Scaling Up Socio-Technological Pedagogies

What does it take to develop students' learning and teachers' expertise in innovative environments?

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- environnement de cours sociotechnologique
- changements de pratiques d'enseignement

RÉSUMÉ

La pensée actuelle sur la réforme pédagogique est fortement influencée par les théories constructivistes (Piaget, 1975) et socioconstructivistes (Vygotsky, 1978) de l'apprentissage. Leur principale conjecture veut que les nouvelles connaissances soient construites par l'étudiant à partir de savoir acquis et soient influencées par les contextes sociaux. L'enseignement devrait donc être centré sur l'étudiant en lui fournissant des occasions d'interagir avec ses pairs autour d'une matière académique. Ce type d'approche est souvent connu comme l'apprentissage actif centré sur l'étudiant.

Les tendances récentes dans la recherche l'apprentissage mettent l'accent sur l'environnement physique et sur la façon dont il peut favoriser l'apprentissage actif. Le projet TEAL *(Technology Enabled Active Learning)* du MIT (*Massachussetts Institute of Technology*) offre un exemple de telles études avec la construction des salles de cours sociotechnologique. Même si les recherches démontrent que les pédagogies centrées sur l'étudiant facilitent l'apprentissage, on sait encore peu de choses sur les liens entre la pédagogie et l'environnement de cours. La présente étude s'est fixée comme objectif d'analyser l'interaction entre la pédagogie et l'environnement physique des salles de cours.

Cette recherche a été divisée en deux thèmes. Le premier examine les effets de la pédagogie et de l'environnement de cours sur les étudiants. Le deuxième examine les effets de cet environnement sur l'adoption par les enseignants de pédagogie active centré sur l'étudiant.

L'Étude 1, axée sur les étudiants, se divise en deux parties : (1) un modèle quasi expérimental compare deux formes d'environnement de cours (traditionnel et sociotechnologique) et deux types de pédagogies (l'apprentissage actif centré sur l'étudiant et l'enseignement traditionnel); (2) une étude de cas qualitative analyse la perception de l'apprentissage dans un cadre sociotechnologique par les étudiants qui ont reçu les deux types d'enseignement. Le savoir conceptuel en physique des étudiants est évalué à l'aide d'un outil d'usage fréquent, le FCI (Inventaire du Concept de Force), le déroulement des cours est observé, et des entrevues ciblées sont menées.

L'Étude 2 comporte trois parties axées sur les enseignants : (1) une étude de cas narrative documente le développement professionnel d'un enseignant utilisant une pédagogie active centrée sur l'étudiant; (2) une étude de cas se penche sur l'utilisation d'un environnement de cours sociotechnologique par six enseignants; (3) une analyse qualitative compare les différences entre les perceptions des enseignants et nos observations in situ de leur enseignement en classe. Les données recueillies comprennent les observations en classe, les entrevues avec les

enseignants et le questionnaire ATI (*Approaches to Teaching Inventory*), qui comporte deux échelles : l'une mesure à quel point le cours est centré sur le professeur et l'autre mesure à quel point le cours est centré sur l'étudiant.

Ces deux études ont livré d'intéressants résultats. L'Étude 1 (partie 1) présente de meilleurs gains conceptuels pour les étudiants ayant bénéficié d'une pédagogie d'apprentissage actif. Cependant, le cadre sociotechnologique ne semble pas avoir d'effet en soi sur l'apprentissage conceptuel. Découverte importante : en l'absence de pédagogie active centrée sur l'étudiant, le cadre sociotechnologique n'est pas aussi efficace pour les étudiants possédant moins de savoir acquis.

Les résultats de l'Étude 1 (partie 2) indiquent que la pédagogie joue un rôle essentiel. Les étudiants ayant bénéficié d'une pédagogie active centrée sur l'étudiant dans des salles de cours sociotechnologiques ont gardé une impression positive de leur apprentissage dans cet environnement. Ils se sont montrés plus conscients de leur responsabilité d'apprenants et de l'effort requis pour apprendre. Au contraire, les étudiants qui ont reçu un enseignement traditionnel ne voient pas les avantages des salles de cours sociotechnologiques. En résumé, les étudiants sont plus prêts à apprécier les changements amenés par les nouveaux cadre d'apprentissage quand la pédagogie est adaptée aux nouveaux cadre.

L'étude 2 (partie 1), étude de cas narrative sur un enseignant, expose les changements de valeurs et de pratiques qui ont fonctionné pour cet enseignant. Son expérience nous fournit des éclaircissements aptes à faciliter le développement professionnel d'autres enseignants désireux d'adopter cette approche pédagogique. L'Étude 2 (partie 2) révèle l'impact positif de l'environnement sociotechnologique sur plusieurs enseignants. Un tel cadre peut encourager des enseignants prêts à modifier leur approche pédagogique à faire le saut. Finalement, l'Étude 2 (partie 3) indique que les approches pédagogiques sont fortement reliées à l'apprentissage. Les résultats du questionnaire ATI étaient très reliés aux gains normalisés des étudiants selon l'inventaire FCI. Il existe donc une étroite corrélation entre l'apprentissage conceptuel des élèves et la perception des enseignants sur l'intensité avec laquelle leur enseignement est centré sur l'étudiant.

Dans la section de discussion, nous discutons des implications de ces résultats. Aussi nous élaborons des directives permettant d'appliquer ces changements pédagogiques et d'exploiter ces nouveaux cadres d'apprentissage.

FIVE PRINCIPAL DESCRIPTORS (KEY-WORDS)

- active learning
- social constructivist pedagogy
- information and communication technology (ICT)
- socio-technological learning environments
- changing teacher practice

ABSTRACT

Current thinking about pedagogical reform is strongly influenced by constructivist (e.g., Piaget, 1975) and social-constructivist (e.g., Vygotsky, 1978) theories of learning. A major assumption is that new knowledge is constructed by the learner from prior knowledge and is mediated by social contexts. Instruction should therefore be student-centered and provide opportunities to engage both with content and people. This is often called student-centered active learning.

Recent trends in rethinking learning have begun to focus on physical environments and how they can help to support active pedagogies. An example of such work is the construction of socio-technological classroom environments is the Massachussetts Institute of Technology's (MIT) *Technology Enabled Active Learning* (TEAL) project. While evidence from research shows that student-centered active pedagogies improve learning little is known about the interaction of these new classroom settings and pedagogy. The current study set out to investigate several of these relationships.

This research project was divided into two studies that examined the impact of pedagogy and classroom setting on students as well as the impact of classroom setting on teacher's adoption of a student-centered active pedagogy.

Study 1 focused on the students and was divided into two parts: (1) a quasi-experimental design comparing 2 forms of classroom settings (Conventional and Socio-technological) with two types of pedagogy (student-centered Active-Learning and Traditional Instruction); (2) a qualitative case-study designed to investigate how students instructed with different pedagogies perceived learning in socio-technological environments. We assessed students' physics conceptual knowledge with the widely used Force Concept Inventory (FCI), and conducted classroom observations and targeted interviews.

Study 2 had 3 parts that focused on teachers: (1) a case study narrative documenting the professional development of a student-centered active pedagogy teacher; (2) a case study involving six teachers use of the socio-technological environment; (3) a qualitative analysis comparing and contrasting differences between self-reported perceptions with our in-the-field observations of their classroom teaching. Data collected include classroom observations, teacher interviews and the *Approaches to Teaching* (ATI) questionnaire which has two scales: (1) measurement of teacher-centeredness and (2) and measurement of student-centeredness.

These two study yielded several interesting results. Study 1 (part 1) showed that students have better conceptual gains when taught with an active learning pedagogy. However, the socio-

technological environment when viewed on its own had no impact on conceptual learning. An important finding is that without the accompanying student-center active pedagogy the socio-technological environments may not be effective for students with low prior knowledge.

Study 1 (part 2) results showed that pedagogy is paramount. Students taught with the student-centered active pedagogies in the socio-technological environments perceived learning positively. They were more aware of their responsibility as learners and of the effort required to learn. By contrast, students instructed with conventional pedagogies did not see the benefits of the socio-technological classrooms. In short, students are more willing to value the changes brought about by these new environments when they are taught with a pedagogy that is adapted to the environment – i.e., a student-centered active learning pedagogy.

Study 2 (part 1), the teacher case study narrative, informs us on the changing values and practices that worked for our case study teacher. From his story we gain insight and pointers that may help with the professional development of others teachers who wish to adopt this pedagogical approach. Study 2 (part 2) showed that the socio-technological environment can have a positive impact and encouraged teachers who wanted to change their pedagogy in doing so. Lastly, Study 2 (part 3) shows us that teaching approaches are highly related to learning. The results of the ATI questionnaire were highly correlated with students' FCI normalized gains. That is, teachers' self-report of how student-centered their practice is correlates highly with students' conceptual learning.

In the discussion we elaborate on these findings and discuss their implications. Lastly, we develop guidelines for implementing changes to pedagogy and using these new learning environments.

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CHAPTER 1

INTRODUCTION

A paradigm shift toward pedagogy informed by social constructivist theories of learning is quickly becoming an established part of primary and secondary school education in the province of Québec. These theories, influenced by recent views on cognition and socio-cultural research, include *situated cognition* (Brown, Collins & Duguid, 1989; Lave & Wenger, 1991), *distributed cognition* (Cole & Engeström, 1993; Hollan, Hutchins, & Kirsch, 2000; Salomon, 1993), and *situated action* (Theureau, 2004). The implementation of this major educational reform, named the Québec Education Program (QEP), was started in 2006 with grade 7, courtesy of the Ministère de l'Éducation, du Loisir et du Sport (MELS); and has expanded up one grade level each year. This interest in reform education, science in particular, is not unique to this province or this country. In the United States much attention has been focused on changes to middle school science (grades 7-9). Notably, several large initiatives, that study the impact and implications of pedagogical approaches to learning science, have been funded by the National Science Foundation (NSF) (*e.g.*, *BioKIDS* project, Blumenfeld, Soloway, Marx, Krajcik, Guzdial & Palincsar, 1991; *LBD* project, Kolodner, Camp, Crismond, Fasse, Gray, Holbrook, Puntambekar & Ryan, 2003; *WISE* project, Linn, Clarke & Slotta, 2003).

Efforts to change the face of science education have not stopped at the high school doors. A recent headline in the *New York Times* (Rimer, January 13, 2009) reads: “At M.I.T., large lectures are going the way of the blackboard.” This article reports on the trend toward more interactive and collaborative learning in physics classrooms and lecture halls at major American universities such as Harvard University, Massachusetts Institute of Technology (M.I.T.), Rensselaer Polytechnic Institute (R.P.I.), University of Maryland, and University of Colorado, to list a few. In part, this move responds to general demands from students, taxpayers and educational policy makers to see improvements in science education at universities and colleges. But more importantly, there is growing evidence of the viability and efficacy of such pedagogies even in higher education. For instance, the Peer Instruction project at Harvard (headed by Professor Eric Mazur), the Technology Enabled Active Learning (TEAL) project at MIT (headed by Professor John Belcher) and the Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) project at North Carolina State University (headed by Robert J. Beichner & Jeffery M. Saul of University of Central Florida).

But what is the future of this new educational approach at the college level? Additionally, what is the impact of changing access to technology, the new designs for labs and classrooms, and the ramifications of students with different instructional experiences brought on by the QEP pedagogical reforms? The objective of this research was to expand the conversation so as to ready the CÉGEP network for the upcoming decisions and changes that may be required to continue the job of improving student success at college.

Problem Statement

There is growing agreement among theorists and practitioners that *scaling-up* the implementation of instructional innovation, such as those based on social constructivist theories, raises important and urgent questions (Blumenfeld, Fishman, Krajcik, Marx & Soloway, 2000; Elias, Zins, Graczyk & Weissberg, 2003; Bransford & Darling-Hammond, 2005; Shore, Aulls & Delcourt, 2008). On the theoretical side there are questions such as: how do we know that social constructivist pedagogies can improve learning? What types of learning are they best suited for? What are the mediating factors involved in learning with such pedagogies? Or, how do cognitive, affective, regulatory and socio-cultural processes intertwine during active learning? On the practical side, we need to find answers for questions such as: How do we design learning environments (including physical lay-outs and technological supports) to promote the activity and thinking that these theories tell us promote deep and meaningful learning? Or, what are the essential and sufficient features of such environments? For the sake of simplicity, and here forward, we will refer to these learning and instructional environments (which include information and communication technology (ICT) resources) as student-centered *Active*

Learning pedagogies (we will refer to it as *AL*) and *socio-technological* environments (we will refer to it as *Soc-Tech)*, respectively.

Other practical concerns involve preparing and supporting teachers in their efforts to add these pedagogies and use the technologies and the opportunities offered (i.e., *affordances*) by new learning environments. Dillenbourg and Fischer (2007) argue that it would be simplistic to view the teacher's roles in social constructivist instruction as merely changing from "the sage on the stage" to "the guide on the side." Though such change is an important epistemic feature of social constructivism these authors suggest that teachers also have to engage in synchronizing or *orchestrating* the cognitive, pedagogical, and practical aspects of the classroom (or learning environment) without being at the centre of the instruction (Fischer & Dillenbourg, 2006). Thus other important and urgent questions are: What skills and capabilities do teachers need so as to effectively use AL pedagogies; how do we prepare (train) and support them as they gain the skills, experience and expertise in using these AL pedagogies and socio-tech environments effectively? These are particularly relevant in light of the thinking that "teaching is the most public of activities carried out in private."

We argue that the factors mentioned above – i.e., development of students' learning and teachers' expertise – are likely to have mutual dependencies, which are mediated by the design of AL pedagogies and Soc-Tech environments. Consequently, we designed two studies that looked at both students and teachers simultaneously. In short, our research design took on a systems-based approach to study the interaction of these two important stakeholders within the learning system. Broadly speaking, this study looked at the following: (1) What is the impact on learning when students are taught with AL pedagogies, and what role(s) does the used of Soc-tech environments have on this learning? And, (2) How do teachers come to use such pedagogies and Soc-tech environments effectively?

In Chapter 2 we will start by defining some of the key terms that will be used throughout the report. Most importantly, we will define what we mean by *Active Learning*. Additionally, we will provide some background to the theories that inform this new pedagogical approach. In

Chapter 3, we will describe the general methodologies used in the two studies, the constraints of said methodologies and some of our key assumptions. Chapter 4 and 5 will describe the specific methods used for Study 1. Chapter 6, 7 and 8 will address the issues of impact of the new socio-technological environment for both teachers and students. Chapter 9 is the conclusion and suggests guidelines for designing student-centered active pedagogies and the accompanying classroom spaces – i.e., socio-technological environments.

CHAPTER 2

THEORETICAL FOUNDATIONS AND RATIONALE

How Do People Learn?

Cognitive factors

Learning is a complex process. Factors affecting learning fall into several domains, the cognitive, metacognitive, affective and emotional, as well as the social. Within the cognitive domain factors such as the limitation of human neurophysiology need to be taken into account when considering the design of learning opportunities. Factors to be considered are the limitations on human working memory and the bottlenecking of the possibly unlimited long-term memory – leading to *Cognitive Load Theory* (Sweller, 1994; Pass, Renkl & Sweller, 2003). There are also important reflective processes, known collectively as metacognition, which involves our thinking about our thinking. This type of cognitive process is vital for learning because it allows us to gauge what we know and what we do not know. It establishes an iterative feedback loop that influences the process of restructure and refining our knowledge.

Motivation, self-regulation and effort

Educational research has shown that self-regulation and effort are powerful mediators of learning (Astin, 1985; Pace, 1984; Pintrich, 1995; Schunk, 2001; Zimmerman, 2000). Both are linked to motivation and all are mutually constituted phenomena. Interestingly, both self-regulation and effort often arise from the learner's perceptions. Such perceptions of learning can include beliefs about teacher support and feedback from peers (Zimmerman, 1989), and overall ratings of teaching effectiveness (Ryan & Harrison, 1995; Cashin & Downey, 1992; 1999). Thus, perceptions are an important determinant of effort. Why is effort important? When students view learning as meaningful they expend more effort and use more effective ways of learning (Entwistle, 2010). Such ways are often referred to as deep or meaningful learning versus surface or rote learning (Ausubel, 1968; Marton & Säljö, 1997). It will become clear later on that when students are engaged in active learning their perceptions of learning can change as they view the activities are more meaningful and relating to their daily lives.

Social factors involved in learning

Recent views on motivational and self-regulatory processes have begun to take into account social and cultural aspect as well (e.g., Hickey, 2003; McCaslin & Hickey, 2001). Järvelä, Järvnoja and Veermans (2007) propose that motivation is a mutually constituted phenomenon arising from the interaction of the individual and context. They state “motivation is fostered, shaped and maintained through an active and on-going process of co-regulation” (p. 123). Accordingly, the social system that individuals are part of is assumed to provide opportunities and constraints for members, to participate or to stay at the periphery or avoid engagement.

In other words, the social environment of the classroom influences the individual. They either sees themselves as entitled to participate (acknowledging the teacher’s wish to share the authority to act) or not. This process is a product of the many social feedback loops within the classroom system. For example, the teacher designs opportunities for students to ask questions. If some students take up this opportunity, they set the stage for others to follow suit. This modeling of how to engage is reinforced if the teacher accepts those actions as acceptable practices. Thereby a micro-culture of question asking is established through the feedback loops that are made up of co-regulated processes of peers and teacher. From this perspective, motivation is created and maintained through the collective, interactive and even shared activity of group members (Jackson, McKenzie, & Hobfoll, 2000). We will show how many of the social and cultural aspects of active learning classrooms allow students to model these regulatory processes, which helps to develop the skill for all students.

Furthermore, social factors include notions of practice and the cultural aspects of learning, both from the perspective of the learner situated within a context as well as the context of the knowledge itself. Discipline expertise (or competency) involves developing skills in the use of specific tools of the trade and practices of the field. What is not as evident is that these very tools and practices help to shape students' knowledge and thinking in a discipline. This knowledge and thinking includes understanding of rules, methods, philosophical assumptions and ways of knowing. These might be considered *epistemic frames* of a discipline (Shaffer, 2004). One way of thinking about this knowledge is to picture it as a type of "meta-knowledge" or "meta-competency" that is gained through the use of tools and practices. It is the "stuff" that is often taken-for-granted by experts in the field because it is embedded in the very interactions between them and their tools (Cobb, 2002).

Social Constructivist Theories of Learning

Constructivism and social constructivism are learning theories that inform the pedagogical movement toward student-centered active learning[1]. Examples of such pedagogies are: inquiry-based science instruction (e.g., Shore, et al., 2008) and problem-based learning (PBL; Barrows, 1985; Bransford et al, 1990; Duffy & Savery, 1994; Jonassen, 1991; CTGV, 1990, 1993); to list a few. The key assumptions of these theories of learning are that knowledge is constructed out of one's experiences with the world[2] and, that providing opportunity for appropriate active engagement with appropriate tools is essential to learning – i.e., designed or engineered environments with *affordances* for learning.

In addition, social constructivism is influenced by socio-cultural theories of knowing, which creates an added dimension that emphasizes the social and cultural aspects of knowledge construction. In doing so, it pushes to the fore collaborative activities and production of shared artifacts. Taking its cue from naturally occurring learning communities – i.e., *communities of practice* (Lave & Wenger, 1991; Rogoff & Lave, 1984) – this paradigm gives importance to the modeling and mentoring provided by experienced members of a community – *e.g.*, teachers, experts. Consistent with this thinking are the notions of learners working within a *zone of proximal development* (Vygotsky, 1978), which means there are individuals close to your stage of development and not only the polarized novice and expert. Such environments also mean that

[1] Our research is more closely based on theories of social constructivism.

[2] Early on in the development of these theories radical interpretations view all knowledge as individually constructed thus each individual had his/her own reality. Today, most would argue differently.

the newcomer (student) has a place to practice their skills alongside more knowledge others, which Lave and Wenger (1991) considered *legitimate peripheral participation*.

Furthermore, context is key because knowledge is viewed as distributed and situated within the environment where the activity takes place. In short, the process of learning involves becoming a practitioner within a particular field, which involves using and understanding the tools of the trade. This includes both physical and abstract tool that in and of themselves embody the knowledge of the discipline or field. For example, in learning about acceleration, a student does much more than learn a formula. They learn about a complex relationship that can be measured and treated in a certain way – a way that is part of the tradition and community of physicists.

What is Active Learning?

Active Learning has become a way to describe the type of pedagogy that is derived from both principles in Constructivist, Social Constructivist and Socio-Cultural theories of learning and knowing as well as empirical findings from the fields of the Learning Science and Science Studies[3], which includes such sub-categories as physics education research.

Two key tenets of an AL approach are: (1) learning is an active process of building knowledge and meaning from experiences (e.g., Bruner, 1966; 1990; Piaget, 1972; 1985; Vygotsky, 1978) and (2) people have different ways of learning (e.g., Kolb & Kolb, 2001). It can be summarized as a pedagogical approach that engages students in the process of purposefully thinking, questioning and reflecting on specific aspects of their understanding while engaged in authentic activities that are domain-specific. The latter is critical because of the recognition that disciples have different epistemic frameworks that underpin their key assumptions and practices. In fact, knowledge and knowing are highly dependent on content and context (e.g., Brown, et al., 1989; Duschl, 2008). Thus, AL pedagogy acknowledges that it is important to consider such key

[3] According to Duschl (2008), the Learning sciences are "a group of disciplines focusing on learning and the design of learning environments that draw from cognitive, developmental, and social psychology; anthropology; linguistics; philosophy of mind; artificial intelligence; and educational research" [meanwhile, science studies are] "a group of disciplines focusing on knowing and inquiring that draw from history, philosophy, anthropology, and sociology of science as well as cognitive psychology, computer science, science education, and artificial intelligence" (p. 270).

ideas and practices when designing learning activities for a specific domain or field.

For instance, in physics it is important for teachers to design activities that account for the difficulties students have when faced with conflicting models of the world, what are commonly referred to as misconceptions. Learning physics generally requires *conceptual change*[4] and AL activities in this domain of study must be designed with this process in mind; one that is neither easy nor linear (see Chi & Roscoe, 2002; diSessa, 2002; Vosniadou, 2002).

Empirical studies of implementations of student-centered active learning approaches show benefits such as more meaningful construction of knowledge and deeper understanding (e.g., Blumenfeld, et al., 2000; Edelson, Gordin & Pea, 1999; Slotta & Linn, 2009). Approaches such as peer instruction have resulted in improved conceptual understanding (Hake, 1998; Lasry, Mazur & Watkins, 2009; Charles, Lasry & Whittaker, 2009; Crouch & Mazur, 2001), while PBL has been shown to promote critical and deep thinking about abstract concepts as they relate to real life (Fyrenius, Wirell & Silén, 2007). Additionally, research shows that student-centered active learning approaches encourage students to take on a more meaningful approach to learning, with implications on strategies used in the process of knowledge construction – i.e., deep approaches versus surface approaches (Entwistle & Ramsden, 1983; Marton, Hounsell & Entwistle, 1997). While these studies suggest active learning can result in better learning outcomes we still need to understand more about which aspects of the instruction work best, and what are the necessary and sufficient features of the instruction approach. These two questions formed the bases of our research questions (see questions in Study 2).

[4] C*onceptual change* is a process by which learners build new ideas in the context of their existing understanding (diSessa, 2002). It is based on schema-based learning theories, which describe three types of learning: accretion, tuning and cognitive restructuring (Rumelhart & Norman, 1976).) Concepts live in a network of other concepts and are not arbitrary isolated entities (Keil, 1989). Thus the relationships between concepts relate to features frequencies and correlations, as well as provide explanations of those frequencies and correlations that are often causal. The implications of this supposition are that conceptual knowledge building requires the reorganization of these networks of relationships. Much of the content that CÉGEP students are required to learn in their science program can be described as conceptual knowledge and falls under the umbrella of cognitive restructuring.

What Are Socio-Technologic Learning Environments?

When social constructivist theories inform educational reform not only do classroom activities change, but often, so too do the physical environments. For instance, the TEAL project, mentioned earlier, has replaced blackboards with electronic white boards. Instead of rows of desks facing the front of the class, students sit and work together in circular pod-like groupings while the teacher circulates around the class, thereby providing students with easy opportunities of collaboration and group work (see Figure 2.1).

Figure 2.1. Photograph of TEAL learning environment (http://edtechtrends.blogspot.com/).

Other models of new environments include the Problem Based Learning (PBL) labs at Georgia Institute of Technology's Bio-Medical Engineering undergraduate program where classroom spaces are designed with writable walls. Like the electronic white boards, such features allow students to save their discussions as images or word documents, which can be used later to focus further discussions. The socio-cultural literature considers such objects *historical and cultural artifacts*. These examples suggest that the physical environment, and the product of the work within, can promote peer interaction and discussion, which can lead to deeper learning through the negotiating of meaning and the practice of newly gained skills of the discipline.

In TEAL classrooms lectures are brief and intended to start the inquiry process rather than provide students with lecture notes. In such environments students and teacher are required to conduct experiments together and publically share results and conceptual knowledge – a departure from traditional college teaching. Furthermore, TEAL integrates technology by using visualization software (*e.g.*, simulations and animations) as well as *WebAssign*, an automated system for students' submissions and grading. This application also allows teachers to monitor students' preparedness in their pre-lecture reading assignments, which facilitates adapting lectures to meet students' needs. Given these examples it would seem that pedagogy is an important part of these new environments. However, there is little research to determine whether this is true or what role the environment plays in the learning. This current research looked at this relationship with the intent of assessing whether there were dependencies between these two variables (see questions in Study 1).

