3rd law or external)

7.4.2 Activity 5 - Research Question A

Did students improve in their statement of a 3rd Law heuristic after activity scaffolding/iteration?

We represent the group's initial concepts (H1) and change (H2) in the figure below (Figure 7.18). The left column describes the six groups (and the students within by number) and the concepts identified in their original heuristic (Codes). The right column represents the second heuristic (H2) for the group (note that all but one student was changed) and the additional concepts that appeared in the revised heuristic (Codes).

	Low (Red)	Medium (Violet)	High (Green)
Heuristic 1	1	2	3
Heuristic 2	1	1	4

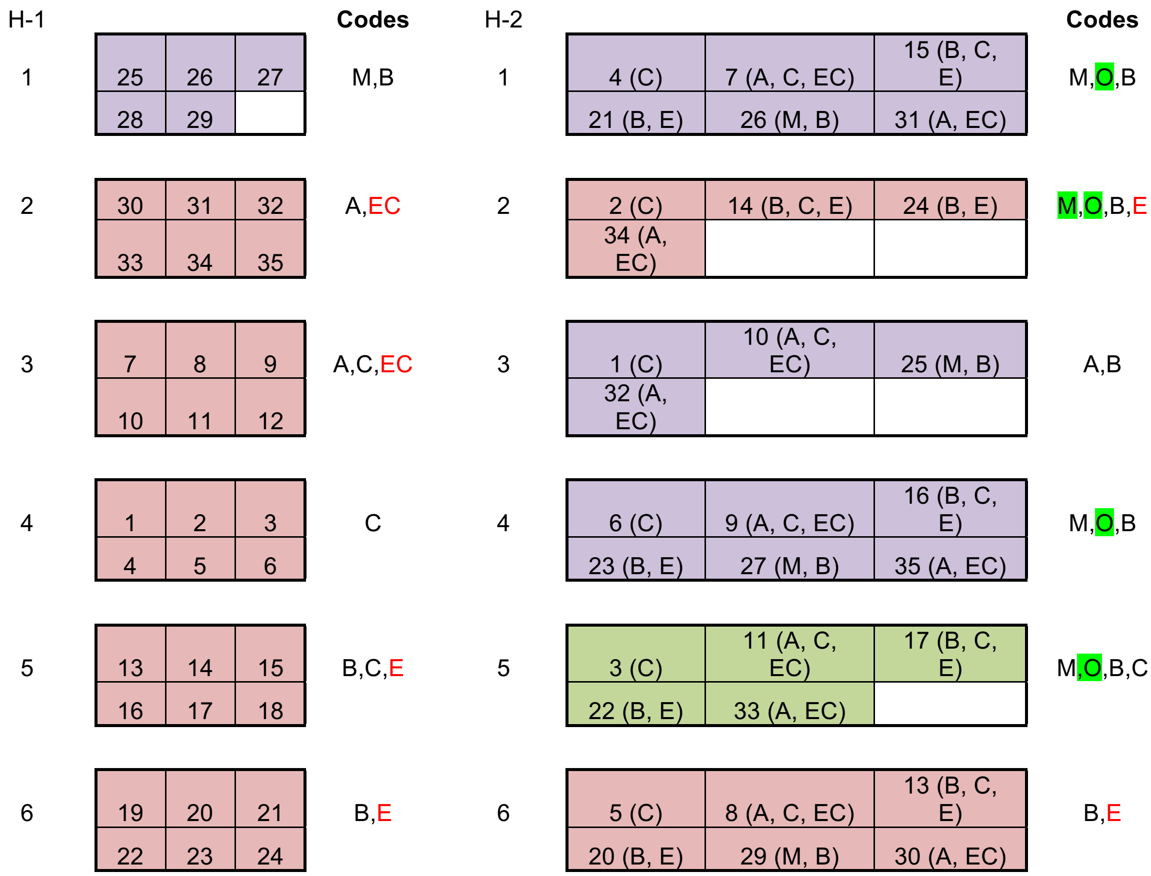


Figure 7.18 Activity group heuristic response patterns in Heuristic 1 (H1) & Heuristic 2 (H2). For H2, students are presented with the coded concepts that their H1 groups had submitted.

7.4.3 Observations for the RQ-A

Group's Conceptual Change

Using the grading rubric above (Table 7.2), the results show an increase in the number of correct properties of Newton 3rd Law force pairs were identified in the follow-up assignment (H2). Note that concepts A, C (incl. EC) and B are prevalent in H1. Seemingly, the concepts M and O emerged from A but that concept C (*i.e.*, acceleration) was dropped from most heuristics from H2 onwards.

Individual's Conceptual Change

When we consider how individual student's conceptions changed, we developed a method to represent the data through a spider graph, or plot. The spider plot below (Figure 7.19) indicates what heuristic concepts were scored for an individual through the activity (H1 &H2) and delayed post-test.

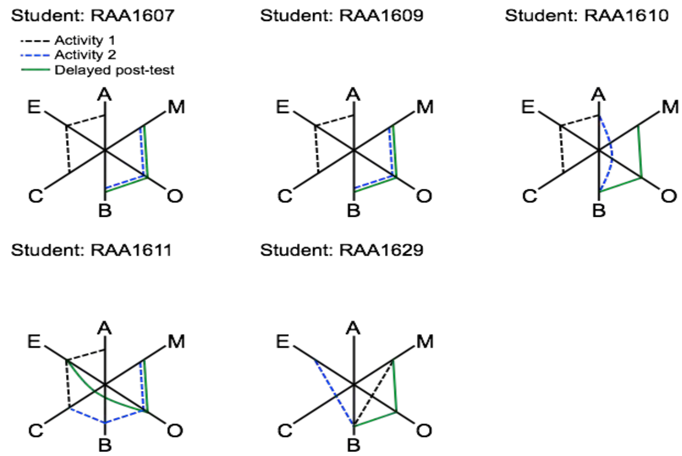


Figure 7.19 Sample spider plots for tracking student heuristics. Note, these 5 students correspond to the students interviewed in the delayed post-test.

Observations: Students RAA16-07, -09, -10 & -11 all share the same Heuristic1 (H1) profile (*i.e.*, A+E+C) as they were all in the same H1 group. Notably, all students except for RAA1611 had a delayed heuristic of M+O+B, which was the most common form of the heuristic in the delayed post-test.

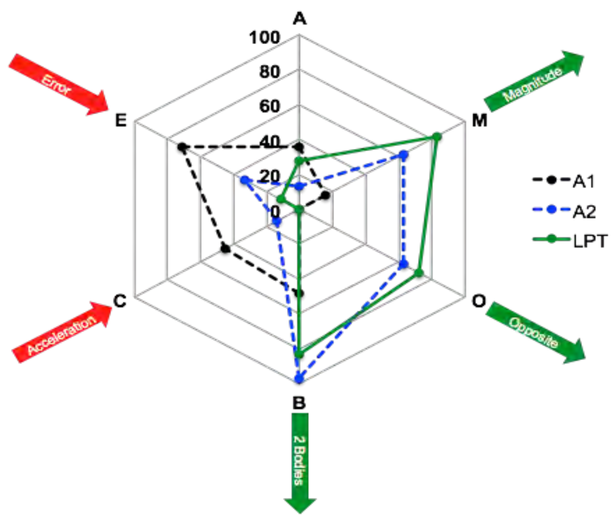


Figure 7.20 Evolution of student heuristics over the duration of the activity + a late post-test assessment. The radial axis represents the percentage of the class who identified the respective 3rd Law component. H1- Heuristic 1; H2-Heuristic 2; LPT-late post-test. NB: *i)* H1&H2 responses were done in groups while the LPT was an individual response. *ii)* This data includes all students who participated on a given assessment.

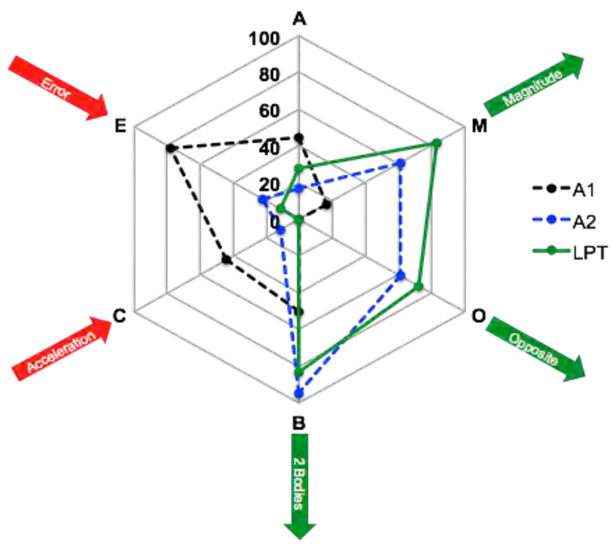


Figure 7.21 Evolution of student heuristics over the duration of the activity + a late post-test assessment. The radial axis represents the percentage of the class who identified the respective 3rd Law component (circumferential axis). H1- Heuristic 1; H2- Heuristic 2; LPT-late post-test. NB: *i)* H1&H2 responses were done in groups while the LPT was an individual response. *ii)* This data includes only the students who were present for the late post-test (LPT).

7.4.4 Activity 5 - Research Question B

Did students improve the accuracy of their artifacts (i.e., FBD) after the scaffolded activity – i.e., the adapted iteration?