Examples of Active learning Activities

- <u>Think-Pair-Share activities</u>: these involve giving students a question or problem to solve. Allow them a few minutes to think about the problem alone (think), then discuss with another student or group of students (pair). Then provide an opportunity for the thinking to be shared in a public forum (share). Examples of teaching approaches that use this format are: Peer Instruction.
- <u>Analysis and problem solving activities</u>: these involve using case studies, mini research proposals or projects. They are generally types of activities that are planned well in advance and structured so as to involve several stages, planning or problem definition, experimentation or other forms of data collection, analysis of the evidence, discussion and presentation of findings or some artifact. Often, these activities are designed in a *jig saw* approach which means that different groups do different aspects of a larger problem -- this creates a sense of interdependency and mutual accountability. Examples of teaching approaches that use this format are: Problem Based Learning (PBL), Project-Based Learning, Learning by Design (LBD), Inquiry-Based Instruction.
- <u>Visualization activities</u>: generally these involve the use of simulations, and other technology driven tools. However, they could also be non-computer games. Such activities allow students time with other ways to conceptualize the content knowledge. They also allow students to experiment and "play" with the ideas (knowledge) and/or

tools of the discipline. Visualizations are best used along with the presentation of content knowledge. As before, it is always important to allow for reflection and integration of the knowledge acquired from the activity. Examples of such activities: use of simulations, games, concept maps

- Less structured activities: these may involve students working alone or in some form of collaborative groupings. Generally, the object of these types of activities is to engage students in some types of reflection to allow them some time to integrate their knowledge. Examples of such activities: *Just in Time Teaching*, reflective journals, other writing exercises done in close proximity to the presentation of some content knowledge.

Becoming a Student-Centered Active Learning Teacher

Changing teacher role

While AL is generally characterized as "student-centered" it is far from being "teacher-less." In fact, we argue when the teacher's role is reframed there is more work required of the teacher than in traditional pedagogies. For instance, in this approach the teacher is expected to make visible the thinking involved in solving complex and challenging problems. This might be accomplished through modeling of such processes and/or designing reflective activities, often involving the use of technology that can amplify these efforts. Furthermore, teachers are required to design opportunities for learning that involve student participation and use of the domain tools and artifacts (e.g., investigating the evidence of a car accident and determining the cause based on the physics). All along, teachers are responsible for modeling, coaching and supporting students in their efforts to accomplish the task at hand – *cognitive apprenticeship* (Collins, Brown & Newman, 1987).

Activities and challenges selected for active learning pedagogies are intended to be situated in complex problems. They generally require learners to go beyond mere comprehension by involving them in deeper cognitive processes such as analysis, synthesis and evaluation (see Bloom's Taxonomy (Bloom, 1956) and revised by Lorin Anderson (Anderson & Krathwohl, 2001), Figure 2.3).

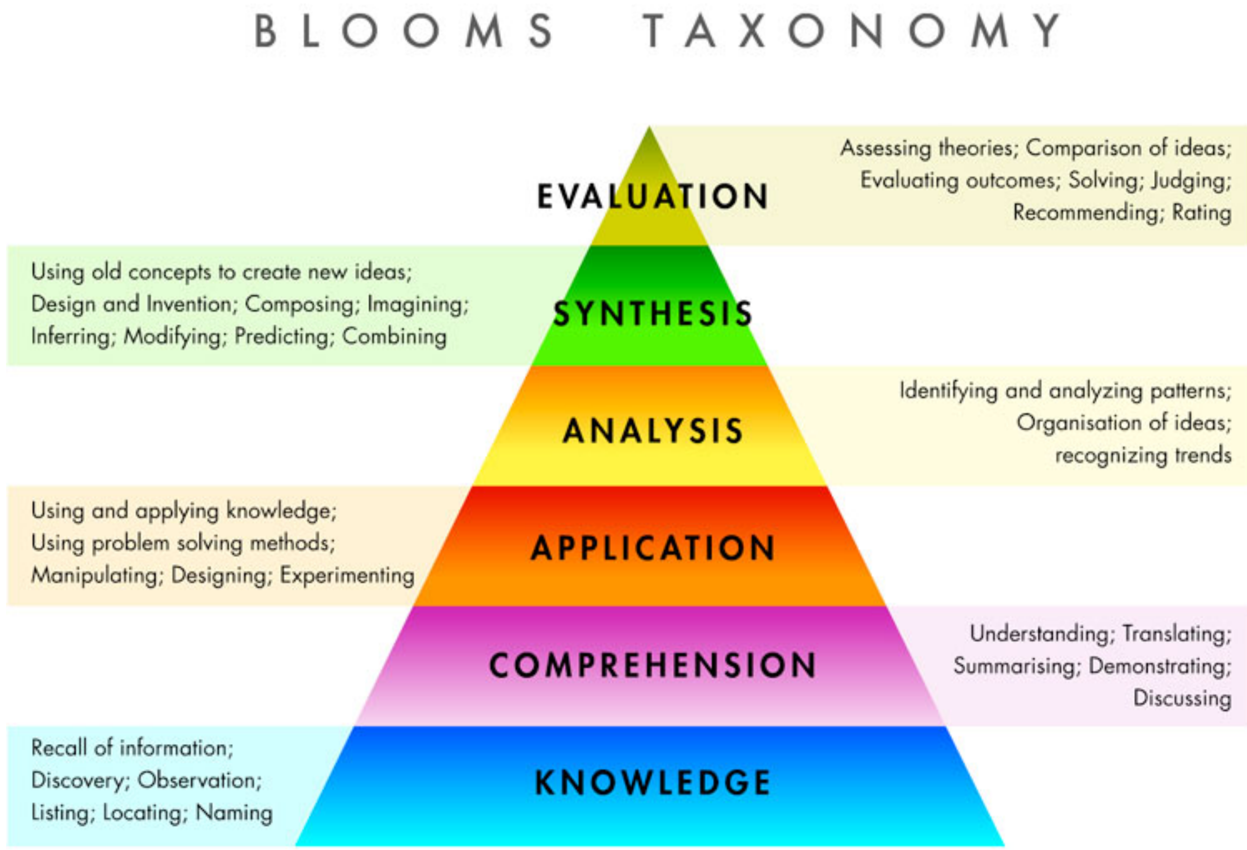

Figure 2.2. Bloom's revised taxonomy of cognitive engagement (retrieved from http://www.creativetallis.com/creativity.html, June 23, 2011.

Role of technology in the changing teacher role

Furthermore, we recall Dillenbourg and Fischer's (2007) assertion related to the teacher's role is the *orchestrating* of the cognitive, pedagogical, and practical aspects of the classroom without being at the centre of the instruction. They draw an idealized picture of future educational systems, particularly those that are supported by computer technology.

> At the cognitive level, teachers need to regulate the interplay between individual learning mechanisms (*e.g.* induction), small group interactions (*e.g.* pair argumentation) and class-wide activities (*e.g.*, presentations). At the pedagogical level, teachers must in real time adapt the designed activities to what is actually taking place in the classrooms. The awareness of these processes across different levels will be increasingly supported with

> intelligent technologies (*e.g.*, Dönmez *et al*., 2005). At the technological level, orchestration is used to refer to the dynamic management of transactions between software components. We expect this orchestration perspective of integrated learning environments to become a key issue within both technological and educational research on technology-enhanced learning. (Dillenbourg & Fischer, 2007)

Another issue is related to the culture of teaching. Laferrière and Gervais (2008) tell us that the world of teaching is steeped in cultural traditions. In other words, most teachers still believe that teacher-centered teaching is the best determinant of learning. Who can blame them? Educational researchers (including cognitive and educational psychologists) and pedagogues have muddied the water with many trials and programs that are well-intended but poorly implemented. One identified culprit is the inadequate preparation of and support to teachers, often attributed to insufficient funding.

On this matter Laferrière and her colleagues report that teachers who take the initiative and wish to create learning environments and implement “technopedagogical designs” (their words) to support collaboration and peer interactions meet with both personal epistemic contradictions as well as systemic obstacles. Laferrière and Gervais (2008) state that such teachers often face the personal challenge of developing a deep understanding of social cognition as well as the challenge “of negotiating with colleagues, (as well as) school administrators and even teacher educators who hold shallow understanding of what the co-construction of knowledge entails” (p.2). Their investigations also show the benefit of supporting teachers (pre-service, and experienced) with the construction of ICT environments where they can interact and share teaching practices, resolve class management concerns and construct richer understanding of disciplinary content. As well, there is the benefit of collective activity including collective reflective practice – an adaptation of the *reflective practitioner* model, (Schön, 1983).

Networked teacher communities – a form of communities of practice – designed by Laval University and McGill University Schools of Education, report that those environments create hubs of innovation producing solutions and collective products that are more successful than any individual’s alone (Laferrière & Gervais, 2008). In short, it may be said that enabling teachers to work together in networked ICT environments allows them to experience collaborative learning first hand, which in turn helps to shape their thinking; and makes them more likely to take up social constructivist practices in their own teaching. Additionally, working together collaboratively fostered a sense of communities of practice as the small groups shared with other small groups that were distributed across the region; with groups differing in their make up and levels of expertise. While this is not a focus of the current research, the value of communities of practice as a mechanism for promoting change needs to be better understood.

The changing role of the student

Using AL pedagogy also means new roles for students. With the redistribution of the authority structure within the classroom students are required to be active participants in their knowledge construction. This new role means students have to be willing to take up the opportunities provided by the teacher which include curricula activities and other tools embedded within the designed learning environment. Prior research conducted by members of this project suggests that the promotion of agency is critical in new learning environments (e.g., Charles, Lasry, Whittaker & Trudeau, 2009; Charles & Shumar, 2010); and, arguably promoting agency is one of the greatest challenges for in-service teachers who wish to adopt AL pedagogies.

Connection between teaching and learning

According to Trigwell (2010), there is a growing body of evidence suggesting a strong relationship between teaching and learning. This literature has shown that the approach to teaching and the design of the learning environment can substantially impact the learning outcomes by influencing the approach to learning used by the student. In particular, Trigwell (2010) reports on two qualitative (phenomenographic) studies (Greeson, 1988; Kember & Gow, 1994) that played a significant role in the development of the Approaches to Teaching Inventory (ATI) developed by Trigwell and Prosser (2004) – see Appendix A.

These two studies found a substantial relationship between teaching orientation and the student's approach to learning. Specifically, students who perceived their teachers as using a transmission approach often used a surface approach to their learning, while those who perceived their teachers as using a facilitator of learning approach used a deep approach. The first instrument developed was a 16-item inventory to capture the varying approaches to teaching used in higher education (Trigwell & Prosser, 2004). Further research on the instrument has resulted in the current instrument with two scales – conceptual change/student focused (CCSF) and information transmission/teacher focused (ITTF) – each represented by 11 items making for a 22-item inventory (Trigwell, Prosser & Ginns, 2005; Trigwell & Prosser, 2006).

Studies that have used the ATI to investigate the relationship between teaching and learning have supported the claim that teaching approach, at the level of the class, affects students' approach to learning (Biggs, Kember & Leung, 2001; Kek, 2006; Kim & Branch, 2002; Trigwell, Prosser & Waterhouse, 1999). Both the early results (Biggs, 1987; Biggs, Kember & Leung, 2001; Trigwell, Prosser & Waterhouse, 1999) and more recent ones (Kek, 2006; Kim & Branch, 2002) continue to show that a surface approach to learning is strongly and positively correlated with an information transmission/teacher-focused (ITTF) approach to teaching, while a deep approach to learning is positively correlated to a conceptual change/student-focused (CCSF) approach.

Other studies using the ATI have indicated that approach to teaching also correlates with a teacher's repertoire of teaching methods (Gibbs & Coffey, 2004). In other words, there was a positive relationship between teachers having a CCSF approach and their awareness of various teaching methods. They also reported that their treatment group, compared to a control group, increased their CCSF scores over the period of the study without an increase in their ITTF score thereby suggesting that CCSF teaching approach may be orthogonal to the ITTF approach. These findings are groundbreaking because of their implications on the ways we go about the activity of teaching. In other words, the approach we take towards teaching is "not" a neutral act. Trigwell (2010) goes as far as saying: "The relations observed in the studies described in [his article] are significant because they show connections between teaching and outcomes of learning that point to ways to improve student learning though teaching and therefore help to define good teaching" (p. 122).

The work done by Trigwell and Prosser suggests that to change teacher's approach to teaching may mean that we need to change how they understand teaching and learning (Trigwell, 1996). It all depends on how teachers see their role. The question arising from Trigwell's studies and is also the focus of this current research is how and what can help teachers make the requisite shift in their conceptions (beliefs about teaching and learning) and how can we bring these changes to scale – i.e., the title of our project " scaling-up socio-technological pedagogy." The relationship between teaching and learning is one that needs to be further explored.

Research Questions

<u>Study 1</u>

1. Comparing students experiencing active learning (AL) to their peers in traditional instruction (TI):
    a. What are the differences in performance on a test of conceptual understanding (using the FCI)?
    b. What are the differences in attitudes towards science (using the CLASS)?
2. Examining the beliefs and practices of students in the active learning (AL) treatment compared to their peers:
    a. Are there differences in epistemic beliefs, sense of agency (e.g., roles, motivation and self-efficacy) between students enrolled in AL versus traditional instruction (based on answers to semi-structured interview questions)?
    b. What is the impact of the active learning treatment on students' ways of thinking about their learning and the learning experience?

<u>Study 2</u>

1. Compare teachers using the AL to their peers using TI.
    a. What differences are there between our sample teachers teaching practices?

    b. How do these observed differences compare to teacher's self-perception of their teaching practice?
    c. How do perceptions of teaching practice (i.e., teacher-centered versus student-centered) impact student learning?
2. Document the process of becoming an AL teacher – factors influencing a teacher's development toward social constructivist teaching:
    a. How do we describe the development and implementation of an active learning teacher?
    b. How can we distinguish between teacher's practices?
3. Technology's impact on teaching:
    a. What is the impact of a socio-technological environment on teachers and their practice?
    b. What is the impact of a socio-technological environment on students' perceptions of learning?

CHAPTER 3

OVERVIEW OF RESEARCH METHODS

Our global objectives for this research were to answer questions emerging from the interaction of pedagogy and context as well as increase our understanding of the implications of moving toward a wider implementation of active learning pedagogies. In order to accomplish these goals the researchers constructed a treatment condition that consisted of a introductory physics curriculum with curricula activities designed on the basis of social constructivist principles (described earlier) – particular attention was paid to conceptual change issues. A teacher with four years experience using active learning pedagogies implemented this treatment. This system of activities and enactment was considered the *Active Learning* (AL) treatment which was contrasted against equivalent curriculum for the same course implemented with pedagogical approaches that were somewhere on a continuum between student-centered active learning and teacher-centered traditional. That system of activities and enactment was considered the *Traditional Instruction* (TI) treatment. For the major part of the study both these treatments were carried out in newly renovated labs/classrooms designed to promote collaborative activities and equipped with interactive white boards, desktop computers and other data gathering hardware and software applications. We refer to this environment as the *Social Technological* (Soc-Tech) context.

We studied the impact of Active Learning pedagogy and Social Technology context, both on the learners, in terms of their conceptual knowledge development as well as their motivation (perceptions and willingness to apply effort towards learning). Additionally, we studied the impact of the Soc-Tech environment on a sample group of teachers and how these spaces influenced their teaching and willingness to adopt active learning pedagogical approaches into their teaching repertoire. To accomplish our objectives we designed two studies, *Study 1* focused on student learning while *Study 2* focused on the teaching practices. Note that some aspects of each study used the same data to answer different questions. In this chapter we will describe the general methods used for the two studies. In later chapters we will expand on these methods within the context of the specific research question being addressed.

Research Design – Study 1

Study 1 is divided into two components focused around a comparison of the same participants. Part A was a quasi-experimental design to answer question of whether or not pedagogy and context matters – i.e., research question 1. Part B was a qualitative mixed methods study designed to answer the question on the type of impact such active learning treatment, and the comparison treatments, have on students' perceptions.

Research questions:

1. Comparing students taught in an Active Learning (AL) treatment to their peers in a comparison treatment (TI):
    a. What are the differences in performance on a test of conceptual understanding (using the FCI)?
    b. Do students in the different treatments have different perceptions about their learning experiences? If yes, do these different perceptions differentially influence their actions in regards to how they learn?
    c. Do students recognize different learning opportunities due to the availability of a social technological (Soc-Tech) environment?

Participants – Study 1

Intact sections of the Introductory Physics course (Physics NYA – Mechanics) were the focus of the study – nine from the Fall 2010, seven from the Fall 2009, and two from the Fall 2008 (note the 2008 sections were data from a previous study). Students in these sections were all science majors enrolled in one of the three profiles of the Science Program at Dawson College: Health Science, Pure and Applied Science, or First Choice Science (a program designed for high performing students). Generally, girls slightly outnumbered the boys (55% to 45%). The typical ages of these students were 17 years old, with a small percentage outside this age range (the youngest being 16 and the oldest being 21).

Participants as individuals. The total number of students participating in the two-year study was 351 (with the addition of Fall 2008 data bringing the total to 407). The total for Fall 2010 was 219, while the total for Fall 2009 was 132 (Fall 2008 was 56). Note that these numbers do not represent all the students enrolled in these sections, but only those who answered both the pretest and posttest questionnaire and gave consent to participate in the study. This sample represents approximately 60% of the population of students taking introductory science courses at the College. Participation for the majority of these students involved answering two questionnaires, one related to physics concepts (the FCI) and another related to beliefs about learning physics (CLASS).

Participants as cohorts. Seven of the nine sections were observed as a collective to determine their classroom participation practices. Students were not singled out or recognized as individuals by any identifiers (i.e., no names, pseudonyms, codes, etc.).

Participants as focus groups. From the participating cohorts, we recruited 34 students to take part in focus group interviews in the Fall 2010 (note that 5 were recruited in Winter 2010 to pilot the interview questions). These students were volunteers and were given chance to win a token gift in a drawing held at the end of the semester.

Context – Study 1

Course content

The instructional setting for this study was the first year physics course that is compulsory for all students majoring in science at the CEGEP level – Mechanics NYA. This course is the first of three required physics courses for the pre-university Science Program at Dawson College. Typically, during the fall semester there are 13-15 sections of approximately 35 students each. Students in all sections write a common final exam worth 30 or 50% of their final mark (depending on how each student does throughout the semester). For the remaining grades, teachers are free to use a variety of assessments, including assignments, reports, quizzes and at least 2 tests throughout the term.

Teachers work to ensure that both the material covered and the evaluative tools used in each section are equitable across all sections by meeting before the terms begins and then again at the end of term to agree and monitor what they do. Teachers also communicate with each other throughout the term using First Class Client[5]. The course has 75 hours of structured teacher-student contact time that includes 45 hours of "class" time and 30 hours of "lab" time[6]. "Classes" are twice per week for 1.5 hours each and the "labs" are once per week for 2 hours[7]. In addition to structured teacher-student time, students are supported in three ways: 1) teachers maintain office hours for their students, 2) there is a tutorial room where students have access to teachers other than their assigned teacher, and 3) most teachers maintain separate course conferences for each section on First Class Client.

The course content covers the basics of Newtonian Mechanics: kinematics, dynamics, energy and momentum conservation. Kinematics includes linear and projectile motion which are considered in detail, and rotational motion which is covered in less detail (the kinematics of rigid bodies about fixed axes of rotation are briefly covered). Newton's 3 Laws and their application to simple, single and multiple-body problems are covered in detail. And finally, kinetic energy, gravitational potential energy, energy conservation, work-energy and conservation of linear momentum round out the topics covered. The course involves some derivative calculus (a derivative calculus course is a co-requisite) but no integral calculus. The textbook for the course is "*University Physics*" by Young & Freedman (which is a typical 1st year university physics textbook).

[5] FirstClass Client is a virtual environment where teachers and students can share information, comments, links and resources through "conferences" arranged by the teacher. It is commonly used throughout the Science Program.

[6] The 45/30 split is designated by the Ministry of Education and in reality it is treated differently by different teachers. In recent history, many teachers use "lab" time for lectures however more recently the NYA course committee has agreed to devote at least half of the "lab" hours to hands on activities and not lecturing.

[7] Actual contact time is slightly less because students must be let out of class about 15 minutes early so that they have time to get to their next class. So in actual fact, classes are 1h15min while labs are 1h45min.

The Social Technology Environment

In fall of 2009 Dawson College renovated two of their physics labs in accordance with principles of an active learning pedagogy (see Figure 3.1). These were based on the Dickinson College model. The Dickinson model facilitates group work by organizing worktables into pod-like configuration seating four students comfortably, with one computer for every two students. The worktables were designed to be modular (two trapezoids making up a hexagon) and could be rearranged in a variety of configurations (e.g., individual, rows, conference), allowing for maximum seating flexible. Generally, the worktables are organized in the pod-like clusters accommodating four students. In addition this new room had interactive white boards (see right side of photo Figure 3.1 below) that were similar to the Technology Enabled Active Learning (TEAL) classrooms used at MIT, referred to earlier. Note that this design also included projection screens in the far corners of the classroom so that regardless of where the student sat they could see the projected image from the interactive white board without turning around (see projection screen in center of photo below).

Figure 3.1. Photo of social technologic classroom used in the study.

Measures – Study 1

Conceptual knowledge assessment measurement

The *Force Concept Inventory* (FCI; Hestenes et al., 1992) was used to assess conceptual knowledge both pre and post instruction. The FCI is a structured multiple-choice questionnaire with high reliability will be used to assess conceptual understanding in Physics NYA. We elaborate further in the upcoming section, Chapter 4.

Semi-structure interview questions

We designed a semi-structured interview questionnaire in order to collect students' perceptions of their learning experiences in the new socio technology environment. The questionnaire is comprised of 25 questions focused around eight themes: (1) demographic information regarding high school experience – did their high school implement the QEP reforms; (2) perceptions of the new lab/classroom; (3) perception of collaborative learning; (4) perception and level of awareness of teacher's goals and epistemic framework; (6) perception about learning physics; (7) perception of shared responsibility; (5) degree of willingness to use the technological opportunities available; (8) recommendations. For the full questionnaire see Appendix B.

Observation rubric

The observation rubric (see Appendix C) was used during the in-class observations. It enabled us to collect participation data on the functioning of the classroom system – thus both the students and the teacher. This tool was adapted from one developed at McGill University's Teaching and Learning Services for use in their new Active Learning classrooms. It was modified based on our prior research (see Charles, Lasry, Whittaker and Trudeau, 2009), as well as the guidelines from Stapleton, LeFloch, Bacevich and Ketchie, (2004).

The work of Stapleton et al., (2004) influenced our process of expanding on the observational rubric. Like them we identified "activity markers." However, while they classified their data into three categories each describing some relevant aspect of the classroom experience (see Table 5.2) we classified ours into four. These four are as follows: (1) *the activity* (Stapleton calls, *organization of the class*); (2) *delivery mode* (Stapleton calls, *nature of the work*); (3) *student engagement* (Stapleton calls *focus of the student*); and (4) *professor position* (no equivalent category in Stapleton's work). The protocol for using the rubric will be described closer to its use in Chapter 5.

Table 5.2. Stapleton's example of the categories for coding of the classroom observations.

Marker Types	Activity Example
Student focused	Students engaged in whole class passive listening
	Students engaged in whole class interactive discussion
	Students engaged in individual reading or work
	Students engaged in interactive pair or group work
Class Organization	Teacher-led whole class organization
	Student-led whole class organization
	Small group or cooperative pair organization
	Independent work organization
Nature of work	Textbook/workbook written exercises
	Assigned or student-selected reading
	Original writing assignments
	Visual presentation

STUDY 2 – Teacher Perception and Teaching Practices

Research questions

4. Compare teachers using the AL to their peers using TI.
    a. What differences are there between our sample teachers teaching practices?
    b. How do these observed differences compare to teacher's self-perception of their teaching practice?
    c. How do perceptions of teaching practice (i.e., teacher-centered versus student-centered) impact student learning?
5. Document the process of becoming an AL teacher – factors influencing a teacher's development toward social constructivist teaching:
    a. How do we describe the development and implementation of an active learning teacher?
    b. How can we distinguish between teacher's practices?
6. Technology's impact on teaching:
    a. What is the impact of a socio-technology environment on teachers and their practice?
    b. What is the impact of a socio-technology environment on students' perceptions of learning?

Research Design – Study 2

The implementation of Study 2 followed an *action research* approach in that we were interested in the practice of teachers and needed to follow them as their implementation of the curriculum and unfolded. The objective was to make the participant faculty aware of active learning pedagogies and in doing so promote their use of said approach to teaching.

The research design used in this section is best described as a mixed methods qualitative case study – with a cross-case comparison (Merriam, 1998) – that include both narratives, ethnographic classroom observations and semi-structured interviews to further elicit teachers beliefs about learning and teaching. Additionally, we used data from the Approaches to Teaching Inventory (ATI), a self-reported survey instrument that establishes a teacher's self-perception of their teaching style for a particular context. We elaborate further on the specific design used for each aspect of the study at the beginning of the related chapters – Chapter 5 and Chapter 6.

Caveat to consider when interpreting the results of a case study. One of the key limitations of case study design is the sensitivity and integrity of the investigator. Merriam (1998) reminds us that the researcher is both the primary instrument of data collection as well as the primary data analysts therefore attention and accounting for bias is important. Because of the possibility of such bias conclusions will be framed to provide alternative explanations and expose possible agendas.