To answer this question, we once again we used the same coding schema as for the first semantic analysis (see Figure 7.22). This analysis shows that there was a small increase in the accuracy of the group artifacts was present in the follow-up activity. That is, the FBD accuracy decreased in the late post-test assessment. However, it was not possible to determine whether or not there was individual improvements because the first assessment (H1) was done individually while the second (H2) was a group assessment.

	Low (Red)	Medium (Violet)	High (Green)
Heuristic 1	1	2	3
Heuristic 2	1	1	4

H-1				Codes	H-2				Codes
1	25	26	27	M,O,B,C,D,S	1	4	7	15	M,O,B,C,D,S
	28	29				21	26	31	
2	30	31	32	C,D,S,E	4	2	14	24	B,D,S
	33	34	35			34			
3	7	8	9	M,O,B,C,D,S,E	5	1	10	25	M,O,B,C,D,S
	10	11	12			32			

4	1	2	3	M,O,B,C,D,S	2	6	9	16	M,O,B,C,D,S
	4	5	6			23	27	35	
5	13	14	15	M,O,B,C,D,S,E	3	3	11	17	M,O,B,C,D,S
	16	17	18			22	33		
6	19	20	21	M,O,B,C,D,S	6	5	8	13	M,O,B,C,D,S,E
	22	23	24			20	29	30	

Figure 7.22 Group artifact response patterns in Heuristic 1 & 2.

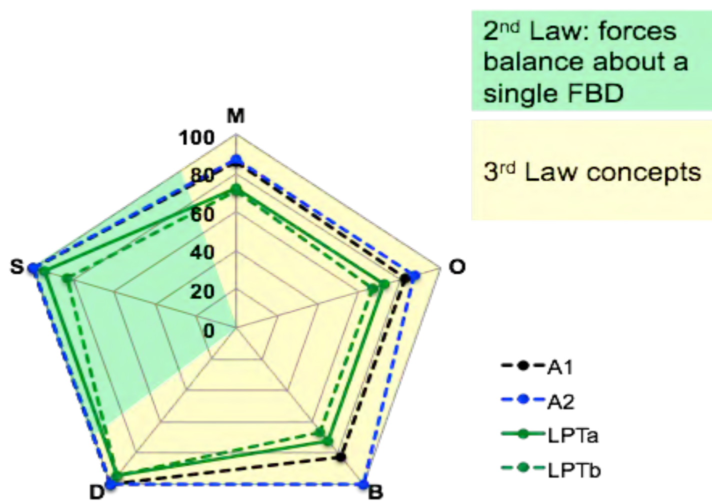


Figure 7.23 Evolution of FBDs by activity artifact and late post-test assessment scoring. The radial axis represents the percentage of the class who correctly drew the forces with the scoring components (circumferential axis). H1-Heuristic 1; H2- Heuristic 2; LPTa-late post-test FBD-image 1; LPTb-late post-test FBD-image 2. NB: this analysis was only performed on the activity FBDs in the case of zero acceleration so that comparisons could be made with the late post-test assessment. Green: forces are balanced about a single object (a=0, FNet=0, concept 'S'); Yellow: 3rd Law concepts.

7.4.4 Activity 5 - Research Question C

Did students improve in their ability to correctly answer a numerical 3rd Law problem?

While the number of low-performing students was equal between the two assessments, the number of high-performing students increased by 6. Note that 2 students who were present in the original activity did not have the completed 3rd Law exam question for scoring.

	Students	Low (Red)	Medium (Violet)	High (Green)
Heuristic 1	35	9	13	13
Final Exam	33	9	5	19

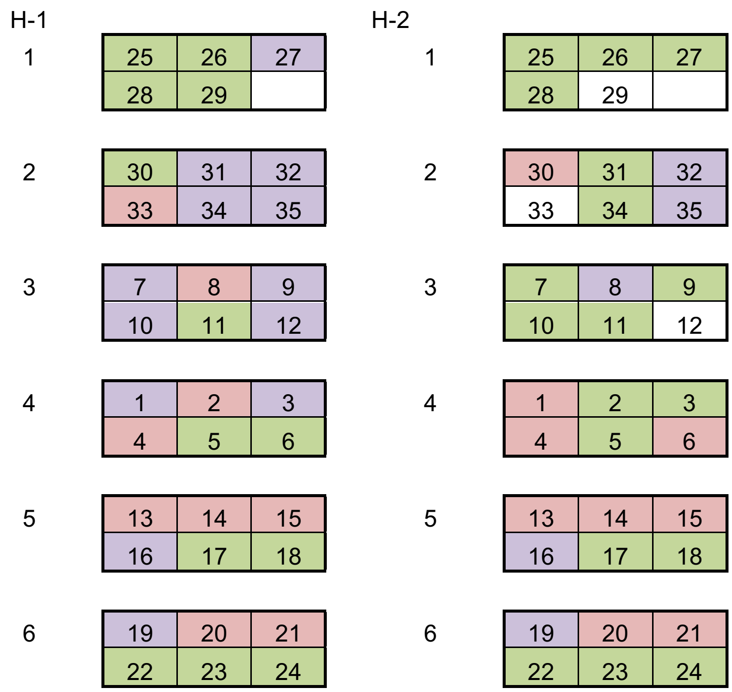


Figure 7.24 Post-activity written assessment from Heuristic 1 and student final exam results from a single 3rd Law question.