Participants – Study 2

The primary data for this study was collected from a sample of six teachers from the physics department in an urban English college, part of the CÉGEP system. Their teaching experiences ranged from 2.5 to 15 years. Their academic backgrounds were also diverse – Ph.D. in Theoretical Physics, M.Sc. in Physics, Master's in Engineering. In addition to these six, we also collected survey data from four other members of the physics faculty. These faculty had similar profiles with a wide spread in their teaching experience ranging from 5 to >25. All teachers participating did so voluntarily and consensually. While it is difficult to maintain anonymity in such cases, we do not disclose the names of any of our participants and use pseudonyms or other non-named identifiers to describe these participants.

Context – Study 2

The context for the teacher participants was the same as for the students. All teachers who took part in this study were physics teachers at the same urban CÉGEP. Teachers who took part in the fall 2009 and 2010 classroom observations and/or survey taught physics in the new socio-technology lab/classroom.

Measures – Study 2

Attitudes toward teaching

The *Approaches to Teaching Inventory* (ATI; Prosser & Trigwell, 2006) is a two-scale questionnaire composed of 22-item in total (shown already in Appendix A). Each of the scales are made up of 11 questions, and fall into one of the two categories: (1) an information transmission/teacher-focused scale (ITTF) and (2) a conceptual change/student focused (CCSF). Previous studies that have used the ATI had done so in one of two ways. One way has been to monitor changes in a teacher's approach to teaching in a subject area over time (Gibbs & Coffey, 2004). The other way the ATI has been used is as a way to establish relationships between teaching and the outcome of the pedagogical approach used. For the most part it has been used for this purpose by its creators, Trigwell and colleagues (Trigwell et al., 1999). They have looked at the relationships between a teacher's self-reporting on the ATI and the approach to learning adopted by the students of said teacher. In this study we will use the ATI in both manners.

The ATI questionnaire is based on prior studies aimed at discriminating between different styles of teaching and learning in higher education. The instrument's design takes into account the integrated teachers' approach to teaching and students' approach to learning. The development of the instrument included three stages: (1) a qualitative approach to gather and identify key factors, (2) the development of the instrument, and (3) its validation with 1,023 university teachers from four countries (USA, UK, China (Hong Kong) and Scandinavia).

The qualitative analysis yielded two categories (74 items questionnaire) that characterize the classroom experience for both teachers and students: (1) *intention* and (2) *action-strategies* (what we might call enactment). From this qualitative analysis, researchers further distinguished two different intentions – (a) *information transmission,* and (b) *conceptual change*. And, three action-strategies – (a) *teacher-focused*, (b) *student/teacher interaction,* and (c) *student-focused*. In their final instrument they retained two subcategories (teacher-focused and student focused) in the acts-strategies category.

The items coalesce into four factors with 4 items each: (1) information transmission, (2) conceptual change, (3) teacher focused, (4) student focused. Further analyses showed a high correlation between conceptual change and student-focused on one hand, and information transmission and teacher-focused on the other. As such, the categories were again collapsed into two factors. By doing so, the goodness of fit (or how well this two factors/scales describe the reality based on the data gathered) and the reliability improved. This was accomplished using a Confirmatory Factor Analysis [8](CFA). The two factors resulting from the goodness of fit indicators and reliability index are as follows: (1) conceptual change/student-focused (CCSF), and (2) information transmission/ teacher –focused (ITTF). The ITTF and CCSF scales have a Cronbach's alpha scale reliability of .73 and .75 respectively (Trigwell & Prosser, 2004).

Regarding the uses and the misuses of ATI, the authors highlighted the fact that this is not an instrument to be used in order to classify professors. They assume that this questionnaire should assume that teachers respond to the questions in a context. That means, teachers might change their teaching approaches depending on different classrooms or courses. Instead, ATI may show how teachers change their teaching approaches according to a professional development process.

Teacher semi-structured interview questionnaire

We designed a semi-structured interview questionnaire in order to collect teacher's perception of learning and how they used the new Socio-technological classroom. The questionnaire is comprised of seven questions focused around three categories:(1) perceptions of learning and how that may have over the years; (2) attempts to design learning for the socio-technological environment; (3) perception of the relationship between teaching and learning; and, (4) perception of themselves as a teacher. Question 1 assessed the perception of learning. Question 2 and 3 assessed the teacher's attempts to design the learning environment. Question 4 and 5

[8] CFA tests whether a theoretical structure (in this case, two different approaches to teaching) fits the data from a sample. The way in which this works is: the researcher designs the factors and determines which items load onto each factor. The CFA then calculates the correlations between the items and the factor in which it loads. If the correlations calculated make sense, then the model (two or one factor structure) fits the data. Otherwise, they need to re-specify (change the structure of the model).

assessed perception of the relationship between teaching and learning. And, lastly, Question 6 and 7 assessed their perception of themselves as a teacher. See Appendix D for the full interview questionnaire. Also see Appendix F for written questionnaire relating to use of the new lab.

Observation rubric and protocol

Same as in Study 1.

Analytical techniques – Study 2

Case study analyses

According to Merriam (1998), there are three main methods of analyzing qualitative data: (1) descriptive accounting of findings, (2) category constructions, and (3) theorizing. At the descriptive level meaning is conveyed through the compression and linking of data, which is then presented in a narrative format. Most case studies generate some type of narrative presentation, however, many strive for the more sophisticated method of analysis involving the construction of categories or themes that captures recurring patterns flowing throughout the data. To emphasize this point, Merriam (1998) states: “category construction *is* data analysis” (p. 180). In this study we analyzed the data using all three methods.

Construction of categories. Categories are not the data themselves; rather they are abstractions derived in both a systematic and intuitive manner. Glaser and Strauss (1967) suggest that the categories should be “emergent” – i.e., they should be born out of the data and in doing so be a perfect fit thereby explaining most of the data collected. Categories may also be considered lenses through which the data may be viewed. In many instances, including this current study, categories are informed by the purpose of the study as well as the literature.

Construction themes. The next level of data analysis is more abstract and involves the construction of explanations through the linking of categories. In case study research, this is considered the cross-case analysis. Merriam’s (1998) description of this process is consistent with the qualitative post-positivist movement. This current research viewed the challenge of constructing themes and testing the links between categories as an important part of the data analysis.

Verification of data. The protocol for verifying the data collected from each instructional session was as follows: (1) meet with other researchers on a periodic basis to discuss the progress of the data collection; (2) critically review field notes and make a random check of audio quality; and (3) use the reflections from the field notes and discussion with other researchers to make modifications for the next session.

Establishing Validity (i.e., Trustworthiness and Authenticity)

Different authors suggest that validity of case studies should be established through a variety of methods (Erickson, 1986; Patton, 1990; Merriam, 1998; Yin, 1994). Some of the generally agreed upon ways of establishing validity include: (1) the collection of different data sources thereby allowing for the cross-validation of findings (i.e., triangulation); (2) the use of two or more evaluators to review material in each case and make independent judgments and interpretations (i.e., inter-rater reliability); (3) an adequate amount of data collected over an adequate amount of time to provide a range of cases (i.e., confirming and disconfirming cases); (4) accuracy of facts and interpretation of data evaluated by the cases themselves.

Attempting to reduce the first and third threats to validity, this study used multiple measures to generate the data corpus over an extended period of time. Because the data collection process spanned almost two years it allowed us to collect a substantial amount of evidence of teacher development over time. As the principal collector of data, the first author was able to establish a good rapport with the teacher participants thereby increasing the “emic” component of the data. Subsequently gathering evidence of both confirming and disconfirming cases.

The second recommendation to improve validity was addressed by having several different individuals code the data to obtain an inter-rater reliability correlation score. Lastly, accuracy of the facts and interpretation of the transcripts was attempted by having the key participants themselves review the data – what Creswell (1994) calls “members checks”. As such we provided our treatment group teacher with his case report and asked him to comment on it. This allowed for some corrections as well as confirmation of his opinion.

Confidentiality of data. The researchers upheld the requisite “human research ethics” measures to insure confidentiality of the entire data corpus. Raw data were shared only with the research team, which includes research assistants. Students are referred to by a code that was randomly generated to replace their student IDs. Interviewed students are represented simply by gender. The teacher participant data are treated equally, though in some situations it may be possible to identify an individual by extraneous information – i.e., their schedule. In such instances the researchers have tried to eliminate these identifiers. The only person who is not anonymous is our treatment group teacher, Chris Whittaker. Chris has given permission to be identified by name.

Summary of the Research Methods

Table 2.1. Design of the two investigations that make up Study 1 & 2.

Chapter	Study	Focus	Research Question	Data Collected	Analysis
Chapter 4	**Study 1**	Comparison of AL treatment and comparison groups on their conceptual knowledge gains	What are the differences in performance on a test of conceptual understanding (using the FCI)? ▪ AL/Soc-tech vs. TI/Soc-tech ▪ AL/Con-classrm vs. TI/Con-classrm	FCI (pretest and posttest)	ANCOVA
Chapter 5	Study 1	Comparison of AL treatment and comparison groups on their perceptions of learning	Do students in the different treatments have different perceptions about their learning experiences (e.g., ideas about learning and knowledge – epistemic beliefs, sense of responsibility (agency), roles)? If yes, do these different perceptions differentially influence their actions in regards to how they learn?	1. Student interviews 2. Classroom observation	Qualitative analysis - development of categories and themes
Chapter 6	Study 2	Becoming an student-centered active pedagogy teacher - a case study	How do we describe the development and implementation of an active learning teacher?	1. Classroom observations 2. Teacher interviews	Case study narrative
Chapter 7	Study 2	Comparison of observational differences teacher	What differences are there between our sample teachers teaching practices?	Classroom observations	Qualitative analysis - development of

		practices between the six treatment teachers			categories and themes
	Study 2	Comparison of self-reported perceptions of teaching to observed teacher practice and self-reported practice	How do these observed differences compare to teacher's self-perception of their teaching practice?	ATI questionnaire	Correlational analysis
	Study 2	Comparison of self-reporting teacher practice and student conceptual gain on the FCI questionnaire	How do perceptions of teaching practice (i.e., teacher-centered versus student-centered) impact student learning?	1. ATI (teachers) 2. FCI (students)	Correlational analysis
Chapter 8	Study 2	Document the impact of a socio-technological environment on teaching	What is the impact of a socio-technological environment on teachers and their practice?	Teacher interviews	Descriptive case study analysis
	Study 2		Do students recognize different learning opportunities due to the availability of a social technological (Soc-Tech) environment?	Student interviews	Descriptive case study analysis

CHAPTER 4
CHANGING PHYSICAL SPACES AND PEDAGOGIES: Which is more important?

Prominent Ivy-league universities have been pioneering pedagogical reforms through educational technologies by integrating state-of-the-art educational technologies in their learning environments. Recall that Harvard physicist Eric Mazur's Peer Instruction (Mazur, 1997) uses wireless remotes and MIT's TEAL project (Dori, Belcher *et al*., 2003) uses multiple computers and active projection screens to provide a student-centered collaborative learning environment. We are particularly interested in the Socio-technological TEAL classrooms and will study these more closely in this chapter.

One of the most striking features of MIT's TEAL classrooms is that there is no 'FRONT' to the classroom. The learning is genuinely distributed throughout the physical space. Students collaborate, usually around movable tables that have computers for every couple of students. There are also projectors or smart displays showing the same content on different walls. Hence, one can be facing in one direction or its opposite and still be part of the learning environment. In these Socio-technological classrooms, lectures are brief and intended to start the inquiry process rather than provide students with lecture notes. Students and teachers are required to conduct experiments together and publically share results and conceptual knowledge – a departure from traditional college teaching. Furthermore, TEAL integrates technology by using visualization software (*e.g.*, simulations and animations) as well as *WebAssign*, an automated system for students' submissions and grading. This application also allows teachers to monitor students' preparedness in their pre-lecture reading assignments, which facilitates adapting lectures to meet students' needs.

In has been well documented that collaborative student-centered learning improves conceptual learning in physics (see for instance the meta-analysis: Hake, 1998). Physical spaces have also been documented to impact on student learning (Beichner, 2000; Dori, Belcher *et al.*, 2003). In this chapter we ask a simple question: which is more germinal to students' conceptual learning: pedagogy or physical space/technology?

Methods

Design

To address this question we designed a quasi-experimental study in which two types of pedagogies (Active Learning vs Traditional instruction) and two types of classroom settings (Socio-technological vs Conventional) were studied in a 2x2 design. This design enabled us to examine these four possible groups. The first group featured student-centered Active Learning pedagogy that was adopted in a non-traditional TEAL-like Socio-technological classroom setting. The second group adopted student-centered Active Learning pedagogy in a conventional 'frontal' classroom. The third group had the 'non-frontal' Socio-technological classroom with Traditional Instruction and the last group had Traditional Instruction in a Conventional 'frontal' classroom. We then compared students in all four of these learning environments to each other using the instruments described in the next section.

The timing of the data collection in this study was critical. Our study followed a longitudinal design where we began collecting data before the classrooms were physically remodeled into Socio-technological environments, continued collecting data as the rooms were being inaugurated and kept on collecting data throughout the first year they were used. This longitudinal design is critical because Socio-technological classroom settings may influence teachers' pedagogy. In turn, this could limit our ability to distinguish pedagogy from classroom setting. For instance, we report data concerning Traditional Instruction teachers who were early adopters of the socio-technological classroom settings. The socio-technological classroom setting was thus unable to affect the incoming pedagogy used by these teachers. We will discuss further the impact that socio-technological environments later had on these teachers' pedagogy.

Sample

Intact sections of the introductory physics course (Physics NYA – Mechanics) were the focus of the study – nine from the Fall 2010, seven from the Fall 2009, and two from the Fall 2008 (2008 data from a previous study). Students in these sections were all science majors enrolled in one of the three profiles of the Science Program at Dawson College: Health Science, Pure and Applied Science, or First Choice Science (a program designed for high performing students). The gender split in most sections was roughly 50-50; sometimes the girls outnumbered the boys and sometimes the reverse. The range of age in our student population was between 16 and 21, though the typical age of these students is 17 years old.

The total number of students participating in the two-year study was 351 (with the addition of Fall 2008 data bringing the total to 407). The total for Fall 2010 was 219, while the total for Fall 2009 was 132 (Fall 2008 was 56). Note that these numbers to not represent all the students enrolled in these sections, but only those who answered the pretest or posttest questionnaire and gave consent. This sample represents more than half of the student population taking introductory physics at the College. Participation for the majority of these students involved answering two questionnaires, one related to physics concepts (the FCI) and other related to beliefs about learning physics.

In this chapter we report conceptual change data comparing students across different classroom settings and pedagogies. The conceptual change data is based on the changes between the FCI score obtained by students at the beginning of the term (preFCI) with the score obtained on the FCI at the end of the term (postFCI). In all, we collected complete preFCI and postFCI data for 214 students in four different groups displayed in table 4.1 below.

Table 4.1 Four categories of learning environments in our study

Classroom Setting	Pedagogical Approach	
	Student-Centered Active-Learning	Traditional Instruction
Socio-Tech classroom (Soc-Tech)	Soc-Tech_ AL (n=56)	Soc-Tech_Trad (n= 51)
Conventional classroom	Conv_AL (n=49)	Conv_Trad (n=58)

Instruments

The Force Concept Inventory (FCI)

In physics, students may know how to solve problems without having a complete conceptual understanding of the physics involved (Kim & Pak, 2002). The Force Concept Inventory (FCI), a 30-item multiple-choice instrument, is unique in that it asks conceptual physics questions in simple terms and proposes distractors that are compiled from the most prevalent misconceptions given by students in interviews (Halloun & Hestenes, 1985a,b). To answer FCI questions, students do not resort to computations or memorized algorithms but have to identify the accurate concept from a number of "d*istractors*". To expert physicists, the correct answers to FCI questions are straightforward. The gap between what instructors think their students understand and what the FCI shows, has contributed to making the FCI "*the most widely used and thoroughly tested assessment instrument*" in physics (McDermott & Redish, 1999).

We administered the FCI during the first and last week of the semester to examine conceptual change in our sample of students.

Treatment and setting

Described earlier in chapter 3.

Analytic measures

Hake's Normalized Gain *g*

There are a number of ways to use FCI data to determine the extent to which students' conceptions have changed. Analyzing raw FCI scores can be problematic. Indeed, pre-test scores are highly correlated to post-test scores, which would be the case if no instruction were present. This tells us that post-test scores are in part due to how much conceptual knowledge the student came into the course with. This of course is unacceptable if one is trying to measure the specific contribution of an instructional method or classroom setting. If one wishes to know how much the students have gained from the instruction, the raw difference may be sought. However, the possible values for the difference between pre and post-test scores decreases as the pre-test scores increase (i.e. a ceiling effect). Hake (1998) suggested using FCI scores as an intermediary to calculate normalized gains. Normalized gains are defined as:

$$\boldsymbol{g} = (\text{Post-test\%} - \text{Pre-test\%}) / (100\% - \text{pre-test\%})$$

We compared students using normalized gains across our treatment groups.

ANCOVA, PostFCI with PreFCI as Covariate

Hake's (1998) normalized gain remains the most common way conceptual change scores are reported in physics education research. However, some concerns have recently emerged concerning the validity of this metric (Coletta & Phillips, 2005). One concern is that this process of normalizing the gain (i.e. dividing by the maximum possible gain) can make the distribution of gains non-normal. In turn, most statistical tests used to compare gains become invalid. To sidestep this issue, one can simply correct for prior knowledge by using an ANalysis of COVAriance (aka ANCOVA) examining differences on Post-test FCI scores when corrected for Pre-Test FCI scores (i.e. using Pre-Test FCI as the covariate). We provide ANCOVA results as well as Hake gain results for each learning environment.

Results

Uni-ANOVA: The Effect of Pedagogy

We compared conceptual normalized gains across all students focusing uniquely at the type of pedagogy they were exposed to. Students in Active Learning student-centered environments achieved sizable and statistically significantly ($p < 0.001$) larger normalized gains than students in Traditional instruction groups. Recall that FCI normalized gains correspond to the fraction of the maximal possible increase in FCI score, that is the greatest increase in score between the beginning of semester FCI pre-test and the end of semester FCI post-test. Students in the Active Learning group achieved normalized gains of $\boldsymbol{g} = 0.44$ corresponding to pretest-to-posttest increases of 44%. In contrast, students in the Traditional Instruction environments achieved gains of $\boldsymbol{g} = 0.24$ corresponding to pretest-to-posttest increases of only 24%.

Uni-ANOVA: The Effect of Classroom Setting

We next compared conceptual normalized gains across all students focusing uniquely at the type of classroom setting. Students in non-frontal Socio-technological environments achieved normalized gains of $\boldsymbol{g} = 0.32$ corresponding to pretest-to-posttest increases of only 32%. In contrast, students in Conventional 'frontal' classrooms achieved normalized gains of $\boldsymbol{g} = 0.36$ corresponding to pretest-to-posttest increases of only 36%. This marginal difference was not statistically significant ($p > 0.7$) indicating that students' conceptual gains are independent of the classroom setting.

The Effects of Pedagogy vs Physical setting.

We now analyze the impact of both physical setting and pedagogy by comparing the 4 types of learning environments shown previously in Table 4.1. Using FCI data collected at the beginning and at the end of the term, we compared the differences in final conceptual knowledge after a semester of instruction between subjects in all four of these conditions.

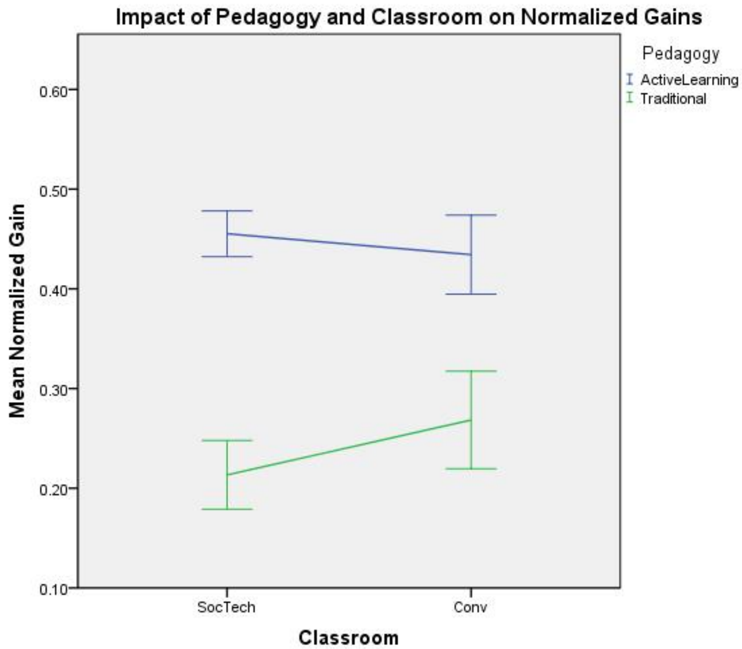

Figure 4.1 The difference pedagogy makes on conceptual normalized gain is significant. Classroom settings alone do not contribute significantly to conceptual gain.

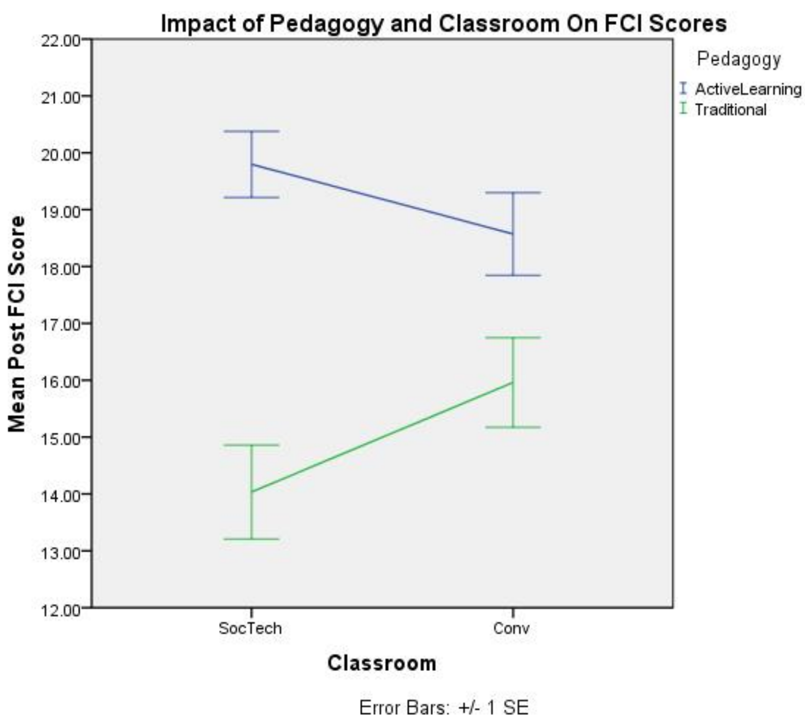

Figure 4.2 Significant difference pedagogy makes on mean Post-FCI score.
Classroom settings alone do not contribute significantly to end of semester conceptual knowledge.

These two graphs show a number of similar results from the perspective of conceptual normalized gain (Figure 4.1) and ANCOVA corrected mean Post-FCI score (Figure 4.2). Recall that whereas the normalized gains correspond to the fraction of the maximal possible increase in FCI score, the mean Post-FCI score is the post-test FCI score that is ANCOVA adjusted using the Pre-Test FCI score as a covariate.

The first interesting result apparent in both Figures is the notable vertical difference between the blue and green lines. This shows that the largest difference in conceptual gain or mean Post-FCI score resides in whether the pedagogy is Traditional or Active and student-centered. Second, the small horizontal difference on each line shows that the classroom environment, whether socio-technological or conventional, does not contribute significantly to conceptual knowledge or gains. We also note two non-statistically significant tendencies. The first is that students taught using traditional methods to achieve marginally (i.e. not statistically significant) higher gains in conventional classroom. The second is that students taught with student-centered Active-Learning pedagogies achieve marginally greater conceptual knowledge and gains when exposed to non-frontal Socio-technological environments.

In summary, using a student-centered pedagogy is more important to conceptual learning than having a high-tech classroom. Socio-technological classroom provide an advantage when the learning environment it is implemented in is student-centered Active Learning.

Does Active Learning only work for the ‘good’ students?

Concerns are frequently voiced regarding the effectiveness of pedagogical methods developed in elite institutions such as Harvard and MIT. Informally, instructors often challenge pedagogical developers such as Eric Mazur at Harvard with questions such as “of course it works, you’re at Harvard! But how do I know this will work in my institution”?

It is useful to replicate and show the effectiveness of various educational technologies and pedagogical approaches across various institutional settings. For instance, Peer Instruction was shown to work equally well in Cegep and to increase conceptual gains both in students with higher and lower incoming conceptual knowledge (Lasry, Mazur & Watkins, 2008). In this study, we designed our study to replicate the effectiveness of active learning pedagogy and Socio-technological classroom settings in Cegep. In particular, we pose the question: how do students with a range of prior conceptual knowledge differ in conceptual gains when placed in student-centered and socio-technological classroom settings?

To achieve this goal, we first analyzed students' incoming conceptual knowledge as measured by their incoming FCI score. The graph below displays the distribution of beginning of term FCI cores among students participating in this study.

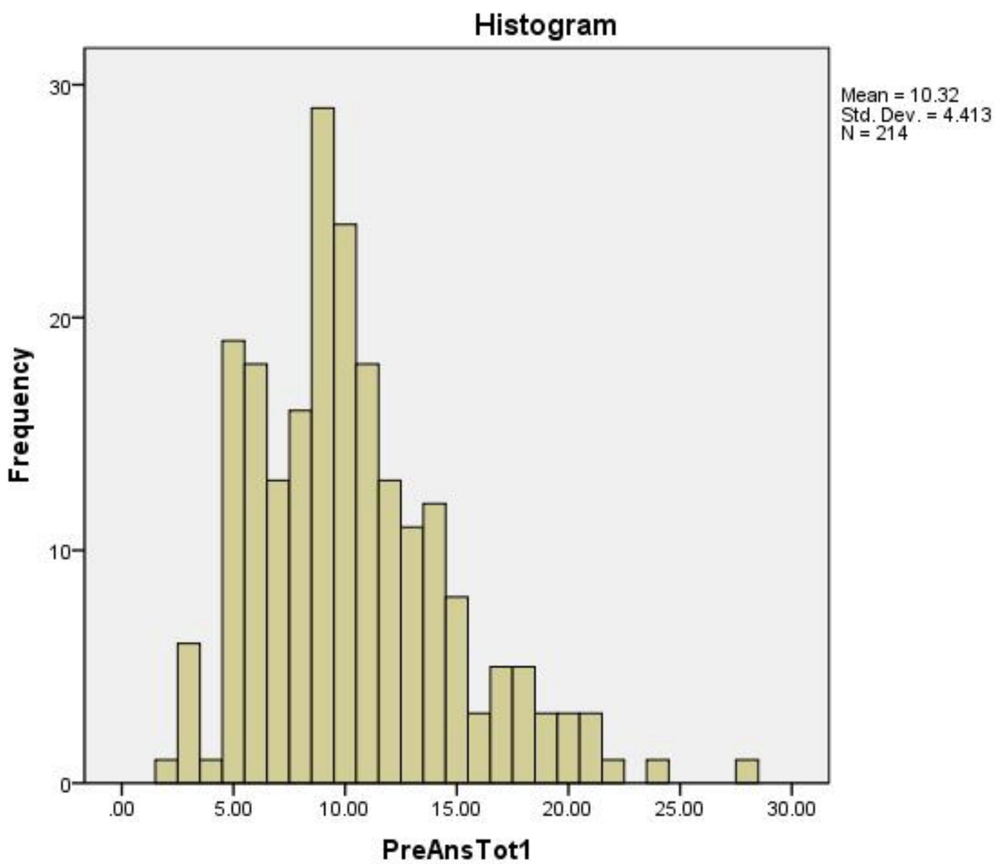

Figure 4.3 Beginning of term student FCI scores are normally distributed

This graph shows that the distribution of students' incoming conceptual knowledge in our population is roughly normally distributed. It is noteworthy that the students in this population are on average quite weak (score of roughly 34%), significantly weaker than those at Harvard and MIT (Mazur reports typical mean incoming levels of roughly 70%).

Given that the distribution appears normal, we can address the questions surrounding prior conceptual knowledge by splitting the population according to a standard deviation (SD) around the mean. Students above one half a SD from the mean were categorize as having higher conceptual knowledge, those below one half a SD from the mean were labeled as having lower conceptual knowledge and those lying within one SD around the mean (within half SD above and below) were labeled as having Medium conceptual knowledge. This process resulted in roughly 25% of students being labeled as Low incoming conceptual knowledge, 50% as Med and 25% as Hi.

Does Active Learning only work for 'good' students?

We now chart the effectiveness of student-centered pedagogies on students of differing prior conceptual knowledge, regardless of the physical classroom setting used. The Figures below show the conceptual normalized gains and mean Post-FCI score of students with Low, Medium and High prior knowledge when exposed to either Active Learning or Traditional Instruction.

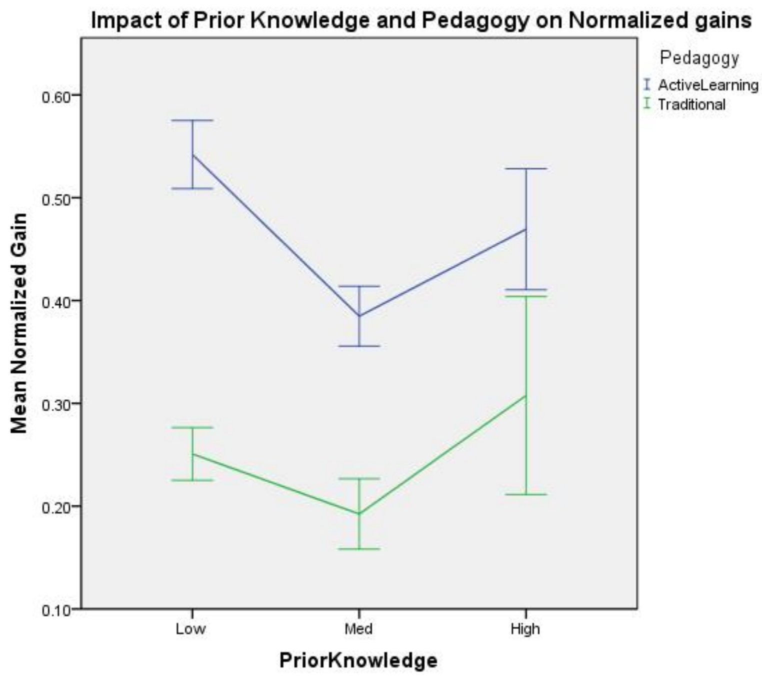

Figure 4.4 Differences in normalized gain for students with Low, Medium and High prior knowledge in either Active Learning or Traditional pedagogies.

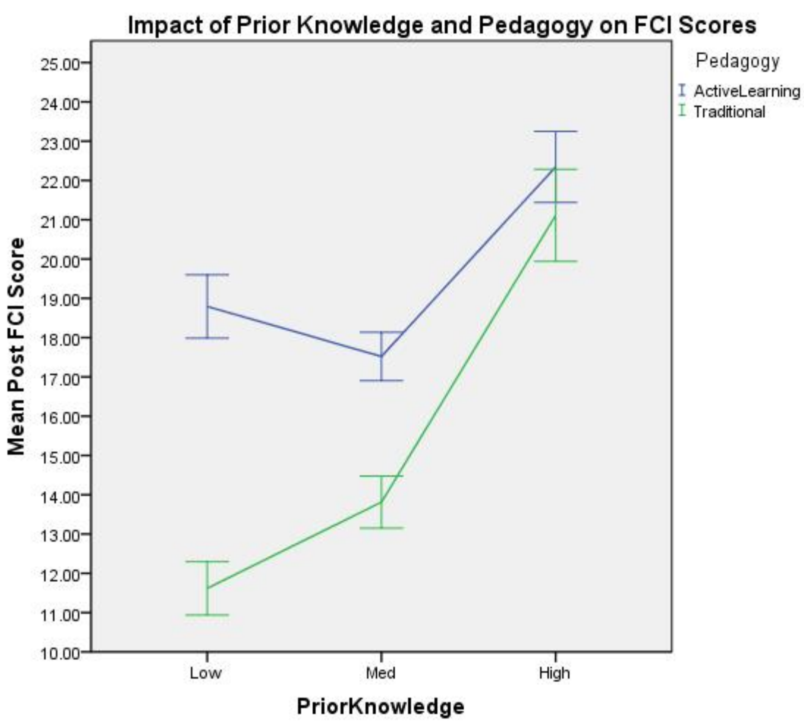

Figure 4.5 Differences in mean Post-FCI score for students with Low, Medium and High prior knowledge in either Active Learning or Traditional pedagogies.

Both of these graphs show once again that the type of pedagogy is paramount. Regardless of incoming knowledge, students exposed to student-centered Active Learning approaches achieve greater conceptual gains and have larger mean Post-FCI score compared to students involved in Traditional Instruction. The second most striking result is that this increase in normalized gain and mean Post-FCI score is most pronounced for students with the lowest prior conceptual knowledge. It remains statistically significant for students with medium prior knowledge and small or marginal for those with higher prior conceptual knowledge. Indeed, Figure 4.5 shows that High prior-knowledge students are marginally affected by the type of pedagogy, whereas Figure 4.4 shows a small but significant effect of pedagogy on high prior knowledge students.

Comparing Low prior knowledge students to those with Medium or high prior knowledge also yields interesting results. Prior knowledge does not significantly affect conceptual normalized gain (Figure 4.4). Only the type of pedagogy yields significant differences in conceptual gain. In Figure 4.5, low and medium prior knowledge students in Active Learning do not differ from each other in mean Post-FCI score. The same is true for students in Traditional pedagogies. However, both Low and Medium prior knowledge groups differ from students with High prior knowledge in mean Post-FCI score.

Do Socio-technological settings only work for 'good' students?

We next chart how the type of classroom setting affects students with differing levels of prior-knowledge, regardless of the type of pedagogy used. That is, these students in Socio-technological or Conventional classroom may have been exposed to either Active Learning or Traditional Instruction.

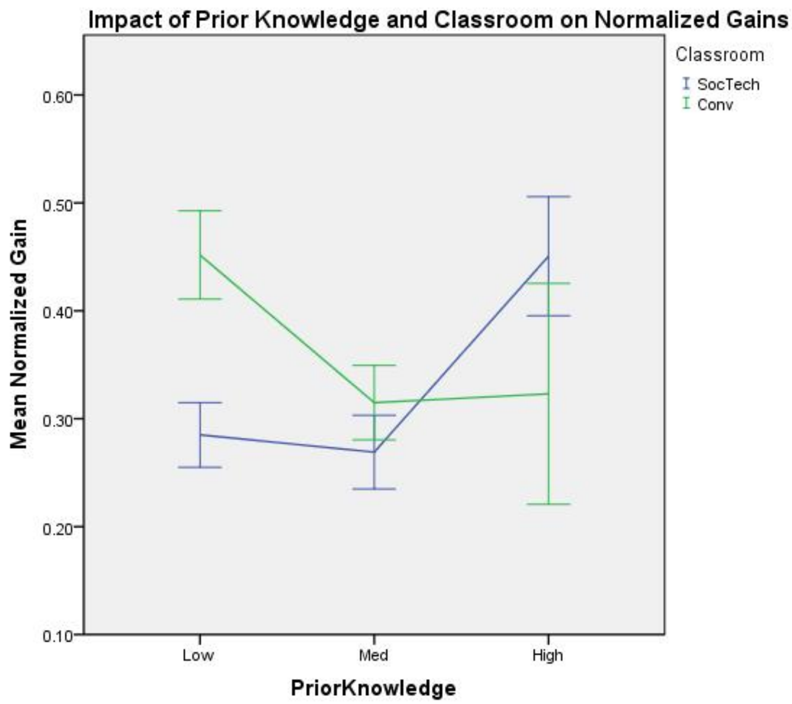

Figure 4.6 Differences in normalized gain for students with Low, Medium and High prior knowledge in either Socio-technological or Conventional classrooms.

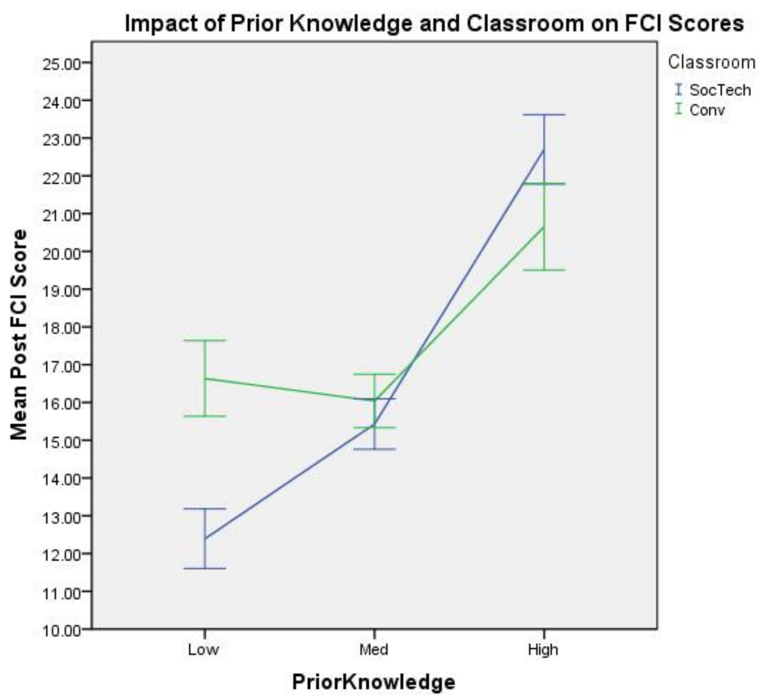

Figure 4.7 Differences in Mean Post-FCI score for students with Low, Medium and High prior knowledge in either Socio-technological or Conventional classrooms.

These Figures show that the difference between socio-technological and conventional classrooms is marginal. That is, taking all levels of prior knowledge together, there is no major difference between socio-technological-classroom settings and conventional classroom settings. This confirms our prior uni-ANOVA finding that classroom setting is has a non-significant effect on learning.

The benefits of socio-technological classroom environments are only marginal for students with high prior knowledge and insignificant for students with Medium prior-knowledge. Intriguingly, the type of classroom setting has a significant effect on students with Low prior-knowledge. The most concerning part of this finding is that students with Low prior knowledge benefit more from conventional classroom settings than from socio-technological ones. That is, socio-technological classroom settings significantly *reduce* conceptual gain and mean Post-FCI score in students with lowest prior-knowledge. Note that in both graphs, the Socio-technological and Conventional classroom lines cross. This crossing of lines indicates an interaction between background knowledge and the classroom settings. Thus, although Socio-technological settings enable students with higher prior knowledge to achieve marginally larger conceptual gains, students with lower background knowledge obtain sizably smaller conceptual gains. This troubling result warrants further investigation. Is it possible that the effect shown in Figure 4.7 above is due to a hidden effect of the pedagogy?

To determine whether the troubling results of Figure 4.7 are due to pedagogy, we present two similar Figures, one for each type of pedagogy. Figure 4.8 displays the effect of classroom settings on students with varying levels of prior knowledge, but in this case *only* for students taught in classrooms that use student-centered Active-Learning. In contrast, Figure 4.9 displays the effect of classroom settings on students with varying levels of prior knowledge, but *only* for students taught in classrooms that use Traditional Instruction.

Within Active Learning environment: Effect of prior knowledge and classroom type on normalized gain

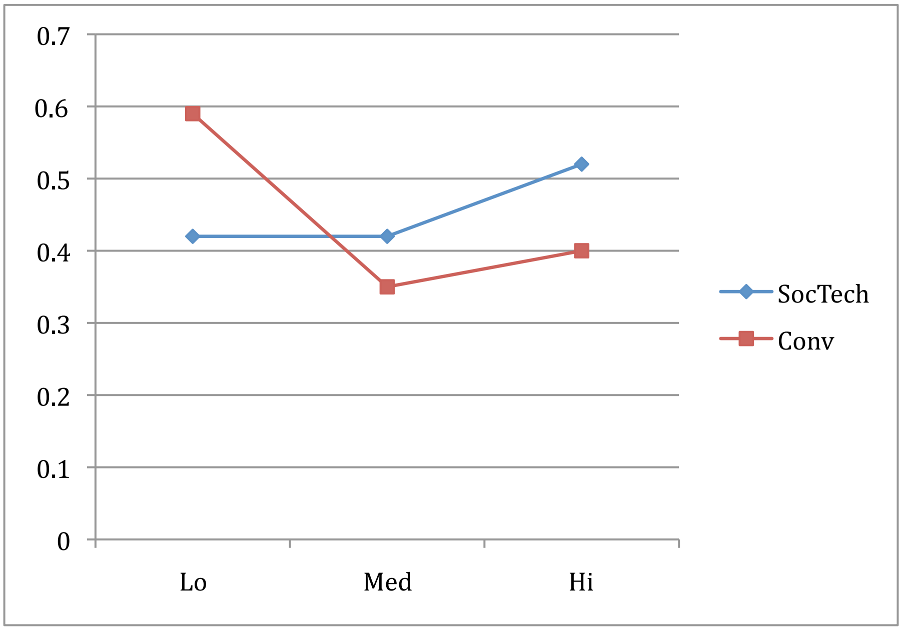

Figure 4.8 Active Learning Pedagogy: Differences in normalized gain for students with Low, Medium & High prior knowledge in either Socio-technological or Conventional classrooms.

Within Traditional Learning environment: Effect of prior knowledge and classroom type on normalized gain

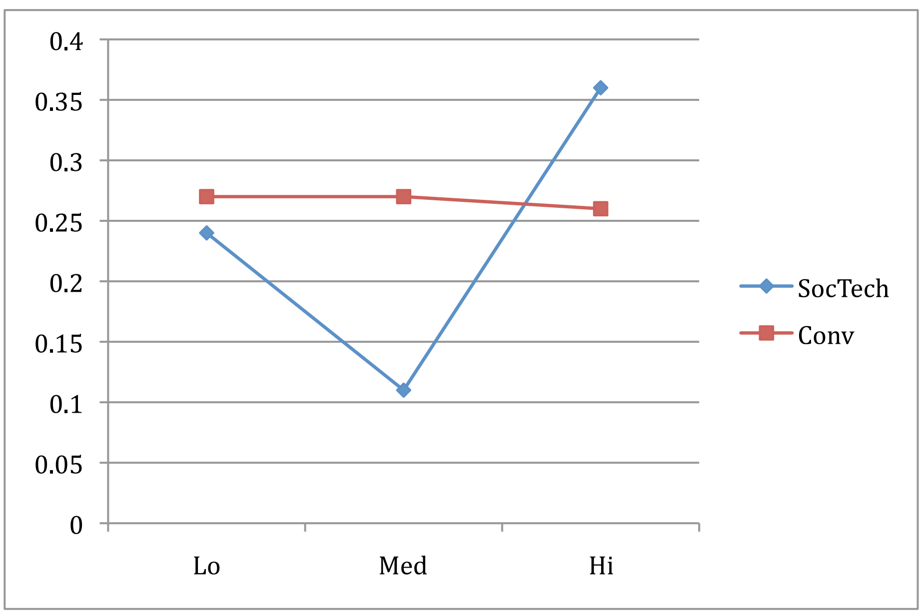

Figure 4.9 Traditional Instruction: Differences in normalized gain for students with Low, Medium & High prior knowledge in either Socio-technological or Conventional classrooms.

These two graphs show that difference in conceptual change for students with different prior knowledge in different classroom settings is not independent of the pedagogy. Although both graphs show that students with less prior knowledge achieve less conceptual change when exposed to Socio-technological classroom environments, this difference is negligible in Traditional Instruction classrooms. Indeed, only lower prior knowledge students in the student-centered Active Learning pedagogy experience noticeable decrease in conceptual change when instructed in Socio-technological classroom environments.

In contrast, students with higher prior knowledge achieve larger conceptual change, regardless of whether the pedagogy is Traditional or Active. Indeed, students with higher prior knowledge achieve a similar 0.1 increase in normalized gain (i.e. a 10% increase normalized gain) both in Active Learning and in Traditional Instruction.

Discussion

Pedagogy is More Important than Technology

In this chapter we take distinct looks at pedagogy and the classroom settings. Much has been written about the importance of student-centered Active Learning pedagogies. Many archetypal examples of these pedagogies, such as Peer Instruction (Mazur, 1997; Crouch & Mazur, 2001; Fagen, Crouch & Mazur, 2002; Lasry, Mazur & Watkins, 2008) and SCALE-UP/TEAL (Beichner, 2000; Dori, Belcher *et al.*, 2003), have attracted much attention because they reform the pedagogy together with the introduction of novel educational technologies. The use of technologies such as wireless-remotes, colloquially called clickers, to collect real-time feedback from students has been instrumental in rendering Peer Instruction into a worldwide phenomenon. Similarly, the wide-scale adoption of SCALE-UP/TEAL implicitly resides in the central role of non-frontal classrooms equipped with computerized student pods and multiple active projection screens.

Indeed, instructors may feel attracted to the idea of using clickers in their classrooms or remodeling the classroom setting to give students access to computers and active projection screens dispersed in the classroom. In adopting these educational technologies, instructors may then be forced to rethink the content of their course and the pedagogy to fit with the novel educational technologies. Our findings suggest that adopting these technologies without rethinking the pedagogy is a bad idea. One should be particularly careful not to think that adopting clickers or placing computer-focused student pods with interactive whiteboards is sufficient to make a difference in student learning. Our results show that these educational technologies are best when used in the context of reformed student-centered Active-Learning pedagogies. This finding reiterates the notion that technology is not pedagogy (Lasry, 2008).

Does Student-Centered Active Learning works for all kinds of students?

Another interesting finding is that those who benefit most from Active Learning student-centered pedagogies are not the 'elite' high background knowledge students, such as Harvard and MIT students, but rather the students with lower prior knowledge. This contradicts the claims that these methods work mainly with high performing students in elite institutions. Our data shows that in our publicly funded institutions, student-centered Active Learning works best for students with lowest prior knowledge. Students with high prior-knowledge gain marginally more in Active Learning environments. The marginal increase in gain for these students may be due to the notion that many of these students may have mastered the lecture-format or found strategies for remaining active in teacher-centered traditional instruction settings.

The last set of findings leads us to consider what we might need to do for students with low prior knowledge. While new socio-technological environments seems synergistic as may provide a welcome setting that provides optimal stimulation for students with high prior knowledge they might offer too high a cognitive load for students with low prior knowledge. Thus it suggests that more work needs to be done to address cognitive load issues in Socio-technological environments. We look forward to the possibility of addressing these issues in a later study.

Conclusion

The study design shown in this chapter as well as the results displayed allow us to address the title question: Changing physical spaces and pedagogies, which is more important? Our findings show that pedagogy is paramount whereas physical setting is secondary. The greatest impact an instructor can have on student learning is adopting student-centered Active Learning pedagogies. Incurring the cost to remodel classroom settings to match Socio-technological environments is useful only if one simultaneously adopts student-centered pedagogies.

In the upcoming chapter we will continue to discuss the issue of what these new Socio-technological settings can provide for those taught with a student-centered active learning pedagogy. And later, we will discuss the impact these environments have on the instructors who come to teach in them.

CHAPTER 5

STUDENT PERCEPTIONS OF THEIR LEARNING EXPERIENCE

Recall that educational research shows that students' perception and effort are powerful mediators of learning (Astin, 1985; Pace, 1984; Pintrich, 1995; Schunk, 2001; Zimmerman, 2000). Thus, this part of the study examined what students perceived as important in their experiences as part of the Active Learning treatment groups and as part of the Comparison groups. The results are discussion in this chapter.

Research Question 1b

Do students in the different treatments have different perceptions about their learning experiences? If yes, do these different perceptions differentially influence their actions in regards to how they learn?

Methods

Participants – Question 1b

Participants as focus groups. From the participating cohorts, we recruited 34 students to take part in focus group interviews in the Fall 2010 (note that 5 were recruited in Winter 2010 to pilot the interview questions). Approximately half of the students were from the Active Learning treatment group, the other half made up of students from the classes of the other five teachers that took part in the classroom observations – we refer to these students as belong to the

Comparison[9] groups. These students were volunteers and were given chance to win a token gift in a drawing held at the end of the semester.

Context and Procedure – Question 1b

We conducted focus group sessions with students during their semester using a semi-structured interview format. In total there were ten interviews with a total of 34 students from both the AL treatment groups and the comparison groups. The average number per session was 4 students in the AL groups and 3.5 students in the comparison groups. The gender spread was near equal with 16 boys and 18 girls in total. The average length of interview was 42 minutes and produced an average of 30 pages of transcribed dialog. The total student interview corpus was 226 pages.

These interviews yielded a rich data source, which was then analyzed using a mix of qualitative analysis involving emergent coding techniques and discourse analysis to extract common themes and understandings. While the context was a focus group, the unit of analysis was one complete utterance or verbal contribution made by an individual student. For instance, if a student began a thought and continued the same thought after an overlapping comment by another individual it was considered "a contribution" and coded as such. These data were then categorized and tabulated.

The process began with the principal researcher using emergent coding methods to identify three major categories: (1) perception of authority structure; (2) perception of learning in physics – what we called "epistemic frames" and (3) affective influences mediating learning. The primary research assistant (Rater #1) was then asked to create a subset of the data based on all dialog that fit within all these identified categories. This data reduction was critical given the size of the corpus – approximately 20% of the corpus was kept. Once this reduced data set was created Rater #1 along with another research assistant (Rater #2) were trained on the coding key, which was developed by the principal researcher (Appendix G). The data were then separated along the lines of AL treatment and comparison groups. Acknowledging the possibility of basis,

[9] Note that because we viewed these five teachers as in transition when it comes to their pedagogical approaches we consider them the Comparison groups and not Traditional instruction as the comparison groups were called in the last chapter.

raters were given instructions to be conservative – i.e., err on the side of caution and not give unfair benefit to either group. Specifically, for the AL treatment, the raters would code an utterance as teacher-authority if there was doubt, and vice versa for the comparison group. These two raters coded the data independently. The inter-rater reliability was over 87%.

Results

The first category presented is that of "Student's Perceptions of the Authority Structure" within the classroom system. Figure 5.1 shows that neither the AL treatment nor the Comparison groups viewed their learning environment as dominated by teacher authority. However, the Comparison groups were approximately 4x more likely to talk about the role of the teacher in their learning. In other words, the Comparison groups perceived the teacher's role as providing notes and telling them how to organize the material. Note the quotes below showing excerpts from both groups coded as Teacher-authority.