7.4.4 Activity 5 - Research Question D

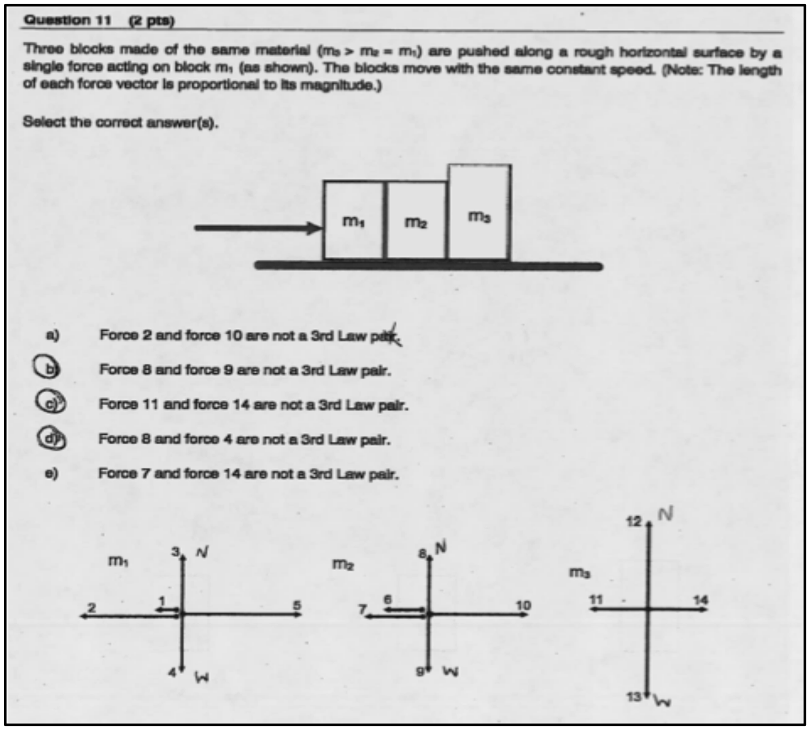
Was there a difference in student performance for those who were given the added scaffolded activity (*i.e.*, Heuristic 2), based on the results of the final exam?

To explore whether or not this activity led to improved ability to distinguish Third Law reasoning from Second Law reasoning, a final exam question (Figure 7.25) was crafted and administered to several sections of Physics NYA. This multiple-choice question presented students with a set of complex free-body diagrams, and asked them to identify which force pairs were *not* action-reaction pairs.

The results (Figure 7.24) clearly show differences between those students who were given the scaffolded activity (A2) in addition to activity A1. While a majority of students in all of the groups were able to identify the weight and normal force acting on two different objects as not arising from Newton's Second Law, the group having been exposed to the scaffolded activity were significantly better at identifying incorrect action-reaction pairs in the following cases:

- The weight and normal force acting on a block in mechanical equilibrium (equal and opposite but not action-reaction pair)

- The horizontal contact (normal) force and friction acting on a block sliding at constant speed (equal and opposite, but not action-reaction).



Question 11 (2 pts)

Three blocks made of the same material ($m_3 > m_2 = m_1$) are pushed along a rough horizontal surface by a single force acting on block m_1 (as shown). The blocks move with the same constant speed. (Note: The length of each force vector is proportional to its magnitude.)

Select the correct answer(s).

a) Force 2 and force 10 are not a 3rd Law pair.

b) Force 8 and force 9 are not a 3rd Law pair.

c) Force 11 and force 14 are not a 3rd Law pair.

d) Force 8 and force 4 are not a 3rd Law pair.

e) Force 7 and force 14 are not a 3rd Law pair.

Figure 7.25 Newton's 3rd Law final exam question corresponding to Research Question 4. The objective of question is to correctly identify force pairs that are not 3rd Law force pairs (b, c, d). **B**) These force pairs are not 3rd Law force pairs because they are acting on the same object (and different force types). **C**) These force pairs are not 3rd Law force pairs because they are acting on the same object (and different force types). **D**) These force pairs are not 3rd Law force pairs because they are not contact forces between the two objects in question (and different force types).