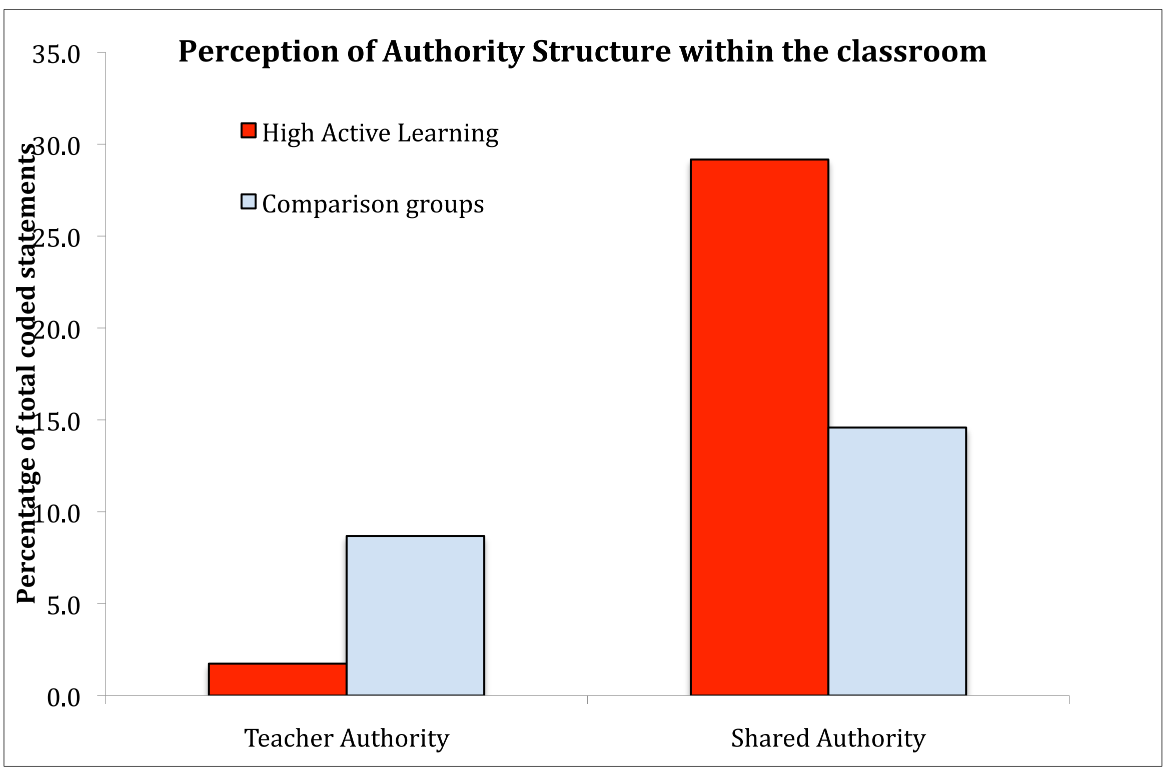

Figure 5.1. Perception of authority structure within the classroom described by the AL treatment and comparison groups.

Examples of Teacher-authority

Examples of what the Comparison students said coded under "Teacher-authority" are:

001. G1: for any kind of lecture I think it's better to be in a traditional classroom where you're like oriented front-wise versus, I mean facing the teacher and stuff, it's just I think it's easier.

002. G2: Like he writes it and we copy it.
003. B2: He writes it and we just copy it and he closes the thing… And he really like, he goes in an order that he knows is the right idea so he goes like from one step to the other.

004. B1: Yeah 'cause then you'd go in with the intention of like, "ok yeah, I'm here to take notes, I'm here to, you know, listen to the teacher, I'm here…"
005. B2: you're more, you're focused on like getting down the information

Examples of what the AL students said coded under "Teacher-authority" are:

006. G2: Yeah like if I just had the book, it probably wouldn't help me understand physics too much like I need someone to actually explain the book.
007. G1: No if I had, if he… I wouldn't read the book. If he didn't tell us to read it, I wouldn't actually read it.

008. G3: now it's just so complicated that I don't want to listen but [the teacher] explains it well so it's good. It's all good.

Even though these are both coded as Teacher-authority we can see in these brief examples some differences between the AL and Comparison groups. There is a sense of a linear or direct transmission of knowledge from the Comparison groups (line 002.G2 – he writes and we copy it). By comparison, there is a sense of a nonlinear or indirect and mediated transmission of knowledge in the AL groups. The students talk about the book being difficult and the teacher pushing them to read it (lines 006.G2 – I need someone to actually explain the book). Or, they recognize that the content is complicated and the teacher mediates between their confusion and their understanding (008.G3). We will return to this notion of mediation again.

Examples of Shared-authority

Meanwhile, when it came to Shared-authority category, those in the AL groups were twice as likely to talk about the role of others in their learning. The AL groups valued the opportunity for peer teaching and collaboration in the classroom. One student likened explaining physics to his peers as a means to achieving a stronger understanding of the concept. These collaborative strategies were seen as a chance to exchange ideas about physics and were helpful when combined with teacher explanations. Another student contrasted these active learning experiences with classes where talking was discouraged and especially enjoyed clicker-based activities that required group debate. Yet another student was able to recognize the wider effect of these classrooms when he noted the global applicability of building group interaction skills early on. AL students perceived themselves as responsible for participating. They recognize their role in their learning and the significance of constructing their own understanding (line 010.B2 – if you could explain physics, you understand physics).

Examples of what the AL students said coded under "Shared-Authority" are:

009. G1: I think that, that for physics [class] it requires an interaction … for physics [class] like, he gets our attention, we learn, and then we like break off into our groups and we discuss it.

010. B2: He also lets us teach each other instead of just having him teach us so like for the clickers uh, after we do it the first time he'll say like, "go ahead discuss it with your friends; try and convince them." So if you could explain physics, you understand physics.

011. B2: Usually most classes, you're not really supposed to talk to other people – you're supposed to listen. Here, you like, you have the freedom to talk about physics…

012. B1: Exchanging ideas. The ability of him to have the open floor to do little experiments because sometimes he explains something and you're a little confused and he shows you and you're like, "oh, that makes sense. I get it now." But mostly the ability to exchange ideas between people. Like sometimes in physics if you get too far behind it's kind of impossible to catch up so at least here if he's explaining something you can say, "oh what was that about? Okay I get it now." You can move on as opposed to just getting behind and having to catch up.

013. B3: Yeah it goes farther than just one sentence. You go back and forth. Not just to read their answer but think about it then you can widen your thinking… your thought process.

014. B3: It's annoying but you have to [read the textbook]. Like you have to, he [the teacher] makes sure that you read the book and you understand and you're up-to-date with what's going on in the class. I don't like the book that much. There's too many symbols and things but he always goes over it in class after so it's okay.

Meanwhile, for the Comparison groups they too had examples of recognizing their role in learning. However, note that they perceived this role more from the physical environment than they do from the pedagogy. In short, the classroom setting provided the unspoken permission to work with and help each other learn (line 017.G2 – it's not like you're in an isolated desk). But also note there is also a sense that the context has limitations (line 016.G1 – I don't really like the layout). We will elaborate a bit more on this idea later. Suffice to note for the moment that this comment suggests that this student's preference would be to be in a traditional space for lecture.

015. B1: when you're doing stuff like this, it's always good to do it with a partner. "Cause you can like fight about it or…" you know, see different ways to solve it because there's, in physics there isn't one set way to do it, there are other ways to arrive at the same answer. Maybe it's easier, maybe it's harder for you but it's good to know all those ways. So we did.

016. G1: The tables are round so you can speak to everyone but when we're not doing labs, I don't really like the layout.

017. G2: But we always sit with other people. So you're never really by yourself. It's not like you're in an isolated desk just doing your work and not talking to anyone… You can ask your neighbour for an answer or whatever.

018. B2: [the teacher] basically like during that classroom, [the teacher would] make us do group work to better understand the whole science way, way of working.

Epistemic Beliefs Category

Looking at the categories of student perception about learning physics – i.e., epistemic beliefs – we see equally big differences between the students taught with the AL pedagogies and the Comparison instructional methods (see Figure 5.2).

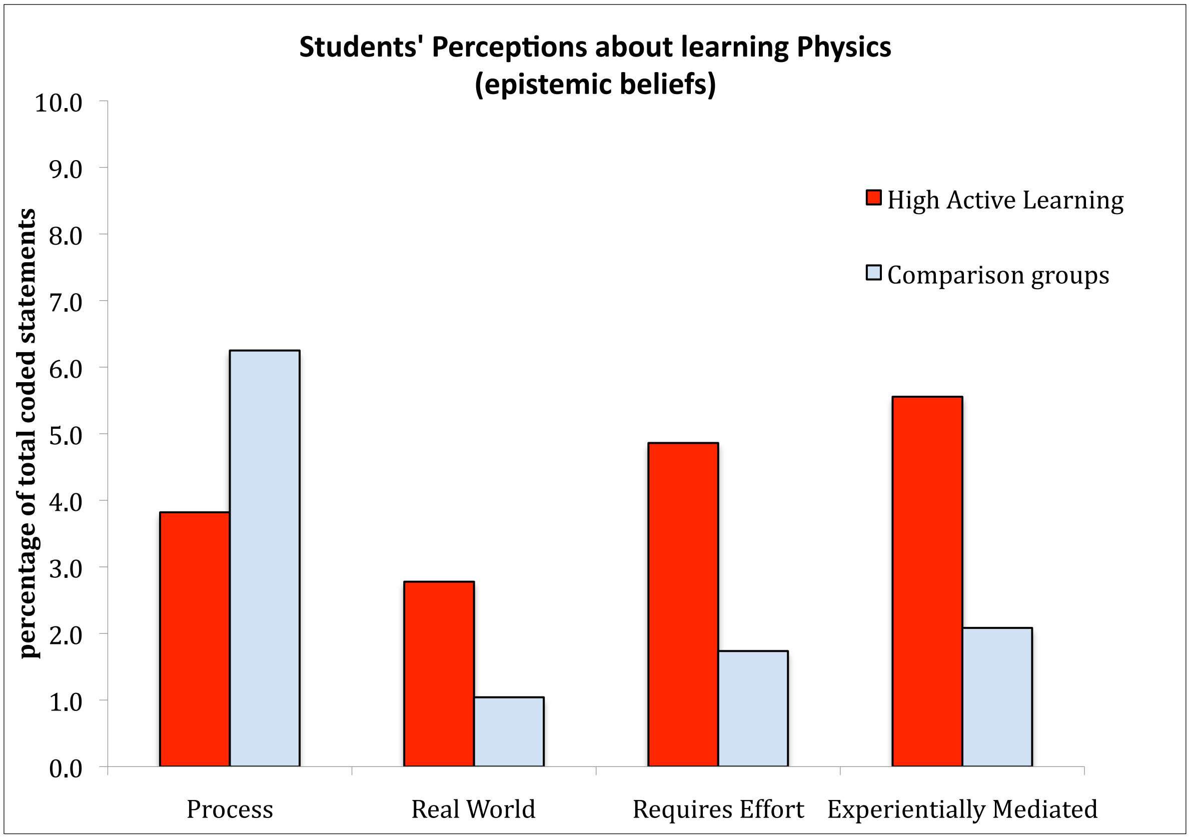

Figure 5.2. Students' perception about learning physics – epistemic beliefs – described by the AL treatment and comparison groups.

While the Figure 5.2 shows a difference between the AL and the Comparison groups on all accounts we will only focus on three factors in which the AL group rank higher than the Comparison groups because we are interested in looking at the impact of AL pedagogy.

Real world category

The real world category described the students' perceptions of physics as relevant to their lives outside the classroom. We only coded in this category if students were explicit about these experiences and spontaneously mentioned some event that triggered their thoughts or saw them using physics when not required to. This is a category that is identified in the CLASS and one we had hoped to capture by means of that instrument, but it was not possible[10].

10 The Colorado Learning Attitudes about Science Survey (CLASS) a 5 point Likert scale to measure aspects of students' attitudes and beliefs about learning physics. Developed at the University of Colorado, Boulder, this instrument builds on existing surveys. It is based on the notion that experts and novices differ in their attitudes and beliefs about science. The CLASS has particularly good results and the team in Colorado is continuing to improve

Examples of what the AL students said coded under "Real World" are:

019. B3: Yeah, every time I go on a bus and it goes around a curve, I'll be like, "oh I have acceleration that way." But for some reason I'm going that way.

020. B2: Like last week, um like it was a couple of days after we watched like the Star Wars or whatever that he was talking about the spaceship. So I was watching the new Star Trek movie with my little brother and I'm like explaining to him, I'm like, "you see there, those spaceships would never work in space… (laughter). Because that's what he was explaining to us. My brother's like, "how?" And I'm like explaining it to him then I'm like, "ha." It definitely like sinks in.

Requires Effort category

The category of "Requires Effort" was identified because of the frequency with which students in the AL group remarked on the fact that learning physics required them to work. We note that this harkened back to the literature that tells us that being motivated to apply effort was a critical part of learning. We propose that the first part of this process is the recognition that learning requires effort and then the feedback loop established within the classroom system encourages the continued effort leading to deeper learning. From the students' comments below we see that they recognize this effort and remark on aspects of the designed activities that require them to put out greater effort. What is worth noting is that they see the benefit of their effort, which suggests the culture of the classroom is such that effort is rewarded.

021. G1: You got to do the effort. You got to put in the effort and do the questions and do your homework and stuff.

022. G2: And you have to… yeah you have to really work hard and uh, you have to try and keep yourself motivated too, if there's something you don't like you may not, you know the teacher may not be able to make you like it, may not be able to make you, to keep you motivated. There's… you have to keep yourself um into it as much as the teacher does, you know. And you have to give back it's not just the

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the reliability and validity of the questions (Adams, Perkins, Dubson, Finkelstein & Wieman, 2004). Two of the factors measured by the CLASS are Real World Connections and Personal Interest.
While we administered the CLASS to the students in F10 data collection, it was only used as a posttest and showed no significant differences between groups, except for one item (#7) which is one of four items that measure Real World Connection. We choose not to report on the CLASS because this result is not stable and does not contribute to our understanding of the research questions.

teacher kind of going like, “learn this, learn this, like you have to do this.” You actually have to do the work and, and, and try to understand it as best you can using also the teacher’s help.

023. G1: Yeah, one time we had a Mastering Physics assignment and [name removed] invited us to her house and we had a great dinner together and we did Mastering Physics together. It was really good and like, from now on whenever we do Mastering Physics we’re like saying, “okay, we’ll all get together and work on it...

024. B1:... when it gets to the point of where I’m actually learning something new then it would be helpful to know what I don’t know. If that makes sense.

025. G3: [the reflective writing] forces you to come prepared to class. So you don’t waste time, kind of, trying to understand like dumb things.
G5: Yeah, you’re not sitting in class being like what? I don’t understand, I don’t understand, because you’ve read it once and you’re like now it’s sinking in…

Learning as experientially mediated

Lastly, in the category of learning as experientially mediated we see that many of the students’ comments focused on the interventions used in the classroom that were facilitated by the both the physical setting as well as the easy access to technology. Kolb and Kolb (2005) remind us that learning is experiential. From the data we collected we would also conclude that these students valued these experiences as an important part of their learning physics.

026. G1: Uh, I also agree. I find doing lectures, like when he explains a new topic and then explains it doing an actual example, not like a theory example, like showing it in real life like with the hockey puck or what he did today with sliding it down the table, by physically showing us what he just said. So it helps me visualize it and it makes me understand physics better.

027. G1: For me, uh, he did the example. Like he made us all stand up and stand in a circle and then he made us push him and I found that helped me understand, cause that, like your concepts of the way the world works is like so ingrained that, like when you learn something new like circular motion’s always inwards, it’s hard to change it. But, by him like showing us proof, then you could accept it.

028. B1: Uh yeah, the representation of the theoretical he’s trying to prove. I mean, those are just numbers right. I mean I can learn from that but I find it makes it an easier transition to fully understand the topic or the theme we’re doing when he does a real life experiment, with the friction, with the puck, with the uh, the carts. It’s… just keep those up.

Perception of teacher category

Recall that perceptions of learning can include beliefs about teacher support and feedback from peers (Zimmerman, 1989). Additionally, overall ratings of teaching effectiveness can determine how much effort students are willing to put out (Ryan & Harrison, 1995; Cashin & Downey, 1992; 1999). What this category shows is in this particular AL group the perception of the teacher's efforts and support was high. In fact, in Figure 5.3 we see there were twice as many mentions of this factor in the AL group compared to the Comparison group. Additionally, there were more comments like the ones following that directly express students' sense of knowing that the teacher cared about their learning and wanted them to understand. They expressed the importance of having a passionate teacher who follows up with students and cares about their success on a personal and academic level. They recognized the effort put into demonstrations and appreciated the effect that these demonstrations had on their learning. They noted that the demonstrations helped make the material more visual and that they had a pedagogical purpose other than entertainment. The students also enjoyed when the teacher was able to break the class into various segments to keep the material interesting.

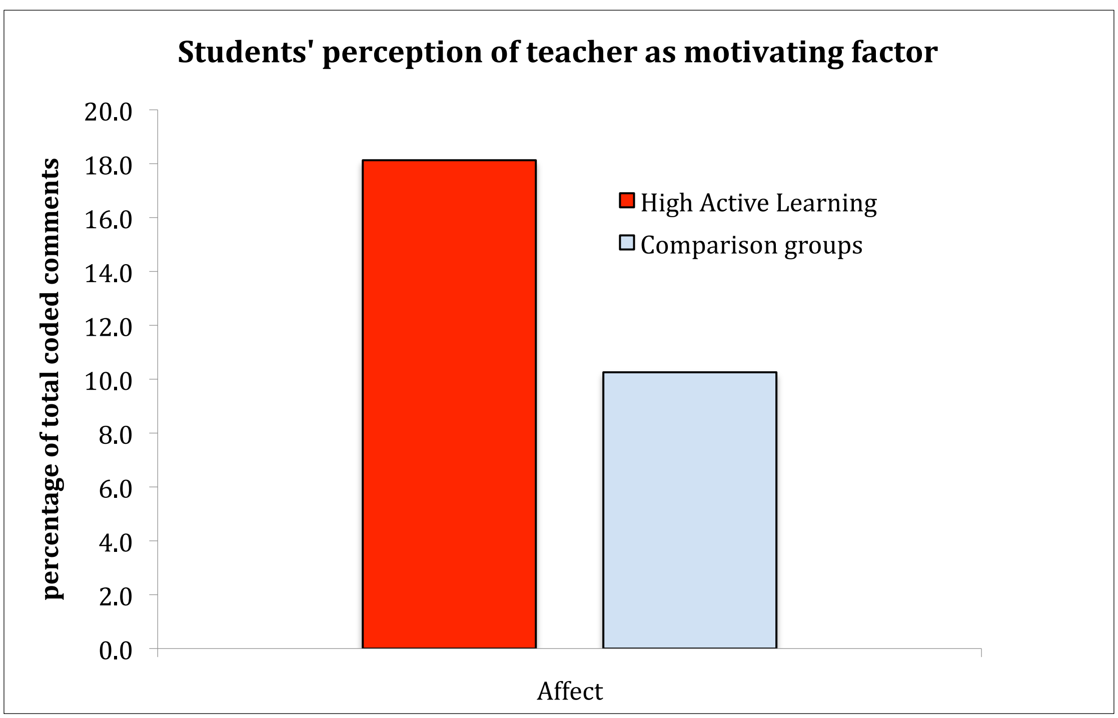

Figure 5.3. Students' perception of teacher as motivating factor.

Quotes from the students' perception of teacher as motivating factor category

029. G2: Um, one of the things I remembered that actually interested me enough to go talk to all my friends about it, which I don't normally do with physics is he was talking about sort of how we jump through space, it wasn't really, it's not like um part of the actual course, he was just going on about it, um…

030. B1: Uh, in this class, you're a name and not just like a student. Like I'm "[name remove]" in this class, he calls me by my name like it's… he cares whether I pass or fail which I feel is different from some of my other courses where I'm… they might care but they don't really, it doesn't matter to them a lot. It's just, "okay, this kid tries hard.. okay, he gets the pass" and [the teacher] wants us to succeed as students. He doesn't do all these examples in different ways and use all this technology because… just for fun… I mean it is fun but he does it so we can learn better, learn more and that's, that's great. And it, it uh, it helps me to learn a lot, so. In that way, it's very different that he cares whether we pass or fail and that's important to me.

031. G1: Um, well, I like the environment in this classroom because, I don't know. [this teacher] gets excited about what he's teaching and I find it's very important to have a teacher who's interested in what they're teaching because it really makes a difference on your understanding. [in other classes the teacher], just reads from like the textbook. And it's just, you don't learn the same and it's boring. I don't know. And here, like he cares about if we understand it. It makes a difference. And like I think we have a good classroom. Everyone's willing to help you and…

032. G4: Most teachers don't bother to learn your name because there are so many students here and they can't but [this teacher] seems like he really cares about, like, if you learn, and if you understand.
G5: If they care if you're learning, that's how we're going to learn.
G1: Exactly.
G5: If they don't care and you just sit… let's say you have a seat in the back and they don't care about you because you're sitting in the back and, apparently, sitting in the back means you don't care [meant with sarcasm] then all of a sudden, it's just like, okay well, I don't need to do anything for you. With [this teacher], he cares that you do well as an individual. That you do well and succeed for yourself. So, he wants you to improve. It's like the best feeling.

033. B3: He also wants us to get like a good understanding of physics not just like the course material. Like he'll bring things that aren't involved in the course. Like he showed us, what was it, that gravity thing like the Sun and the Earth going around it and how space works. He wants us to understand stuff outside of the classroom.

Discussion

An important factor in designing student-centered active learning is the notion of sharing authority with students. What our data shows is that students taught with an AL pedagogy understood this shift in the locus of control. More importantly, they recognized that they and their peers had a role to play in the system of the classroom and were willing to take up the responsible when supported by the curriculum and the appropriate implementation of the pedagogy. This is consistent with Azevedo (2005), Charles & Kolodner (in progress) and others who show students in student-centred active learning environments developing a sense of self-regulation and "agency" – i.e., characterized as the willingness to act and participate.

Additionally, we see that the AL students perception of learning, what we called their epistemic beliefs, included notions of effort and extending learning outside the class to the real world. Vansteenkiste, Simons, Lens, Sheldon and Deci, (2004) have shown that such motivation to learn rises with higher perceptions of an autonomous and supportive learning environment.

Note too that the students in the AL treatment groups continued to value the teacher and the many roles he played in guiding them through this new landscape. Clearly, the teacher's role is not diminished as authority is shared with the student. In fact, we will show in the next chapter how the teacher role is shifted to one of designing and orchestrating new activities.

CHAPTER 6

DEVELOPMENT OF A STUDENT-CENTERED ACTIVE PEDAGOGY TEACHER

While Active Learning is generally characterized as "student-centered" it is far from being "teacher-less." In fact, we argue that by reframing the teacher's role the work involved is different and equal to, and at times more than, for traditional pedagogies. For instance, in this approach the teacher is expected to make visible the thinking involved in solving complex and challenging problems. This might be accomplished through modeling of such processes and/or designing reflective activities, often involving the use of technology that can amplify these efforts. Furthermore, teachers are required to design opportunities for learning that involve student participation and use of the domain tools and artifacts (e.g., investigating the evidence of a car accident and determining the cause based on the physics). All along, teachers are responsible for coaching and supporting students in their efforts to accomplish the task at hand. The very nature of the activities and challenges selected and designed for active learning pedagogies generally require learners to go beyond mere comprehension and involve them in analysis, synthesis and evaluation leading to the generation of richer individual and collective understanding. To accomplish these high goals activities are generally designed to be iterative with many opportunities for formative assessment and with multiple feedback cycles. This means that the teacher must find a way to give timely and frequent feedback at the individual student, the small group and the whole class levels.

In this chapter we report on a case study narrative that describes the making of our model teacher. We describe the process through which this teacher came to use and improve his practices. Later in Chapter 6 we will move on to discuss how other teachers taking part in the study began to use some of these methods and describe what factors facilitated or constrained their development. Note that our characterization of active learning teacher is based upon the activities and teaching of this individual.

Method

Sample

The teacher selected for this case study has been teaching physics for 11 years. His academic background includes a Bachelors and Masters of Engineering Physics. Interestingly, he also has a Master's degree in Social Work. At the start of this study he had already had three years of using active learning techniques, thus we observed him during his fourth year of practice with this approach.

Data collection

The case study is comprised of multiple data sources that include the following: (1) classroom observations that span 10 weeks in the fall 2010 semester and include the two sections taught by this teacher; (2) post-observation notes and debriefing; (3) teacher reflective curriculum planning notes; (4) post-semester semi-structured interview.

Case Study Narrative

We began the observation of Chris in the fall 2010. At this point he had been using an active learning approach to his teaching for over two years. Even before the start of the term Chris began to prepare and organize his course curriculum and associated activities in the summer that preceded the data collection. In doing so, he met with both the principal researcher and the post-doctoral research assistant to ensure his understanding of what activities could be used and determine the possible impact of these activities on student engagement with content and with each other. Interestingly, Chris was aware of factors such as maintaining the cognitive engagement of his students and wanted to address this in the activities that he planned for the fall. In the end, Chris selected several of his tried and true activities that included Peer-to-Peer Instruction and Reflective Writing. He had used both activities in his previous teaching of the NYA course in the fall of 2008. To these he added several new activities including two that featured more ways for students to take on a sense of responsibility and accountability for their learning. Specifically, he designed two jig-saw activities that required students to experiment, collect data, synthesize the information and then find ways to share that information with their peers. Each group was encouraged to do their best to both understand their activity as well as to share this knowledge because everyone would be tested on all components of the global activity.

Table 6.1. Summary of Chris' active teaching components for physics NYA, Fall 2010.

Activity type	Characterization of active component	Student engagement
Reflective writing	• Students are assigned readings from the text book and asked to write a couple of sentences about questions and other thoughts that comes into their minds regarding the content. See Kalman et al (2008) for more details. • Based on Kalman, Aulls, Godley & Rohar (2008)	• Reflection = individual • Write questions on board • Questions form basis of class discussions
Clicker/Peer-to-Peer (P2P)	• Students reflect individually on a short MC question (typically it's a concept question), vote on the answer, then based on class voting results, they discuss the question in small groups before re-voting. • Based on Mazur (1997).	• Reflection = indiv. • Discussion = groups 3-4 • Re-vote = indiv.
Interactive Lecture Demo (ILD)	• An experiment or demonstration is described to students who are asked to write down their prediction (sometimes on a prepared sheet) of what will happen. The exp/demo is then run and students follow-up with a discussion (class or small group) and/or are asked to write down the result and an explanation of why it happened and how it met/differed from their prediction. • Based on Sokoloff, Thornton & Laws (1997).	• Description = indiv. Or group of 2. • Discussion = groups of 2 or 4. • Explanation = indiv.
*** VoiceThreads (VT)	• Students use VoiceThreads (www.voicethreads.com) to view and comment on videos, images or documents posted on the web. Students record their comments by webcam, voice-recording or text and they can see and comment on the comments made by others.	• Comments = indiv. • Groups of 4 • Whole class presentation
Problem Based Lab (PBL)	• Students are asked to solve open-ended problems that involve data collection and analysis. They work in small groups and are given a framework that guides them in their approach - but they receive minimal specifics on how to carry out the data	• Groups of 2, 3 or 4.

	collection and analysis. In many cases, students are assigned specific roles within the group (ex. Recorder, skeptic etc.) Based on Hmelo-Silver & Barrows (2006)	
*** Lab activity (LA)	• Students are asked to explore a physical concept by collecting some data and doing basic analysis. The analysis is completed during the lab/class period and a very brief report is submitted before they leave. (Note: unlike a full lab experiment, the data and analysis required to complete the activity is not complicated.) • This activity sometimes used a *Jig-Saw* approach where each student group will have a different problem then each group will be responsible for teaching the other group.	Groups of 2, 3 or 4.
Group Discussions (GD)	• Students will be asked to engage in group discussions on complex conceptual topics (for example: friction models). These discussions will occur in both face-to-face mode or in a virtual mode using FirstClass. Groups submit a final statement summarizing the result of their discussion. (Note: there may be overlap here with Voicethreads activities.)	Depends on format: • Face-to-face = groups of 3-4 • FirstClass = groups of 10-12.
*** Worksheets (WkSht)	• Individual students are given worksheets to complete during class (or as homework if they don't have enough time in class) and they are encouraged to help each other. • Practice of simple decontextualized fundamental component skills. • Several times throughout the semester • Worksheets usually taken from *Student Workbook – with Modern Physics*, by Randall D. Knight (2nd ed.)	• Individual with support from group of 3-4.

Chris engaged in reflective practices. He maintained a reflective journal as part of his course planning. This is consistent with Schön's (1983) notion of the reflective practitioner – "the capacity to reflect on action so as to engage in a process of continuous learning [is] one of the defining characteristics of professional practice." He recorded what was done in each session and added general comments to note how it went and improvements for the following semester.

These reflections were focused on time management and curriculum, technology use and classroom setting, as well as the feelings he perceived from his students during the term. What is highly featured in his writing is the constant concern for his students and their learning processes. He also continually reviewed his role as a teacher and how to improve is teaching. He valued the use of active learning within his course and continued to raise questions that challenged himself to learn more about this approach. See Appendix E for excerpts.

<u>Interviewing Chris</u>. When asked about his beliefs about learning Chris stated that it was "the building of an understanding um so you create, you build, you construct a framework in your mind. That deals with the subject at hand, allows you to manipulate the subject and solve problems." This way of thinking was a change from his original conceptions of learning. He states that when he was first hired he thought of learning a related to listening rather than constructing knowledge. He describes his own school experiences as consisting of learning outside the classroom.

> I mean, as soon as I think back to [my own experiences as a student], all the learning that I did was outside of the classroom … It was almost like class was really for keeping you up to speed. Telling you what you really had to focus on and what you didn't have to focus on so it was really like a just narrowing down things and then you went home and you actually learned it.

He ended this reflection on his own learning with the optimism that his teaching was changing, particularly when considering the work he was doing to improve the experience for his own students. Making their learning experience more about participating and having their learning happen in the classroom not waiting until they were alone at home.

Reflecting on what ignited his interest in changing his pedagogical approach he talked about several key experiences. One such experience occurred when he was a member of a hiring committee for new physics teachers. When the candidate was asked to justify his lecture-based teaching style and he answered that it had worked for him when he was a student. However, when pressed, the candidate was visibly flustered when it was pointed out that most of his students wouldn't be like him (not a physics major) and when he was challenged, as a scientist, to provide any objective data that lectures actually worked. These questions still reverberated in Chris' mind when other opportunities to become aware of other teaching practices presented themselves. One opportunity was an introduction to the book *Five Easy Lessons: Strategies for successful physics teaching*, written by Randall Knight. This book is based on physics education research. The other opportunity was hearing a talk by Eric Mazur, a physics professor from Harvard University who had created a new approach to improve the effectiveness of his teaching called Peer Instruction (an approach described earlier in this report). Both events have a common denominator. They both involve lessons learned from research interested in understanding how to improve learning rather than improving teaching.

Chris has spent countless hours thinking about and designing new ways of getting his students to interact in meaningful ways. He sees his role as the catalyst to simulate discussion and thinking. As such he is concerned with designing opportunities and situations that will encourage his students to discover what is unclear, question their understanding, and work together with others to build agreement on the meaning of usefulness of the content. This process started in 2006 when he began to use peer instruction. Since then he has developed several activities including his version of peer instruction. For this activity he has worked on a bank of concept test questions and continues to learn how to build better ones. Of late he has begun to consider not only the common problems facing learners – confusion caused by misconception of physics concepts – but now also is thinking of problems related to their inability to distinguish common deep structures between contexts. To this end he has been adapting his orchestration of the peer instruction activity to include a series of questions that reveal nagging misconceptions that often lag behind even when students seem to be getting the lesson. He describes this orchestration as follows:

> A lot of the questions that I ask in the peer-to-peer stuff build one on the other so there might be a more straightforward question and then a more difficult question… If [the students have] progressed towards the right answer [in the first question] … then I give them a second question, that's the same sort of topic, same subject maybe, different surface features or modified slightly um, if in the first vote they don't get it, then that gives me an idea that they really didn't make much progress towards understanding even if they got the right answer [with] the second vote on the previous question.

Furthermore, he uses the reflective writing and Mastering Physics exercises to get students prepared for class. He doesn't believe his class time should be spent giving them material they can read on their own. He wants his students to spend their class time going deeper into the material and applying it while he is there to help. He states: "So I spend a lot less time covering the material [because] I get them to do that on their own. My job is then to dig deeper: 'Okay, so you read that last night, now what do you think THIS means, how do you think it applies HERE?'" The implication of such classroom practices for students is that they must learn to come to class prepared to take action. They must do their readings, and they must start thinking about what they understand and don't understand. Additionally, they soon recognize that they don't come to class to sleep, instead they come to work. These may seem like normal expectations but they establish two important practices: one of employing reflective and metacognitive processes that are important for learning – reflecting on what you know and what you do not know, and; full class participation in many of these active tasks which models the types of regulatory skills necessary for improved use of cognitive strategies resulting in deeper learning.

In addition to this attention to the design and orchestration of his class activities is the change made in attending to the feedback from and feedback to students. In terms of feedback to students he works hard to ensure a timely turn around on the reflective writing assignments, quizzes, lab assignments and tests. And seldom keeps them waiting longer than a week between quizzes and tests. Additionally, he maintains constant contact by postings on the First Class conferencing server, which forms an important part of his course space. In fact, his students comment that they can always reach him by email and his web presence allows them to form a sense of online identity. While the students form the fall 2010 have used the online postings of course notes, questions, etc. Students from the fall 2008 developed a strong sense of community partly based on their frequent online presence in response to Chris' comments and questions.

In terms of feedback from his students, he describes how his thinking has changed. He no longer is satisfied with visual signs of understanding but looks at the ways they participate and the types of conversations they are able to produce. And, he finds many more opportunities to formatively assess learning – e.g., clicker questions, mini-worksheets (individual and group), questions that arise during interactive demos. When asked about what signs he looks for as evidence of his students' understanding he stated that in the past he would be satisfied with students "nodding their heads" then he states "now that means almost nothing." Instead he is interested in more robust signs of understanding:

> I don't think that because they've got the question right they've got everything right about it, or that's it's all that well cemented in their mind. [You have to remember] that students can hold multiple conceptual understandings in their minds at once… [what] I'm looking for [as evidence of understanding] are the little steps in the right direction. And, I think that gets reinforced later on. For example, on tests I look at their qualitative answers, and look to see if they are describing, explaining things well? When they hand in their reflective writing, I look to see if the reflective writing is maturing? Is it showing an understanding of things that they've learned in the past?

As part of changing his pedagogical approach is his changing sensitivity to the classroom environment and the ways his students interact. Particularly he talks about the difference between his old ways of having been satisfied with one or two students asking questions when asked the class "does anybody have any questions?" Now he requires the feedback that comes from seeing and hearing all his students engaged in the assigned activity, whether it is the discussion resulting from the re-voting on a concept test question or the generation of questions brought on by the reflective writing assignment. What he now values is the noise and the evidence of "minds on" participation that comes when all students have some sense of agency within his classroom.

> Now when I say discuss the questions it's an eruption of noise. It's completely different. Or when I get them to do an activity it's not like you have to encourage them to actually do it. They just go right in. In fact it's hard to stop them. The problem now is that once they get going they don't want to stop. Um so, so yeah there's been a complete difference.

Additionally, Chris talked about the importance of the feedback he gets from the reflective writing exercise. He remarked that he would never have gotten the types of questions and the sense of where his students were coming from if he hadn't used this technique. In fact, they now come to class prepared with questions that they identified from their the readings. And, as part of his orchestration of the classroom he often has students start the class by writing on the board all of these questions that arose from the readings. It's a great way to get their attention and to make them feel that the teacher really cares about them understanding the material.

> [Students] asking better questions now. We build a list of things that they didn't understand from the readings [done the night before class]. And we discuss these during class. Yeah, I don't think I would have ever gotten that kind of feedback before. Probably 'cause most of them wouldn't have read it anyway, you know, so they couldn't ask good questions. So yeah, I'm definitely noticing a difference.

He has become "hypersensitive" to feedback from his students and noticing when and how they are attending. The design of the new labs has made this noticing easier. Chris has used them in such a way as to keep his students close to him but also close to each other. In fact one of his students remarked that they hadn't noticed there were so many people in their class because they always felt it was just their group around the pod and the teacher.

Additionally, Chris has used the space and ability to move around in this new environment to try out more demonstrations and immediate responses to student's questions or queries. This is often referred to as "just in time teaching." Often his class sessions included a spontaneous, or seemingly spontaneous, experiment to provide students with a way to visualize what they were learning or to provide evidence to support a theory being discussed. On of the most notable occasions was his demonstration of projectile (i.e., a ball bearing) being shot at different angles to demonstrate the question. The students were glued to the scene but not because of the demonstration alone, but because Chris had used a particular method of interactive demonstrations which asks for predictions to be made prior to the demonstration and conflicting explanations to be investigated after. On this occasion the majority of students predicted incorrectly and the discussion that followed the demonstration was rich and productive. When students were given a similar question on the final exam the majority got it right. By the way, this is not the norm for classroom demonstrations.

About his vision for the future, Chris is actively working on extending this model of pedagogy to his physics colleagues and the model of classroom to others at the College. He has been working on developing a community of practice (COP) amongst his colleagues. The COP was an informal group of teachers who got together on a regular basis to share resources, ideas and anecdotes about what they were trying in the new labs. The meetings of this Community of Practice were open to anyone who wanted to attend and they were generally held on Fridays over the lunch period. Sometimes there was a formal discussion topic or a guest speaker and sometimes it was just a time to have lunch together and talk. Some of the highlights included the following:

- Report and discussion session: discussion on the activities and efforts different teachers tried and some specifics on a lab activity being worked on by two faculty members.
- Discussion session: discussion on the formation of groups and how to optimize groups, as well as the use of online resources that might be useful on SmartBoards.
- Seminar session: reading of two assigned research paper and group discussion. Readings: (1) Reay, Bao, Li, Warnakulasooriya, and Baugh (2005). Toward the effective use of voting machines in physics lectures. *American Journal of Physics*, 72 (6), 554-558. (2) Ding, Reay, Lee, and Lei Bao (2009). Are we asking the right questions? Validating clicker question sequences by student interviews. *American Journal of Physics*, 77 (7), 643.
- Guest presentation: presentation by Nathaniel Lasry showing the group the online active learning resources he has used as well as other resources.
- Discussion session: discussion on the research of Sokoloff and Thornton on Interactive Lecture Demonstrations (ILD's) and the steps needed so that a demonstration goes from something a student observes to something a student actively becomes engaged in. We also discussed a specific activity aimed at helping students understand the friction model and an activity that was being developed by the physics faculty tried with regards to projectile motion.
- Active demonstration session: review of a friction activity prepared by one of the physics faculty.
- Presentation session: presentation and discussion on the DALITE activity being developed through our research project with the Ontario Institute for Studies in Education (OISE). The general feedback was very positive.

Summary

Chris' journey to becoming a student-centered active pedagogy teacher was an interesting and enjoyable one. The practices he developed along the way continue to grow as he continues to be a reflective practitioner. In the chapter 9 we will describe some of the guidelines extracted from his practice and which may help others on their journeys.

CHAPTER 7

HOW DOES TEACHING APPROACH IMPACT LEARNING

Throughout the two years of the study the research team actively worked with members of the physics faculty to support other teachers who wished to adopt an active learning pedagogy. This process, as we will discuss later, is not a linear one. What is worth noting at this time is that the teachers who allowed us to collect data from their classroom can all be described as lying somewhere on a continuum of student-centeredness.

Research Question

How does teacher-centeredness versus student-centeredness impact student learning?

Methods

Sample

Six teachers were recruited to participate in the active learning study conducted in fall 2010. These teacher participants were all volunteers. All teachers taught the physics NYA course, some taught two sections. All the sections observed were scheduled into the new Soc-Tech lab facilities. All the teachers of these sections could be described as attempting to implement some form of active learning in their classrooms. However, most teachers were not actively taking part in formal pedagogical development toward these ends.

The six teachers who were part of the teacher classroom observations were also involved in this part of the data collection. Recall that the teachers ranged in their years of teaching experience and academic backgrounds. Generally, they fell into two categories: (1) those with 10 or more years of experience (most experienced had15 years of service); and (2) those with less than 4 years of experience, the average being 3 years of service. Their academic backgrounds also fell into two categories: (1) theoretical physics doctoral or masters degrees; and (2) Master's in Engineering degrees. The sample was heavily skewed when related to gender, with the majority being male teachers.

Instruments

Approaches to Learning Inventory (ATI)

The Approaches to Teaching Inventory (ATI) consists of two scales: (1) the conceptual change/student-focused (CCSF); and (2) information transmission/ teacher –focused (ITTF). See chapter 3 for full details.

Data collection and development of observational protocol

The data collected for this study were generated from observations of 7 sections of physics NYA, in the fall semester of 2010. Observations were carried out by two members of the research team. Reliability and consistency of coding was established between the observers was established through a process of joint observations, post-observation discussions and coming to consensus on the protocol and how to apply the codes. Inter-rater reliability on the training portion of the coding schema was 87% (based on the two raters coding of 25% the data). The major portion of the data used in the final analysis was collected after this training process.

Each course section was observed an average of three times, in the Soc-Tech classroom. A total of 42 observations were made from the seven sections, however, only 22 were used in the comparisons. Generally, these observations were made when the teacher informed the researcher that they would be holding sessions focused on presentation of content. Sometimes, however, sessions turned out to be more focused on lab work. These observations were not included in the data analysis. While the main treatment groups were observed for over 12 sessions each only those sessions that related to the same time period and similar content were included in the comparison analysis. Once all classes were observed and coded, the codes were compiled into a data set. This data set contained a total of 39 classroom observations (see Table 7.1).

Table 7.1. Summary of classroom observations for fall 2010 NYA sections.

	Sections represented	Observations	Average length
Treatment (high AL) sections	2	24 observations	80 minutes
Other sections	5	15 observations	80 minutes
Totals	7	39 observations	

The time frame for coding the start and stop of events was captured within five-minute intervals - the average class was 90 minutes making for an average of 16 time intervals. The decision to use five minutes instead of a small interval (e.g., used a one minute interval) was based on the fact that the teachers in higher education spend longer time periods in a single activity. Every shift in activity was coded within the five-minute period, therefore the total number of events could equal more than the 16 time blocks. Similar to Stapleton et al., we defined a change in activity as a point at which the teacher and/or the students changed their focus of attention.

As with Stapleton et al., generally, two or three indicators (signals) were coded simultaneously within a time interval. For example, we coded what the teacher was doing and how the students were responding. Therefore if the teacher was lecturing we would indicate "Lecture" and look simultaneously to see whether the students were "Attending/Listening" or "Asking Questions" or "Off task/Sleeping" and so on. Additionally, if the teacher or students changed their activity during the 5-minute time block, that change was noted as an additional code. Consequently, it was possible to determine the type of engagement within a class from the number of codes used as well as the quantity of each code – quality and quantity variations. Within the 39 observations there were an average of 71.7 discrete activities/events per observation (SD=15.0; Mode=78); providing a total of 1649 discrete coded activities.

Procedure and Reliability

Two researchers collected the classroom observation data. They used the observation data capture instrument. They would capture the general classroom layout data within the first few minutes of the class (page one of the instrument). They would then turn to the time stamp log entries and enter both the in situ coding of the events as well as a narrative commentary of the events. Additionally, any questions or comments about the class were added into the assigned boxes for follow up with the teacher, or for the research team. After class the research took a few minutes to talk briefly with the teacher. This debriefing was for the benefit of both the researcher and the teacher, particularly with regard to the AL teacher. Because of the action research approach these debriefing sessions were particularly important for the AL teacher as it provided an opportunity for the researcher to provide feedback on how successful the activity was in providing students with opportunities for engagement and/or whether or not these opportunities were recognized and acted upon by the students.

Reliability between coders and development of the coding rubric was obtained using several methods. First both coders attended several of the same classes and separately coded their observations. After these sessions they discussed their differences and came to consensus on the meaning of the codes (refining the code key) and/or added or deleted certain codes (modifying the code list). After each coding session the researchers met to discuss any issues that may have arisen during the class observation. At that point they discussed the coding and worked to improve the reliability between coders. Once the coding list and coding key were stable it was used for the rest of the observations. Note that while both coders overlapped on approximately 15% of the observations, one coder subsequently collected the majority of the observations using the agreed upon coding rubric.

We used the results of our ethnographic study – coded classroom observations (process described above) – to classify teachers. The ATI was used to confirm the classification taking into account the limited application of the instrument (i.e., teacher approach within the context of their NYA courses). See chapter 3 for further details on this limitation.

Results

We began our analyses to answer the research question by looking at how the classroom observations ranked the six teachers participating in this study. Starting with the degree to which the percentage of the events coded on the classroom observation protocol fell within the activities categorized as student-centered - i.e., group activities, interactive events that engaged the entire class, etc.

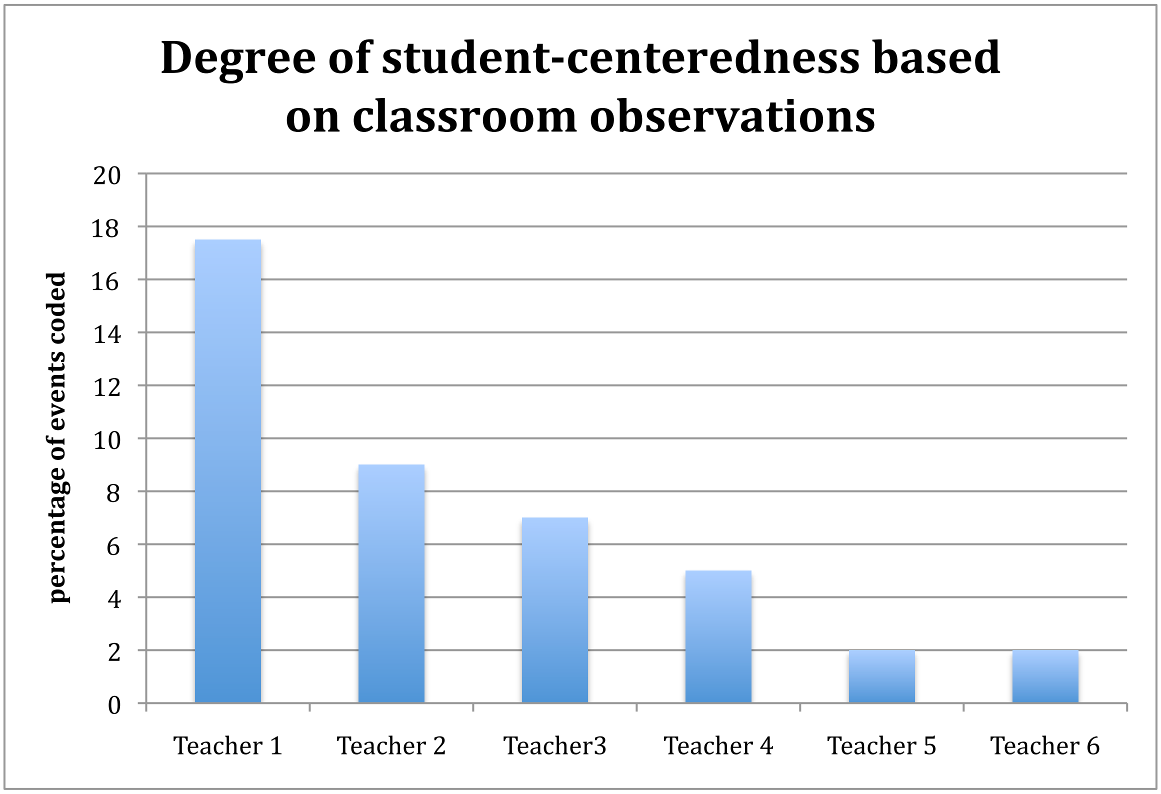

Figure 7.1. Teachers categorized based on their percentage of student-centered activities.

From Figure 7.1 we see a clear pattern of decreasing use of active learning pedagogy across the six teachers, with teacher 1 on the high side and teachers 5 and 6 on the low. While teachers 2, 3 and 4 show signs of moderate student-centeredness there are still differences between teacher 2 and teacher 4, thereby making it difficult to categorize teacher 2. Still it is reasonable to create three categories to describe the use of active learning pedagogy: Teacher 1 as high active learning; teachers 2, 3 and 4 as medium active learning; and teachers 5 and 6 as low active learning.

Next we looked at the percentage of time the six teachers spend on teacher-centered activities – i.e., lectures, Inquiry Response Evaluation (IRE, Mehan, 1979) protocols, etc. This protocol describes teacher-led questioning with an identified protocol. It is often thought of as a quintessential description of teacher-centered teaching and includes the following steps: (1) the teacher asks her/his students a question that s/he knows the answer to (the Inquiry); (2) the student either is nominated/selected to answer or self-nominates/selects to answer the question (the Response); (3) the teacher then evaluates the correctness/accuracy of the answer, commending the student or correct the student in the process (the Evaluation). Sometimes there is a follow up step involving further elaboration of the answer.

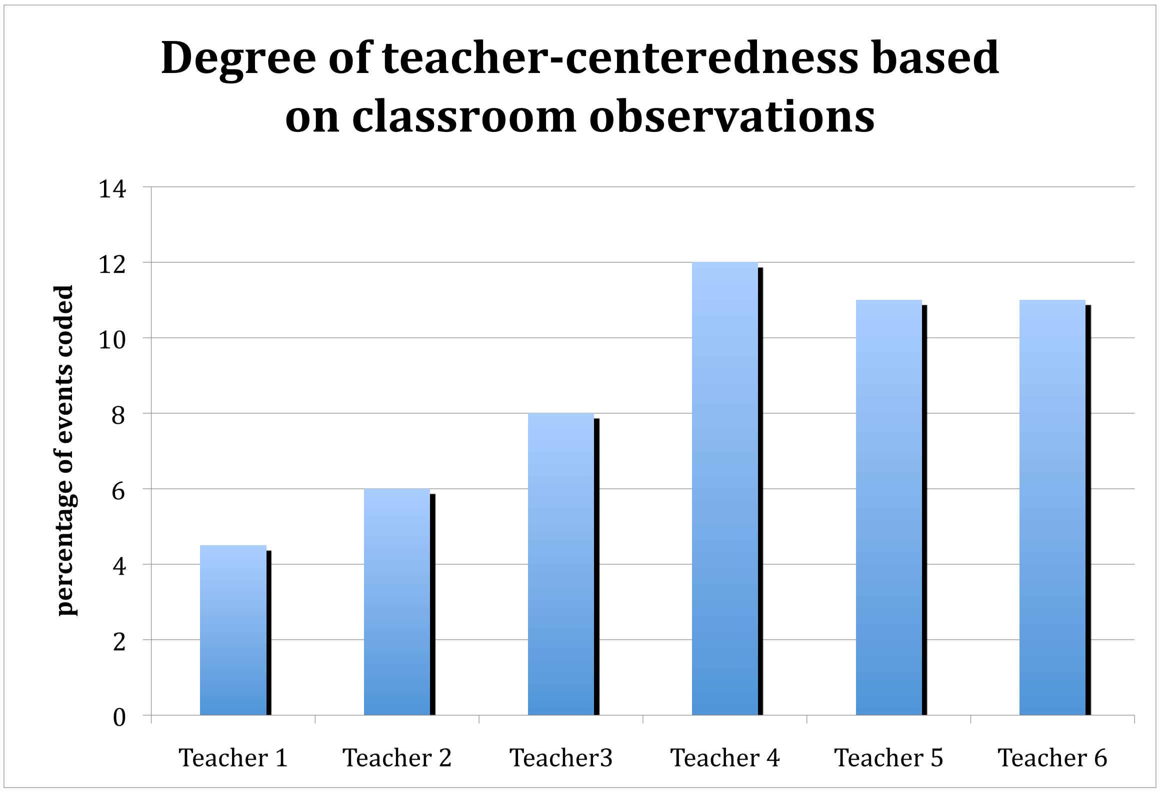

Figure 7.2. Teachers categorized based on their percentage of teacher-centered activities.