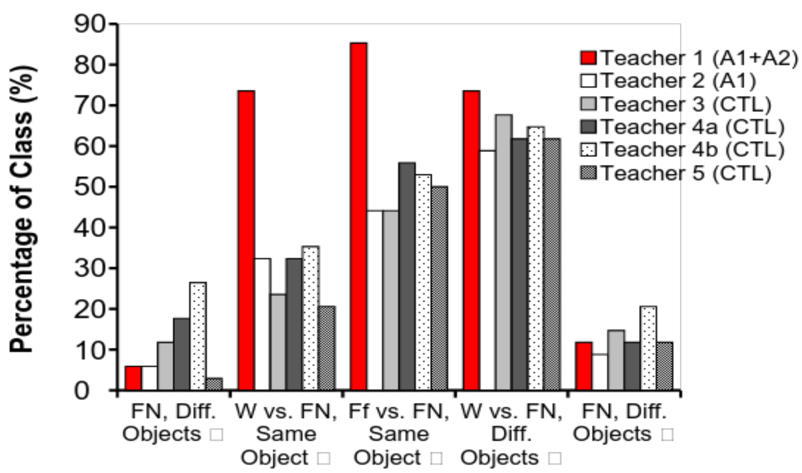


Figure 7.26 Student response histogram for Newton's 3rd Law final exam question.

Statistical Results: 2-way ANOVA (Prism). Here, the percentage of class correctly identifying the choice was input for each statement (A-E), for each class/teacher.

Table 7.3 Summary of 2-way ANOVA - Newton's 3rd Law final exam question

Source of Variation	% of total variation	P value
Teacher/Class	11.23	0.0188
Question (A-E)	76.06	<0.0001

Source of Variation	P value summary	Significant?
Teacher/Class	*	Yes
Question (A-E)	***	Yes

Table 7.4 Summary of 2-way ANOVA: comparison with Teacher 1 (H1+H2) - Newton's 3rd Law final exam question.

Question	Teacher 1 (T11)	Teacher 3 (T8)	Teacher 4a	Teacher 4b	Teacher 5
A	n.s.	n.s.	n.s.	n.s.	n.s.
B	*	**	*	n.s.	**
C	*	*	n.s.	n.s.	n.s.
D	n.s.	n.s.	n.s.	n.s.	n.s.
E	n.s.	n.s.	n.s.	n.s.	n.s.

Results: Although the response pattern is uniquely strong in correctly identifying incorrectly associated action-reaction pairs for the students who participated in Activity 2 (the learning objective of this activity), it is not possible to attribute all of this difference to the treatment because the students in this group were already considered high-performing (honours group). The group undertaking only Activity 1 did not perform noticeably better than the control groups.

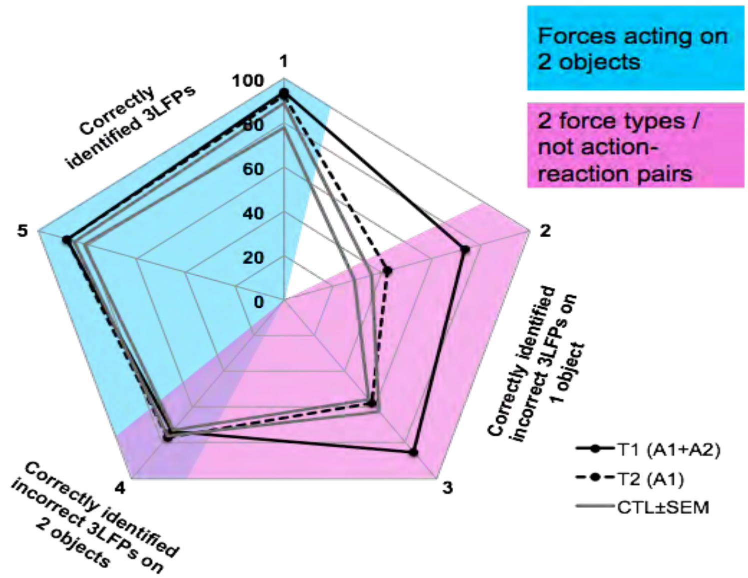


Figure 7.27 Newton's 3rd Law final exam results from Teacher 1 (T11), Teacher 2 (T8) and the control (CTL) classes. With an N=4, the CTL is presented as the upper and lower bounds of the mean ± the standard error of the mean (SEM). The radial axis represents the percentage of the class who correctly identified the type of force pair (*i.e.*, the force pair either *was* or *was not* a Newton's 3rd Law force pair). The circumferential axis represents the question subset (A,B,C,D&E). Cyan: force pairs were acting on 2 bodies; Magenta: force pairs are not action-reaction pairs/not of the same force type (*e.g.*, Normal vs. Weight).

7.4.5 Activity 5 - Research Question E

Research Question 5: Were students able to differentiate a good, conceptually complete heuristic when asked to vote for "the best?"

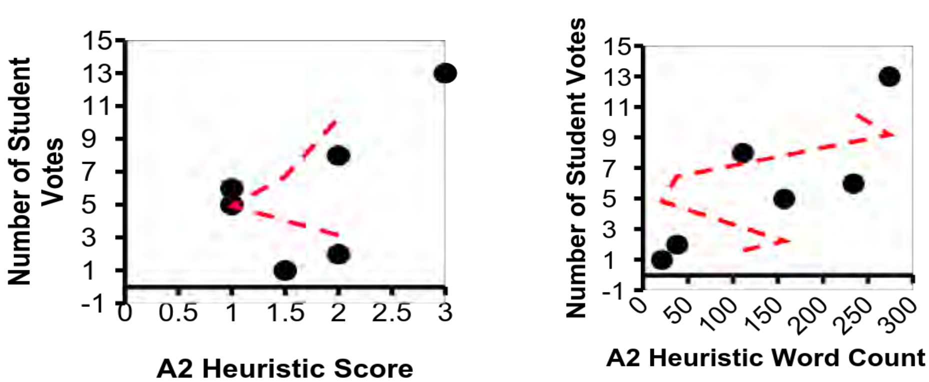


Figure 7.28 Left panel: student votes *vs.* graded heuristic score (1=low, 2=medium, 3=high); right panel: student votes *vs.* heuristic word count. Red dotted line is a linear regression of the data points.

Results: The results of this examination are inconclusive. There was a trend of positive correlation between the number of student votes and the H2 heuristic vote (R^2=0.385); however, there was a stronger positive correlation between student votes and heuristic word count (R^2=0.699).

7.4.5 Activity 5 - Research Question F

Were students able to retain a 3rd Law heuristic over a ~3 month post-activity period (late post assessment)?

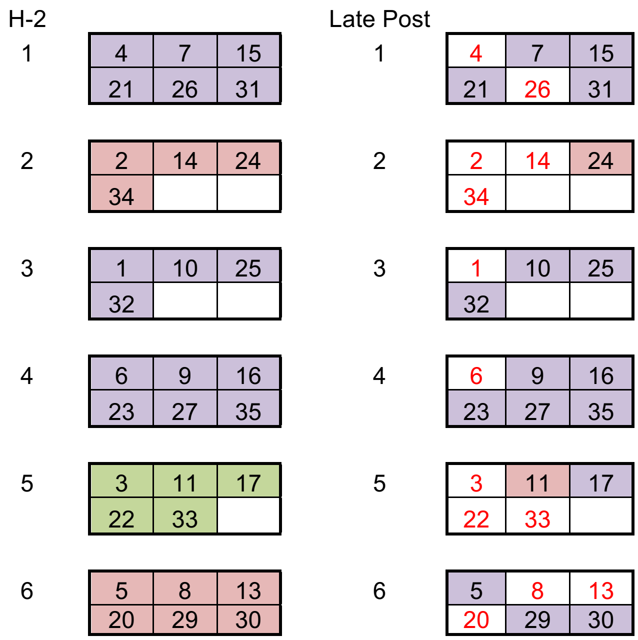


Figure 7.29 Heuristic 2 (H2) group scores for their heuristic *vs.* late-post individual heuristic scores (organized by Heuristic 2 group seating). Red font indicates that students were not present for the late-post assessment.

Observation. Our results show that most students retained a medium (violet) score on their individual heuristic is equal to the median group heuristic after Heuristic 2. Anecdotally, most students quoted concepts M, O & B (see Table 7.2, above).

7.5 CONCLUSION

Results of the quasi-experimental design show that students were able to improve their explanations of 3rd Law heuristics. That is, the longitudinal assessments show changes to the components that are typically troublesome for students to understand. Additionally, the end-of-semester exam show that the one teacher's students particularly strong in correctly answering a set of challenging questions on this concept.

Implications for instruction

While the extended artifact activity show promising results for learning of this difficult but important concept in Physics NYA, it also required more time than is normally allocated to the concept within the curriculum. Therefore, it has substantial implications if it were to be adopted as a regular part of the course. At the same time, it begs the question of whether or not there is too much content within these required courses if, in a typical implementation, students routinely do not master such important conceptual ideas. In short, in the current system, the cost-benefit of such activities may be too great.

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CHAPTER 8
CONCLUSION

Over the last twelve years, Quebec's educational institutions have made considerable investments in reforming the curriculum and redesigning the classroom environments. In particular, there is been more evidence that teachers are using student-centred pedagogies. At the same time, there have been growing interest in constructing new learning spaces, we call Active Learning Classrooms (ALCs). ALCs are often technology rich environments that take advantage of interactive information and communication technologies (ICT). However, there were few studies investigating how the ALCs are facilitating and/or supporting the implementation, and further adoption of these new pedagogies. This research undertook this challenge by conducting three studies. That answered the five research questions following:

1. What types of instruction is used in the ALC?
2. Does the teacher's pedagogical commitment impact the implementation of student-centered approaches?
3. What types of artifacts do students produce for courses taught in the ALC by student-centred teachers? How do students engage during the production of these artifacts? What patterns of engagement are observed?
4. Do High-tech ALCs engage students more than Low-tech ALCs? What other factors have an impact on student-centred activities – e.g., the disciplinary filed?
5. How do students engage and learn with activities that focus on the production of persistent (or extended) artifacts? How is this learning different from other traditional learning?