Figure 7.2 shows that a big difference between the three first teachers and the second group of three. Teacher 4, 5 and 6 spent considerably more of their time in the teacher-centered activities compared to teachers 1, 2 and 3. And, even among the first three teachers, teacher 1 spent nearly half as much time in teacher-centered activities compared to teacher 3.

Based on these two histograms we categorized our six teachers on the continuum of their application of a student-centered active learning pedagogy. Note that the groups placed teacher 1 in a different category from teachers 2, 3 and 4, and teachers 5 and 6 into a third category, ranking them high, medium and low active learning.

Approaches to Teaching Question Results

The results of the ATI show the following relationships between the self-reported perceptions of teacher-centered approach and student-centered approach.

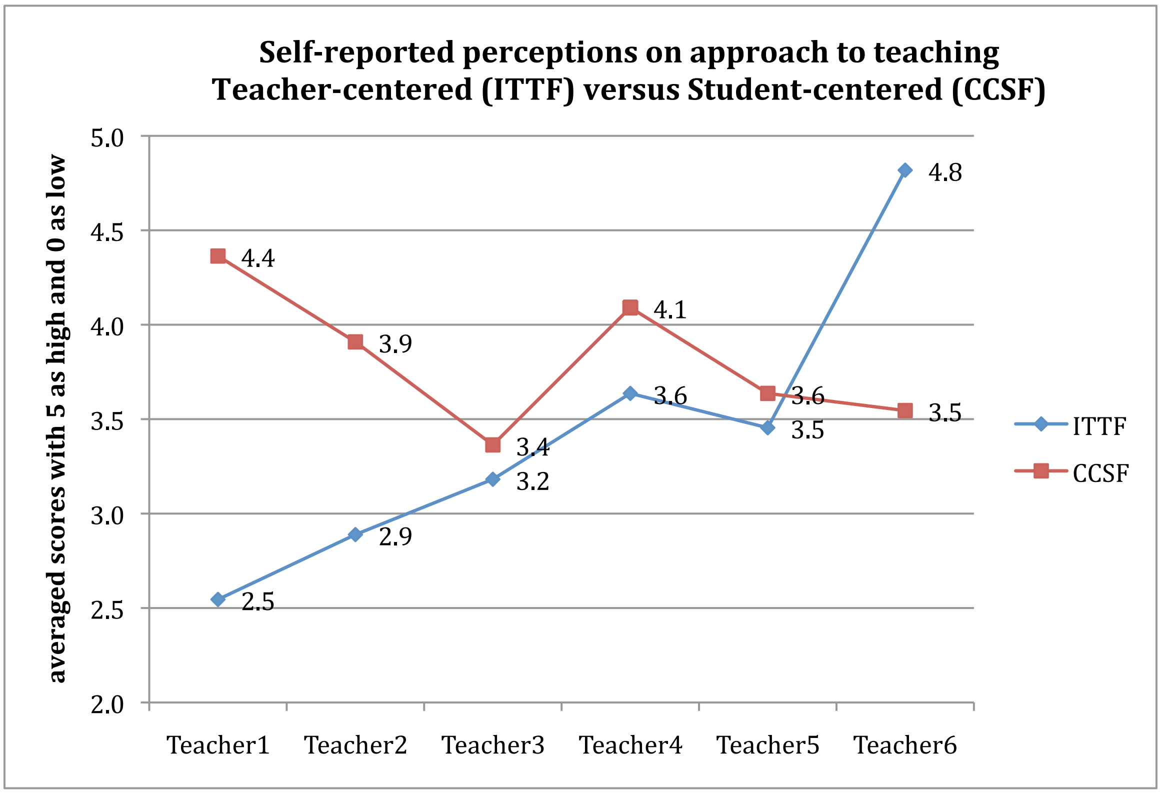

Figure 7.3. Self-reported perceptions on approach to teaching: Teacher-centeredness (ITTF) versus Student-centeredness (CCSF).

We see from Figure 7.3 that there are large discrepancies between the two scores for three of our teachers. While teachers 3, 4 and 5 have near parallel relationship between their scores on these two scales, teachers 1, 2 and 3 vary widely. These results were intriguing because we expected that as the teacher-centeredness (ITTF) went down, the student-centeredness (CCSF) would go up. This was true only for teachers 1 and 2. Meanwhile, the reverse was true for teacher 6. The teacher-centeredness and student-centeredness were near equal for the three teachers in the middle – teachers 3, 4 and 5.

What is the relationship between the observed rankings and the ATI?

We next looked at how closely the classroom observations of teaching practices matched the self-reported perceptions of approaches to teaching. We started by looking at the teacher-centeredness.

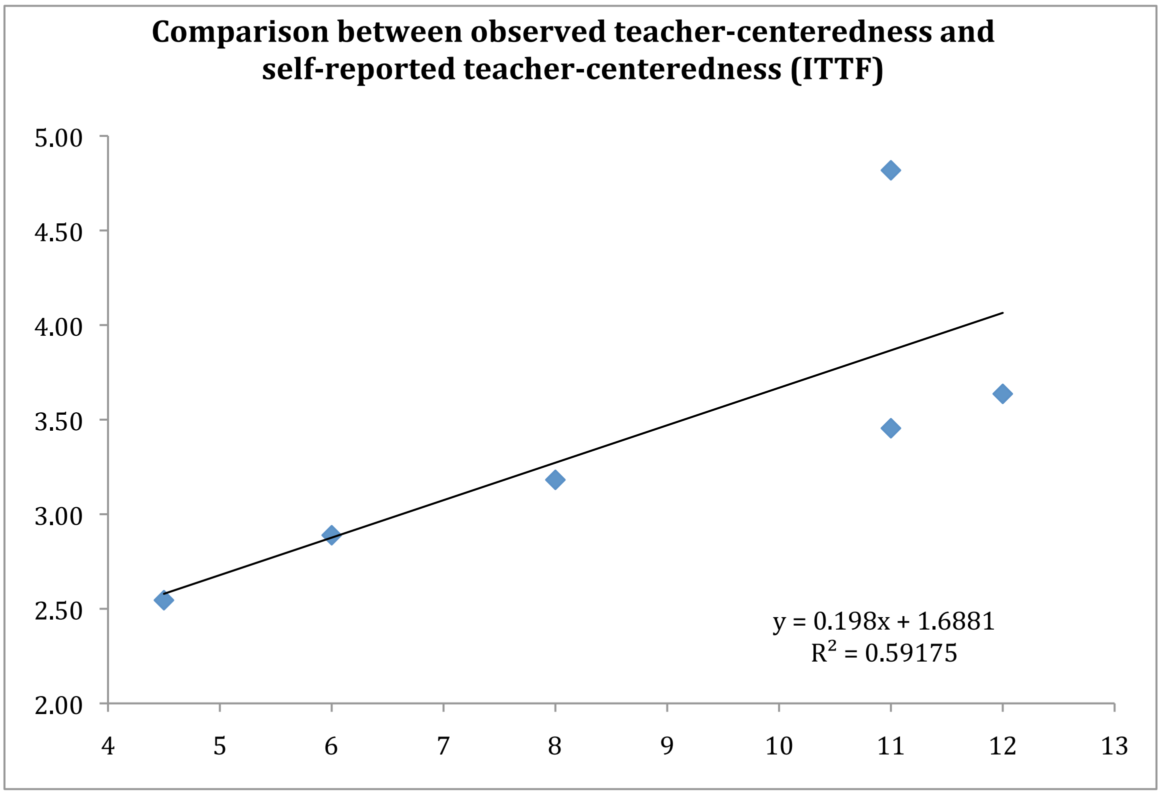

Figure 7.4. Comparison between observed teacher-centeredness and self-reported ITTF.

Figure 7.4 shows a high correlation between the teacher centered observations and the self-reported perceptions on teaching. This correlations = 0.77.

We then turned to see the correlation between the coded observations of student-centeredness in the teaching practices and the self-reporting of approach to teaching identified as student-centered (CCSF).

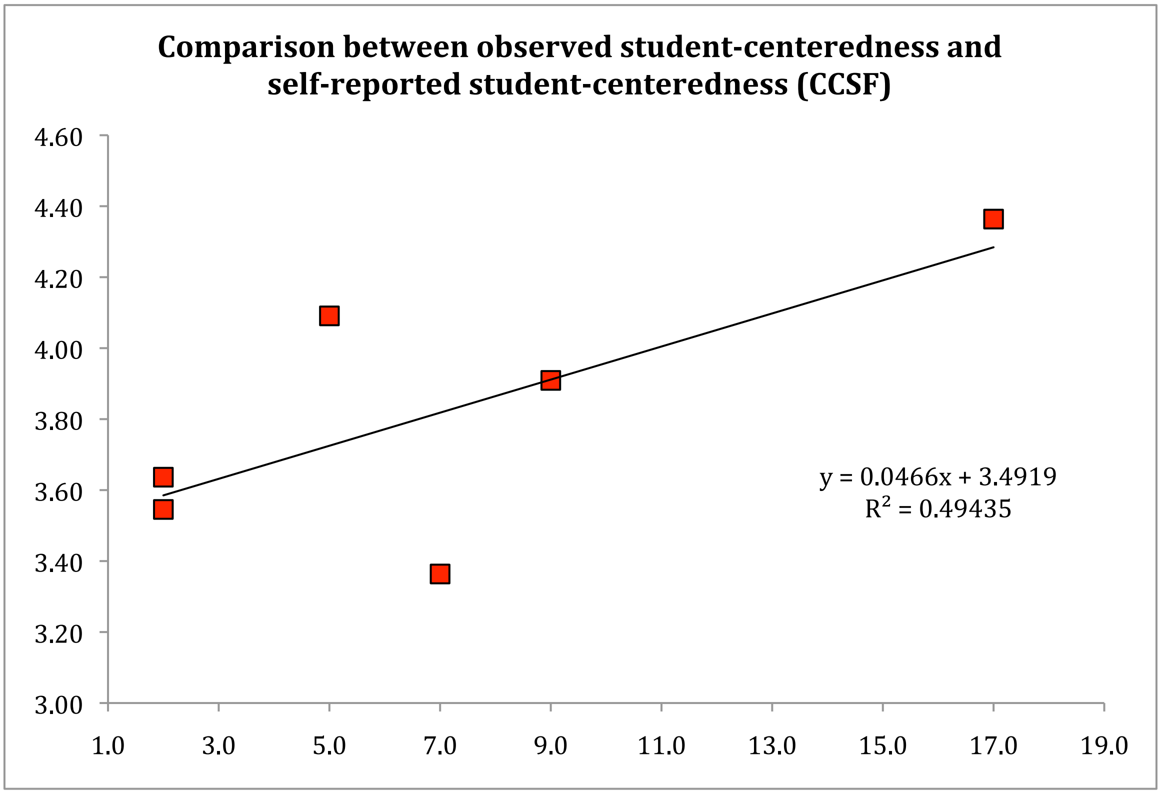

Figure 7.5. Comparison between observed student-centeredness and self-reported CCSF.

Figure 7.5 shows a high correlation between the observed patterns of student-centered activities and the self-reporting of student-centeredness (CCSF) as determined by the ATI. This correlation = 0.702.

Interestingly, both aspects of the classroom observations correlated highly with the associated scale of the self-reported ATI instrument. This suggests that the ATI as a self-reporting instrument is highly effective in capturing teacher's actual practices.

How does teaching approach impact learning?

Recall that studies that have used the ATI to investigate the relationship between teaching and learning have shown that teaching approach, at the level of the class, affects students' approach to learning (Biggs, et al., 2001; Kek, 2006; and others). These results continue to show that a surface approach to learning is strongly and positively correlated with an information transmission/teacher-focused (ITTF) approach to teaching, while a deep approach to learning is positively correlated to a conceptual change/student-focused (CCSF) approach (Kek, 2006; Kim & Branch, 2002). Given these relationship we were curious to know whether a similar relationship exist between the ATI and improvement on the conceptual physics test used in this study – i.e., the Force Concept Inventory (FCI).

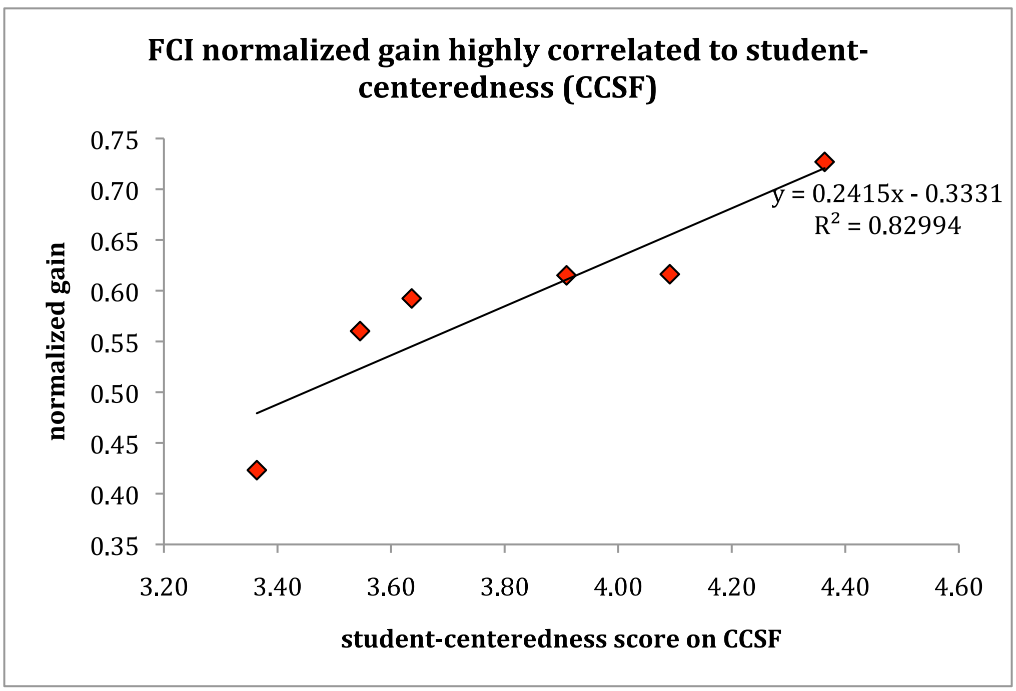

Figure 7.6. Relationship between the self-reported student-centeredness and gains on the conceptual test of physics understanding.

Figure 7.6 it shows a correlation of .91 between the normalized gain on the FCI and the student-centeredness rating on the ATI. Based on Bigg's and Kek's work described above, we did not anticipate this high a correlation.

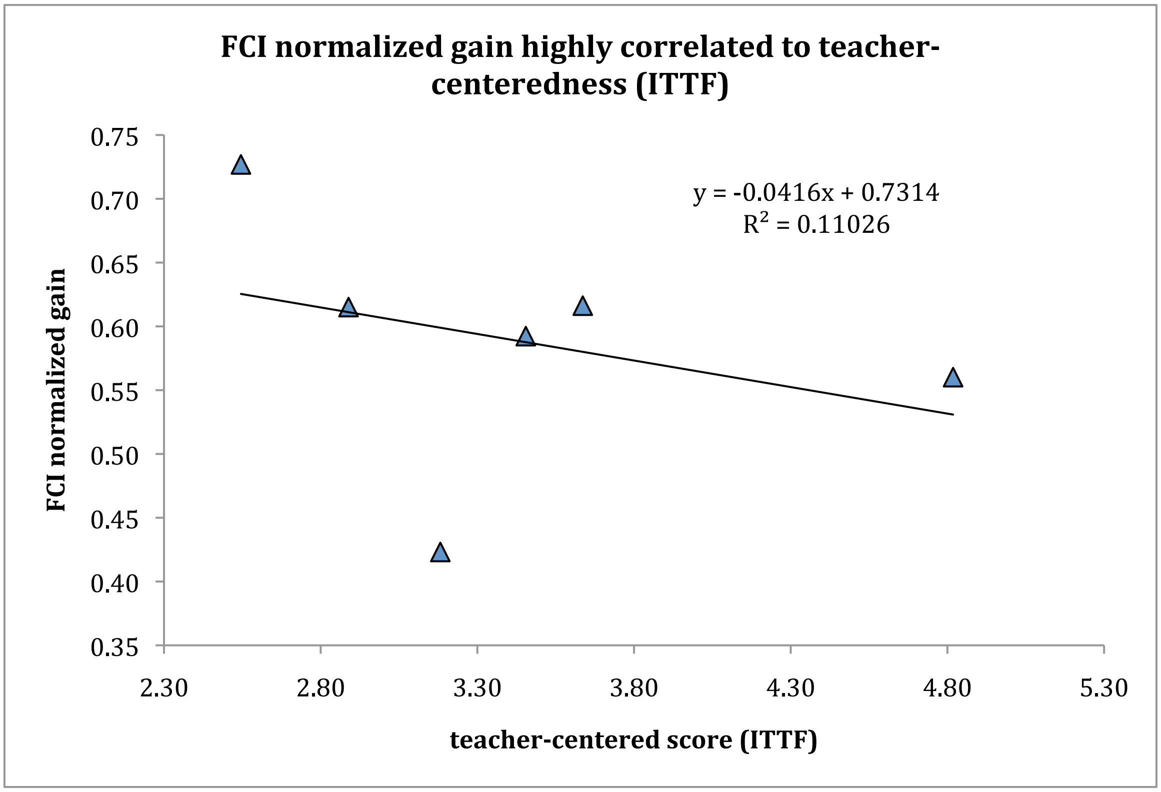

Figure 7.7. Relationship between the FCI normalized gains and the self-reported teacher-centeredness on the ATI.

When we looked at Figure 7.7, the teacher-centeredness scale and compared it to the FCI, it is not as good predictor of conceptual learning gains. In fact the correlation was -.33, which would be considered low.

Discussion

It is interesting that in both the student-centered and teacher-centered observation codes showed a strong relationship to the results of the Approaches to Teaching Inventory (ATI) questionnaire. This is surprising given the self-reporting nature of the instrument and the expectation that teachers would know what to say. It is equally possible that teachers were on their best behaviors during the researcher's classroom observations thereby producing correspondingly crafted projections of themselves. Another explanation might be because of the similar scales used in the observational rubric regarding the teaching event. These events marked changes in activities and methods used to engage students. If this were the case our results might support Gibbs and Coffey's (2004) findings that showed approach to teaching correlated with a teacher's repertoire of teaching methods. In other words, there was a positive relationship between teachers having a CCSF approach and their awareness of various teaching methods. While this too is a reasonable explanation it is still a very high correlation and deserves further investigation.

The truly important finding revealed here is the relationship between the student-centered scale (CCSF) and the normalized gains on the FCI. These results are both fascinating and flabbergasting. Why should a teacher's self-reporting of a pedagogical practice (student-centeredness) correlate so highly with actual student learning? Clearly these results support the works cited early (e.g., Biggs, et al., 2001; Kek, 2006). Like other who have used the ATI our findings adds to the growing body of evidence that the approach we take towards teaching is "not" a neutral act. Indeed Trigwell's (2010) position that these results should beg the question of how we might "define good teaching" (p. 122). One thing is sure, these findings give us courage to continue the effort to explore further the relationship between teaching and learning.

CHAPTER 8

PERCEPTIONS OF THE SOCIO-TECHNOLOGICL SPACES

In both the student and teacher interviews we found many references to the use of the new learning spaces – i.e., the Soc-Tech environment. In order to answer this research question we present a complied report of there comments.

Students' perceptions of Soc-Tech environment

In the students' interviews we found many references to the physical setting of the Soc-Tech environment and the technologies therein. Comparing the two groups of students (AL versus Comparison) there were clear differences in terms of their perceptions of working in these new spaces. While the Comparison groups liked the computers and space for labs they often commented on the inconvenience of having lectures in these spaces. Many of these students gave mixed reviews to their teacher's reconfiguration of the arrangement of the desks as they attempted to accommodate their lectures style preference. Recall that the hexagonal desks were designed in such a way as to allow for changing around of seating arrangements – i.e., great flexibility. Sometimes this reconfiguration of seating was successful and sometimes it was viewed as making things worse by limiting access to writing surfaces or creating a sense of overcrowding. When it came to the accessibility of computers, some mentioned that they would be distracted if such technology was available during a lecture. In essence, lectures and Soc-Tech do not co-exist pacifically.

> G1: 'Cause like you said, like it's hard to write notes if like you're sitting here and it's projected on that screen *(indicates sitting in front of her and screen behind her)*. But in a normal classroom, everyone's facing the same way. Everyone can see easily.
> ---
> G2: 'Cause I might have to say that the, like, if we're doing lectures in our lab room that, I don't know, I associate more the lab room to doing the lab, so if he starts lectures, then I am kind of zoned out a bit 'cause I, I don't know, I associate it differently. But if I'm in a classroom, then I'm totally, I know it's for theory and I know that's what it's for. So I

don't know, maybe that has an influence also but…

B1: Yeah, I think the layout of the room is very good if you're trying to, if you're like working in a group and the teacher's working on any kind of problem and you have a question for your friend about how to solve a particular kind of problem that he's not working on. It's a lot better for kind of small group communication but uh, when he's giving a lecture, it's harder to listen 'cause, it's also you're not oriented towards the teacher, a lot of the time you'll be looking at that board *(points behind him)* or the two screens so it gets a little bit harder to follow what he's doing because you just see stuff appearing and he might be, you know pointing here and there, it's kind of hard to understand what's going on.

G1: And it's hard… um it's hard to say because that way not everyone gets the same view of the teacher so it would be, he'd have to be doing semi-circles all the time. So the rows, I just don't think this class is really proper for configuration for a traditional class but for lab space, it's good.

G1: Um, I, I guess I'll go with the lecture because the labs I mostly like them. They're, they're pretty good. It's just um…one that didn't work? It's never that nothing works. I mean like it's always more or less smooth it's just more enjoyable to be in a traditional classroom where you have a blackboard and um…

Interestingly, the perceptions of the AL groups were different. They made little to no mention of inconvenience in the new spaces. In fact, they found them to be beneficial for learning.

G1: Yeah, I feel like it's easier like it's easier to pay attention at the round table. You can talk to more people and you get more help, I find at the round table.

G2: It's much more interactive than the other rooms.

G1: … there's really no person who sits at the back of the class and doesn't pay attention because he's in the middle so it's always…

B1: Yeah, it's a nice environment. It's like boisterous and people are talking and exchanging ideas. It's better than sitting in a row quietly and when somebody talks it's like *(taps on desk)*, "stop talking." It's more open and inviting and it makes learning easier.

Unlike the Comparison groups, the AL groups made little distinction between their use of technology and the teacher's use of technology. Instead they gave examples such as the use of clickers, or when the teacher engaged the class in demonstrations, or used the interactive white board.

> G1: Cause when I'm like, with the clicker questions, half of it is like, "I'm pretty sure it's this one." So I click it. And then the other half, when we see the graphs and we have to discuss then I'm actually like using the rationale.
>
> ---
>
> B2: I actually like the clickers cause then you can like discuss your rationale so then so if I'm listening to them and they think something's wrong they'll tell you.
>
> ---
>
> B2: Uh, I think like the fact that he's able to do more like demonstrations like with all his things so you could never do as much in a classroom but he does it in this classroom.
>
> ---
>
> G2: …So I find like there's more room for us to gather around and everyone um see his demonstrations which make is more interesting where as in the classroom there's like a little aisle and a little front which usually you can't see very well.
>
> ---
>
> G2: And it's cool how like, if he does a demonstration, he can start it on the SmartBoard so everyone can see it again, like you can see the graph right away when there's that demonstration, it's like, "okay this is what the graph will look like."

While the comment of overcrowding appeared in some of the Comparison groups the AL groups saw the new environment as spacious giving them room to easily move around. Additionally, in regard to the possible distracting effect of having computers available during a lecture, they saw no problem citing that "if you're interested you're not going to be distracted."

> G2: I think it depends on the person and how well you know how to pay attention, like if you don't want to be there, you're probably going to talk to your friends more or go on the computer and stuff. Um, but, if you want to use [the computer] the right way, then it's better to have it [available].
>
> ---
>
> B3: Yeah so if you actually want to learn, it's really easy to pay attention. You just have to see what he's doing there or there *(points around the room)*. You don't touch the computer unless you're not paying attention. That's your fault.