The answers to these questions are pertinent to the specific colleges involved, as well as the college network system. In particular, they inform three levels of stakeholders: our colleagues, the teachers at our respective colleges; our communities of practice, those teachers who have adopted student-centred pedagogies; and, our administrators and professional development offices. We elaborate on the implications for each of these major findings below.

8.0 PERTINENCE OF THE FINDINGS

8.0.1 Implications for Teaching

<u>College Teachers & Students Will Use New Pedagogies</u>

The findings of this study tell us that student-centred instruction, also called active learning, can be effectively implemented at the college level. Teachers in this study demonstrate that it is not necessary to use lectures as the main instructional strategy. In fact, it is possible to devote major portions of class time to student-centred activity because students can engage with the course content, often in a meaningful way.

A caveat to this claim is that we did not attempt to assess the effectiveness of these student-centred pedagogies, except for the Design Based Research (DBR), which we elaborate on later. Instead, we rely on the literature which shows student-centred instruction supports conceptual change, deeper learning, and reduces students failures better than traditional instruction (e.g., Charles, Lasry & Whittaker, 2013; Charles, Lasry, & Whittaker, 2010; Dedic, Rosenfield, & Lasry, 2010; Freeman, et al., 2014; Lasry, 2006, 2008; Lasry & Aulls, 2007; Lasry, Charles, Whittaker, & Lautman, 2009; Lasry, Mazur, & Watkins, 2008; Prince, 2004). Additionally, in our study it would not have been possible to conduct a meaningful comparison between the various courses and disciplines. Lastly, we point to a major weakness of conducting comparisons in pedagogies, that is, measures that do not match the instruction. Often, the traditional measures of learning outcomes rely on content knowledge and do not assess deep learning and complex problem solving. That said, when we did design assessments that matched the instruction (see Chapter 7) the results show that students did learn more deeply, as evidenced by their ability to explain their reasoning and retention of concepts in a delayed post-test, three months after the end of the study. However, this same curriculum took considerable time to design and required adaptations.

Pedagogical Commitments are a State of Mind

Another finding shows that teachers who have adopted these new pedagogies implement them consistently, regardless of content (i.e., the course material), the year of study (e.g., first year or graduating students), or the environment (high-tech or low-tech). This finding suggests that adoption of student-centred approaches is a true pedagogical commitment, or stance, that is taken by the teacher. In fact, we might argue that such a stance represents a change in a teacher's epistemic belief system which means that the teacher will find a way to use the approach in all their instruction.

8.0.2 Implications for Design of Future ALCs

Teachers Will Use the Technology in the New Learning Environments

For years, studies have shown that technologies often go to waste and remain unused. This study suggests that when teachers change their pedagogy they also are more willing to use the tools that have been made available. That is, while we found no differences between the design of activities in high and low tech ALCs, we did learn that when the classroom resources are different, teachers will use them. This is consistent with the findings of two large meta-analysis that show pedagogical commitment and instructional design are interdependent (Bernard, Abrami, Borokhovski, Wade, Tamim, Surkes & Bethel, 2009; Schmid, Bernard, Borokhovski, Tamim, Abrami, Wade, & Lowerison, 2009). It also supports Hakkarainen's (2009) claim that social practices of teachers and students need to be merged with ICT-based tools, it we are to witness the potential of these intellectual resources to improve learning.

Limitation to generalization. In this research, we observed that the field of study (i.e., the Discipline) appears to be an important consideration in the types of student-centred activities teachers use. This may be particular to our cohort, which has a remarkably strong community of supporting science teachers. This question is one that needs further investigation in the future.

Student Engagement is Dependent on Access and Instructional Design

When it comes to supporting student engagement, our findings showed that artifact production was at the centre of most student-centred instruction. How students choose to engage with this process of generating the artifact, however, was different. The Team-play type of engagement clearly showed how all students could be involved in the group tasks. Other engagement types could also have positive impacts. The research allowed us to identify the importance of both special design and instructional design features, noting that both can impact student engagement. From this study, we have learned that the two most critical features for promoting a Team-play type of engagement are: (1) access to the artifact, for all members of a team; and, (2) a sufficiently complex task that involves more than one person. While there is still much to understand about the subsequent instructional design, these results inform how we design our ALCs.

Teacher's Orchestration and Student Engagement

Along with the call for changing teachers' practice towards student-centred pedagogy, the classroom work teachers need to perform in the classroom should be reconsidered. As innovative educational technologies and new student work requirements emerge, it puts greater demands on teacher's responsibility for orchestration. That is, the efficient and effective management of both this new student work and classroom resources. An observed phenomenon is that during intensive student group work, in addition to monitor students' work progress, the most effective active learning teachers also engage in monitoring students' engagement. This ongoing monitoring includes appropriate verbal prompts that guide or scaffold students' engaging more actively in the intellectual work. For example, they use Socratic prompts to help groups move forward, and encourage those students who are slow to work in groups. Often this "push" includes guiding individual students to join the publically shared working space to elicit collaboration, or foster greater communication of ideas by getting students up to the boards and working around the shared artifact. Though this point has not been explicitly elaborated in this report, the importance of teacher's orchestration in transforming student engagement and learning cannot be overlooked.

8.0.3 Implications for Instructional Design

Design of Activities Influence Teacher's Orchestration

The types of activities teachers designed influenced the ways they orchestrated their student-centred activities. In particular, there appears to be types of activities used more frequently by some disciplines, compared to others. At first this seems obvious but it holds important concerns for whether or not instruction can be designed without careful consideration of the norms of a discipline. In turn, this impacts how the instruction can be orchestrated effectively.

To illustrate this point, we can compare and contrast two specific observations. We observed several science teachers using short activities frequently. This implementation seemed possible because the activities provided students with opportunities to be exposed to particular practices and protocols used by the discipline – e.g., problem solving, data analysis. More often than not, shortening the time spent on an activity did not appear to impact its benefits. Additionally, it provided the teacher with opportunities to bring the entire class together frequently for a consolidation of the activity itself, or a mini-lecture that moved the instruction along to the next planned activity. This orchestrational style of stops and starts provides these teachers with a way to move the content along without sacrificing the student-centred experience.

On the other hand, we also observed other teachers using long uninterrupted activities. These implementations also seemed to work because this sort of activity provided students with longer and different opportunities to engage in practices used by the discipline – e.g., understanding "wicked" problems, finding creative solutions by consolidating and synthesizing data from multiple sources. Such implementations meant that teachers walked around from group to group with few whole class interventions. Therefore, the instruction moved along somewhat differently for each group, but students still seemed to be learning. These two examples tell us that orchestration may be bounded to the disciplinary norms, or at least to what has been perceived as the norms for teaching in certain disciplines. It also suggests that further research is needed to better understand the relationship between instructional design decisions (i.e., how activities are constructed) and innate practices of a discipline.

8.1 GUIDELINES AND LESSONS LEARNED

Taking our findings as a collective, we have identified several important suggestions for the development of future learning spaces. We provide them as a list:

1. High-tech ALCs are not necessary for implementing students-centred pedagogies, however, when they are available teachers will use the affordances in the rooms to the benefit of their instructional design. In particular, we note that when the instruction is designed with the technology in mind, there is a synergy between these factors that can engage the students in deeper learning as seen in Chapter 7.

2. Innovative classrooms should be designed to facilitate group work by ensuring each student has access to the shared spaces. This includes the physical spaces as well as the technologies. Take the following instances as examples: a keyboard is great to enter information but it allows only one user at a time; a whiteboard that is placed in the corner of the room, and perhaps with only one marker, will limit who gets to produce the artifact; and, so on. In all these cases, the impact of restricting access is the limitation of possible types of student engagement.

Ways of overcoming some of these limitations are: (1) provide more resources (e.g., markers for each student; (2) designing better flow for work areas); and, (3) model or tell students what are good collaborative group work habits. In the case of the latter, we have seen a change in student engagement when the teachers asked all students to get up to the Whiteboard.

3. Teacher's instructional design should anticipate their orchestration decisions. That is, it is not only important to consider what students will engage in with student-centred pedagogies, but how the activity will support this engagement.

8.2 FUTURE DIRECTIONS

This research shed light on several important questions related to the use of new learning spaces and how they may or may not benefit from instruction and student engagement. Our results have identified several important considerations and offer guidelines for improving the design of these learning spaces. Furthermore, we have identified new challenges and questions that remain unanswered and require further investigation so as to ensure better learning outcomes for these investments in technology and pedagogical innovation.

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L'équipe de recherche qui soumet ce rapport fût productive lors des trois dernières années ayant soumis plus de deux douzaines de publications, présentations à des conférences ainsi que plusieurs conférences invitées. En voici quelques-unes :

Publications:

Lasry, N., Charles, E., & Whittaker, C. (2016). Effective variations of peer instruction: The effects of peer discussions, committing to an answer, and reaching a consensus. American Journal of Physics, 84(8), 639-645.

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