Why are these perceptions so different? One possible reason is that students, people in general, are more comfortable with what they are familiar with. This does not explain why the AL groups did not generally view the new environment as inconvenient. The seeming acceptance and valuing of soc-tech spaces by the AL groups would be seen by scholars who argue from a socio-cultural perspective as evidence of changed cultural norms and standards. It is the development of practices that become "taken as given" (Cobb, 2002). Cobb (2002) was referring to the disappearance of types of discourse which marks the growth of common understand among learners. We propose that this may also explain why we see little mention of inconveniences by students in the Soc-Tech spaces who were also taught with AL pedagogy. Together some refer to this as technopedagogical designs (Laferrière & Gervais, 2008).

We can now revisit the findings from our quantitative analyses comparing pedagogy to context. Figure 4.2 (reproduced below) shows that students taught with traditional instruction in Soc-Tech environments achieve significantly lower FCI scores compared to students taught with AL pedagogies in Soc-Tech environments; note that the converse also showed that pedagogy should match the space but not as drastic an impact. What is becoming clear from these results is the importance of changing pedagogy when using these new spaces. It cannot be business as usual.

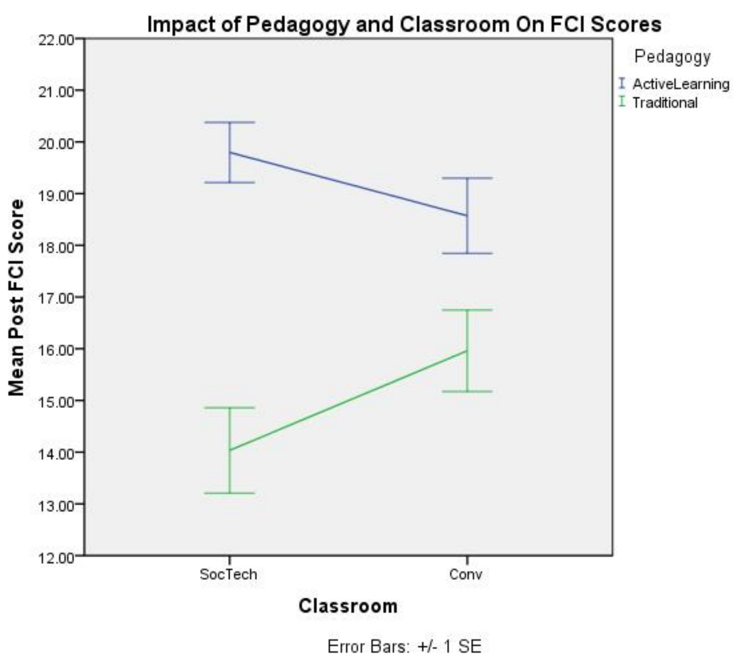

Figure 4.2 Significant difference pedagogy makes on mean Post-FCI score.
Classroom settings alone do not contribute significantly to end of semester conceptual knowledge.

Teacher's perceptions of new socio-tech environments

When it came to teachers and how the new spaces impacted their pedagogy there are similar stories of differential impacts that may also be attributed to their different perceptions of what learning and teaching should be.

We solicited opinions from teachers who used these new facilities in two ways: (1) as part of the teacher interviews conducted in relation to the classroom observations and a way of triangulating those results (fall 2010); and (2) as part of a written questionnaire distributed to teachers the semester after the launch of the new labs/classrooms.

From these early questionnaires we saw that while some teachers were uncomfortable with the new features of the room and saw the design as a mismatch to their style of teaching.

> *For lab work the two labs are both OK. For presenting material, I much prefer 7A.2. The students are closer to the podium. In 7A.6, my experience was that the students at the farthest table from the front, back centre table, had a lot of difficulty staying connected with what was going on in the class, even though they had a clear view of the material projected for them on the back corner screen. (…) They spontaneously moved the desks today to form "rows" and were quite happy.*
>
> *For more traditional courses the lack of [a] large blackboard is missed. I think removing those two whiteboards on the side (7A.2) in favor of (larger) blackboards would be an improvement.*

Others, however, were beginning to reflect how their teaching or the space might need to be modified to accommodate the constraints of the new environment. Though such teachers were uncomfortable, their words suggest openness to the change and a willingness to find ways of using the technology as a solution.

> *Due to the lack of table mobility the promise of amphitheater lecture style and large group arrangements could not be realized. [The] corner projectors and LanSchool made it possible for all students to follow the notes I made on the SmartBoard. (BUT!: it was noticed that students would still twist in their seat to follow the lecturer! What to do about that? ...)*

When it came to recognizing the usefulness of the design during lab work, all teachers perceived a benefit. In particular they all mentioned how the pod design facilitated group work.

> *I liked the "pods" for times when the students were working together on something.*
>
> *We can see student's computers all the time and control them if we need to! Easier interaction between students.*
>
> *No doubt that round tables help teamwork and make it easier for The teacher to maneuver around.*
>
> *The discussions were facilitated by the room layout.*

Some commented on the ease with which they could see what their students were doing. And, the vast improvement provided by this design compared to the traditional labs where students work in long tables set up in rows making it difficult for the teacher to get around. Additionally, making it clumsy for a group to collaborate especially when it came to computer work where only one person would do the computer work while others were cut off by the shear distance.

> *Seating / Table arrangements: easier for students to work in groups, discuss, perform experiments (equidistant from each other at a table); easier for me to see all the students, assist when needed (almost equidistant from all tables).*
>
> *It is more natural for students to work together. Access to computers is improved.*
>
> *Way better! Much easier to go around the room. Easy to talk to all students of a team at the same time. Easy to get to the computer to help. You don't feel like you are explaining to only one student when on the computer.*
>
> *I really felt that during labs and activity the amount of work was more balanced in a team. I saw fewer groups where one student was doing everything. This is especially true about the work done on the computer.*

Lastly, when it came to perceived need to change their teaching half of those surveyed reported they felt the new space gave them a push to try new ways of teaching.

The way I see it, these new labs give a myriad of new possibilities and flexibility to the teacher. Therefore this technology gives me an edge; it allows me to optimize what I do.

Jump off the cliff. It is not as tall as you fear.

Elaborating further on feedback from these two individuals one in particular reported that the new design encouraged him to reduce the amount of teacher-centered presentations and increase the amount of student-to-student interactions with activities such as group problem solving. Additionally, he began to give his students permission to use the Smartboard technology thereby providing them with a new sense of authority and way to participate in his class. In fact, he reports that his students grew to enjoy this way of contributing so much that they looked forward to it and "literally fought to go to the Smartboard." When asked what he would like to do in the coming semester he stated "I want to bring the student to the board more often. By this I do not mean one student at the time but all of them simultaneously to work in small group. I tried it a couple of time last semester and there are a couple of space issues to address, but I think it could be great."

In terms of his perception of how the students used the room he reported that more students were able to participate more fully – the teamwork was more balanced. He said, "I saw fewer groups where one student was doing everything. This is especially true about the work done on the computer. I had a couple of activities where they had to use Excel, and I felt that they could all follow what happened on the computer, in opposition to what we see in the old labs."

Follow up on with him 18 months later his enthusiasm for the new spaces continued to be high. He still saw the design as great, and the potential of the room's design for supporting students as they worked together. In fact, he stated that more students get involved and work on his designed activities. "I use Excel spreadsheets a lot in my labs and all members of a team were participating in filling it. It was not only one person, even when they were doing this in groups of four." Furthermore, he observed that students seemed to be starting to create a kind of community with neighbouring pods helping each other. He stated, “It is a very good design to use interactive learning of many types.”

Not surprisingly he reported the development of new teaching practices in order to be affective in the new room. He learned how to use the interactive white board in such a way that allowed him to work with the students who face away from the teacher and look toward the projected screens. This change from pointing was an important improvisation that made working in the room effective.

Lastly, he sought pedagogical assistance to develop activities that would allow his students to engage in a *jig saw* peer-mentoring activities – i.e., having students teach each other some topics (each one responsible for a part) and then quizzed on it.

Meanwhile the other teacher also began trying out new ways of teaching.

> *[What’s special about] the new lab is that the students, all of the students in each working group can actually have contact with the physical system or the apparatus…The main thing I’ve tried to do is try to get them to do more activities, labs where they’re actually working with the physical apparatus. So I mean the thing I’ve been trying to do this past two semesters is that I’d have them do the labs before I taught to them the content so it’s like, here’s the system and I want you to think about the “think tracks.” Like, what is this thing in front of me? Mass on a spring for example. Change the mass, see how it oscillates. Grab a hold of it, each of you take a turn, and play with it. I want you to have a kinesthetic idea, I want you to have a visual memory, I want you to have some impressions of what this system is doing when you manipulate it. Then return to it later and try to describe, “okay, what did we see in the lab?” If you put more mass on it, did it oscillate faster or slower? Everyone says “slower.” So I say “okay.” Now, put on your mechanics hat from last semester.*

Note the types of cognitive processes described by the teacher. This marks a distinct change where teaching is no longer transmission but designing ways to cognitively engage students in multiple ways of knowing and reflecting.

Making thinking visible

Lastly, while one of the key features other than the room itself was the role the interactive white board played in changing these two teacher's ways of thinking.

> *In a standard classroom, you chalk and talk. You erase the blackboard and you move on. You're three boards past where the question was, you gotta take time to redraw it. Here, you can go back, change it, annotate it, there's one thing uh, I think there's been a few occasions, a question about something… wait a second where did that come from? Go back to it. Find out that my presentation was not the most succinct way or it didn't say it in words that made sense to the students. And so through the back and forth of the question answering, a better formulation of how to present that is made and I can write it right in there. I can include it in that slide that was from three, three pages ago.*

While much is written about the activities and direct student engagement that make up active learning pedagogies, not much is reported on the types of lecturing that Bransford and Schwartz (1999) refer to as "a time for telling." Also, not much is written about the types of lecture-demonstrations that demonstrate not how to do something, but how to think about something. We contend that this latter lecture-demonstration is what is being described by this teacher and is consistent with what Collins et al. (1991) describe as cognitive apprenticeship. Specifically, this teacher is talking about model his thinking or put another way, making his thinking visible. This is an important aspect of active learning and one that allows student to better understand what it means to reason in the content domain. In this instance, the interactive white board facilitates such demonstration of thinking.

Summary

Clearly, technology has a role to play when it comes to learning and teaching. What we see for the examples and quotes above is this role is varied and not always easy to tease out. If we are to take away any lesson it would be that the design of technology is critical for its effectiveness in learning.

CHAPTER 9

Discussion & Conclusion

> *B1: Personally, for me, I think when he does the lecture mixed with the clicker questions. It's cause you're interacting within the discussion and you have a mini-discussion with your little group and... I mean you might all get it wrong but then he'll explain it and you'll see why this or that wasn't the case. Why it was "A" and not "B." Your group learns with it and if one person clicks for them then they'll really try to explain. I think, it's like the smaller groups again, becomes a factor [in learning].*

Our research started with the question of how might we bring to scale the growing evidence that pedagogies based on constructivist theories can improve learning. One of our key questions was to determine whether or not new socio-technological environments offer any added benefit in this process. And, if yes, what role could these environments play in helping teachers make the requisite shift in their conceptions related to teaching and learning. Furthermore, our research wished to investigate Trigwell and Prosser's observation that to change teacher's approach to teaching may mean that we need to change how teachers understand teaching and learning (Trigwell, 1996). In essence, how do teachers see their roles and how do these perceptions of roles change?

This study took a holistic approach to the investigation. By looking simultaneously at teachers and students use of the new socio-technological spaces we were able to determine the impact and effectiveness of the space and the pedagogy. In each chapter of this report we have tried to use a different method to dig deeply into these issue. Additionally, these various methods allowed us to triangulate our findings. In the remainder of this chapter we will summarize what we have learned thus far.

Our first study looked at the question of the impact of pedagogy and classroom setting. Our findings show that pedagogy is paramount whereas physical setting is secondary. If we are to gain the benefit of the new settings, a change to the physical setting of learning must be accompanied by a change to the pedagogy as well. Socio-technological settings provide new opportunities for both teachers and learners to engage in different practices. Hence, investing in educational technology may be useful inasmuch as it stimulates instructors to rethink their pedagogy and adopt student-centered Active-Learning.

Study 2 also showed that a student-centered teaching focus (based on the Approaches to Teaching Inventory - ATI) was a highly related to students' improved conceptual knowledge (Force Concept Inventory). Like other who have used the ATI our findings adds to the growing body of evidence that the approach we take towards teaching is "not" a neutral act. We again cite Trigwell (2010) who suggest that we need to take a scientific approach to how we "define good teaching."

Lastly, changing the physical setting also supports efforts teachers themselves are making to change their practice. This is encouraging news and leads us to propose further questions that will continue this line of research. For instance, what is the trajectory of this change to teaching practice? What support is required to complement such efforts and how should it be provided? In an effort to begin addressing such questions as those posed above, we propose a set of guidelines and roles for teachers as they enter into this new frontier.

Guidelines for designing student-centered active learning:

- <u>Designing lectures</u>: not all lecturing is bad, but keep it brief with time for students to absorb and reflect on what you said. Additionally, instead of "tell" remember to *"model" how you think*. Students need to see how an expert goes about the process of reasoning in the discipline of study and how reflect on how their thinking might be different. In the sciences this process is referred to as intentional conceptual change.
- <u>Designing demonstrations</u>: demonstrations are important but more important is having students begin to *participate actively while watching*. For example, ask your students to "predict" the results before you start and then "compare" their prediction to the evidence. This activity not only gives them a role to play in your demonstration but also marks the start of a thinking activity and a reflective activity.
- <u>Designing collaborative activities</u>: tasks should be complex enough to warrant collaboration and *provide opportunities for discussion*. The value of collaborative work comes from the discussions that are generated in the process of understanding and completing the task. Additionally, tasks should be designed so that members of the team have to *work together* and not merely distributed to individuals.

- Building in time for reflection and feedback: in all activities it is critical to *allow students to reflect on what they have just learned* and how it might be used or relate to what they already know. This includes allowing them to discuss with others as well as self-reflect. Examples of activities that generate such thinking include small group or whole class discussions, concept mapping, reflective writing.
- Organizing groups: keep in mind that it is beneficial to have some overlapping capabilities that extend the group's collective capability - what Vygotsky considers the "*zone of proximal development*." In other words, it is best to have moderate variations in abilities where some students are able to engage in peer mentoring and modeling of how to accomplish the task at hand while still being able to create a common understanding.
- Encouraging student participation: *share the responsibility for learning* and trust that your students will do their part if they can see how the activity builds on your overall course goals.

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APPENDICES

APPENDIX A

APPROACHES TO TEACHING INVENTORY 22 (ATI22)

This inventory is designed to explore a dimension of the way that academics go about teaching in a specific context or subject or course. This may mean that your responses to these items in one context may be different to the responses you might make on your teaching in other contexts or subjects or courses. For this reason we ask you to consider the context of the Smart Lab where you will be teaching Physics NYA. Please, refer to this course in your responses to each item below.

For each item please circle one of the numbers (1-5). The numbers stand for the following responses:

1 - this item was **only rarely or never** true for me in the course.
2 - this item was **sometimes** true for me in the course.
3 - this item was true for me **about half the time** in this course.
4 - this item was **frequently** true for me in this course.
5 - this item was **almost always or always** true for me in this course.

Please answer each item. Do not spend a long time on each: your first reaction is probably the best one.

		Only Rarely				Almost Always
1.	In this course students should focus their study on what I provide them.	1	2	3	4	5
2.	It is important that this course should be completely described in terms of specific objectives that relate to formal assessment items.	1	2	3	4	5
3.	In my interactions with students in this subject I try to develop a conversation with them about the topics we are studying.	1	2	3	4	5
4.	It is important to present a lot of facts to students so that they know what they have to learn for this course.	1	2	3	4	5
5.	I set aside some teaching time so that the students can discuss, among themselves, key concepts and ideas in this subject.	1	2	3	4	5
6.	In this course I concentrate on covering the information that might be available from key texts and readings.	1	2	3	4	5
7.	I encourage students to restructure their existing knowledge in terms of the new way of thinking about the subject that they will develop.	1	2	3	4	5
8.	In teaching sessions for this course, I deliberately provoke debate and discussion.	1	2	3	4	5
9.	I structure my teaching in this course to help students to pass the formal assessment items.	1	2	3	4	5
10.	I think an important reason for running teaching sessions in this course is to give students a good set of notes.	1	2	3	4	5
11.	In this course, I provide the students with the information they will	1	2	3	4	5

	need to pass the formal assessments.					
12.	I should know the answers to any questions that students may put to me during this course.	1	2	3	4	5
13.	I make available opportunities for students in this course to discuss their changing understanding of the course.	1	2	3	4	5
14.	It is better for students in this course to generate their own notes rather than copy mine.	1	2	3	4	5
15.	A lot of teaching time in this course should be used to question students' ideas.	1	2	3	4	5
16.	In this course my teaching focuses on the good presentation of information to students.	1	2	3	4	5
17.	I see teaching as helping students develop new ways of thinking in this course.	1	2	3	4	5
18.	In teaching this course it is important for me to monitor students' changed understanding of the course matter.	1	2	3	4	5
19.	My teaching in this course focuses on delivering what I know to the students.	1	2	3	4	5
20.	Teaching in this course should help students question their own understanding of the course matter.	1	2	3	4	5
21.	Teaching in this course should include helping students find their own learning resources.	1	2	3	4	5
22.	I present material to enable students to build up an information base in this course.	1	2	3	4	5

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APPENDIX B

Teaching and Learning Experiences in Active Learning Classrooms

Semi-Structured Interview Questions for Students

Impact of the new lab/classroom:

1. What it's like taking classes in this classroom? Are they different from those in regular classrooms? If so in what way?
2. What are the major advantages and disadvantages in learning in this classroom?
3. What do you believe is the role of the technology in the classroom (e.g., SMARTBOARDs)? Can you recall how the use of such technology was beneficial to your learning? Can you recall how the use of such technology was detrimental to your learning?
4. Describe a class or class activity in the classroom that worked BEST for you.
5. Describe a class or class activity in the classroom that DOESN'T work so well for you.
6. What are the biggest challenges in learning in the classroom?

Reform Science Program (QEP) impact:

7. Would you say that your HS science prepared you for Cegep? Did your HS science teacher use similar methods of teaching? Were the labs and assignments similar?

Learning Style - Collaboration:

8. Generally, do you communicate or work with each other outside of class on homework or lab assignments? If yes, what media do you use?
9. Does working together in the "pods" help to create a sense of "team".
10. Have you always worked together with others (study group) outside of class? If yes, How would you normally create this study group? Did you create your study group differently because of the way this classroom is organized – i.e., are the composition of study groups affected by the working in pods?
11. Is there anything that your teacher does, in the course of helping you learn, that is NOT like other teachers? If yes, can you list/name some of these things that makes him/her different?

Awareness of Teacher's Epistemic Frames:

12. What are some of the things your teacher keeps repeating?
13. From the things your teacher focuses on, what do you believe he/she thinks is important in this course?

14. Would you say that your teacher explains how you should be thinking about physics, in general, and about solving physics problems, specifically?
15. Do you believe that the way he/she teachers influences how you think about physics/science?

Uptake of Technological Opportunities:

16. Does your teacher use First Class Client to communicate with the class? If yes, do you check this often? Do you use it to communicate with others? What would make this communication more useful?
17. Does your teacher make his/her lecture notes available? Does he/she use the Notebook feature of the Smartboard to work out the solutions to problems? Does he/she make these solutions available afterward? Have you ever used these archived solutions?

Learning Physics:

18. Do the examples used in teaching physics affect your interest in learning the concepts, understanding the problem, solving the problem?
19. Describe 2-3 major things you learned in the past few weeks related to physics.
20. Describe 2 activities or assignments from your physics classes that you had in the past few weeks. [MODIFIED & COLLAPSED INTO ONE QUESTION #19]
21. How would you describe the relationship between these two? [MODIFIED AND REMOVED]

Sense of Responsibility:

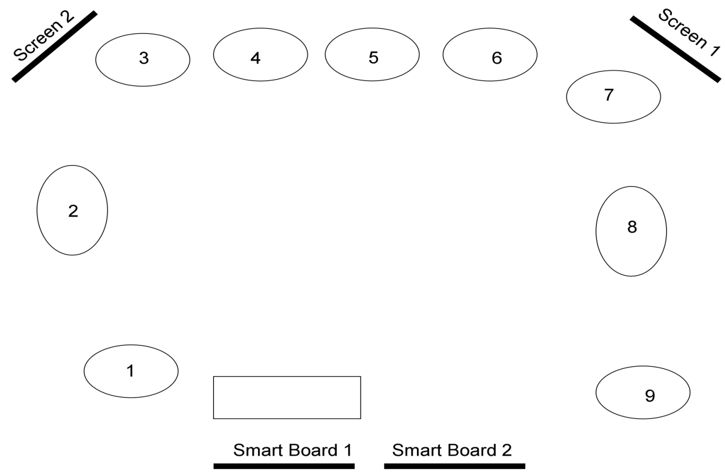
22. How would you describe the teacher's responsibility for making your learning successful?
23. How would you describe your responsibility for making your learning successful?
24. What role might your peers' actions have in making your learning successful? [MODIFIED & SHOULD BE ADDED FOR THE FUTURE]

Recommendations:

25. What would you recommend to students or teachers who are going to use this classroom/lab (tips, learning strategies, etc)?

APPENDIX C

Sample Observation Protocol Form

Date		Time		Place	
Group #				Instructor	
Observer(s)				# of students	
Topic					
Plan of the classroom (please specify locations of observer(s), etc.)					
Technologies in use	• Projector / Screen • Smartboard (only for projection) • Smartboard (for its function) • Black/whiteboards • Student desktop computers/ personal devices • Clickers • Physics equipment (demo) : motion detector _ • Physics equipment (desktop): motion detector _				
Data collected	• Videotape of the observation • Audio recording of the class conversation • Photographs of the observation • Handouts • Professor (e.g., post-lecture discussion) • Student products: (e.g., tests, quizzes, survey questions)__________________________________ • Others:______________________________________				

Time (Real time)	Activity	Delivery Mode	Professor Positions		Student Engagement	Descriptions
			SB, CB	C, DM	Activity	
00:05						
00:10						
00:15						
00:20						
00:25						
00:30						
00:35						
00:40						
00:45						
00:50						
00:55						
00:60						

Coding Key
Activity: L = Lecture; IRE=Inquire-Response-Evaluation; GA = Group Activity; IA = Individual Activity; PA = Peer Activity; CD = Class Discussion; DM = Demonstration; SP = Student Presentation; MM = Multimedia Viewing (film, video, music); O=Other (Add descriptions))
Delivery Mode: LP = Lecture Projection; CQ = Clicker Question; SB = Smartboard; WB: Whiteboard (chalkboard); AV = Audiovisual; WWW = Web; WS = Worksheet (handouts); PC = Student Computer; O = Other (Add descriptions)
Professor Position: SB1 = Smartboard1; SB2 = Smartboard2; CB = Chalkboard; DM: Demo; CST: consulting (circulating the room); Other (Add descriptions)
Student Engagement: R-IRE = Response to IRE; SQ = Student Question; SC= Comment; AL = Attend and listen; AW = Attend and write; NAT= Not attend and talk; NAS = Not attend and sleep (HOD); PI = Peer instruction; GD = Group discussion; SPM = Spontaneous peer mentoring; Exp=Experiment; Other (Add descriptions)

Questions for participants:
Overall comments and observer's reflection:
Note for the next observation:

Revised coding key – used in Treatment group later in semester

Activity > answers the question: what is the immediate focus of the activity system?

L = Lecture (presentation of content materials, includes providing definitions, explanations);
PS = Problem Solving (active working out of physics problems including mathematical calculations); includes lectures that relate directly to the problem solving;
DM = Demonstration (presentation of physical demonstration involving physics equipment/apparatus, including software readouts);
IA = Individual Activity (assigning students to individual activity – e.g., problem solving, homework, quiz);
GA = Group Activity [**GA-Lab** (assigning students to planned lab activity); **GA-Other** (assigning students to planned group work, involving ≥ 2 students – e.g., group problem solving, *Peer Instruction* (PI) activities];
CD = Class Discussion (specifying all students work together – e.g., whole class debate, *Jigsaw* activity, *Poster* presentation activity);
SP = Student Presentation (student presentations as individual or groups; may be also a part of CD);
Special activities that may be part of a lecture, problem solving session or demonstration
MM = Multimedia presentation (presentation of film, video, music which are ≥ 5 minutes of a lecture or demonstration)]

Instructional Approach > answers the question: what approach is the teacher using to get the activity accomplished?

Transmissive:
ST = Static Transmission (one-way transactions and presentations – e.g., "chalk & talk", powerpoint presentation, one-way feedback to presentations);
DY = Dynamic Transmission (one-way transactions and presentation using multiple modalities: visual, aural, kinesthetic – e.g., drawing, physical demonstrating, vivid explanations including personal stories;
Interactive:
IRE-Q =Inquire-Response-Evaluation Questioning (2-way transactions – teacher-generated questioning with single anticipated answer – e.g., *who knows which formula we use here?*);
DQ = Dialogical Questioning (questioning provoking feedback loop of related questions: i.e., asking for predictions, rhetorical questioning/conjecture, metacognitive thinking rather than single answer, – e.g., *what would happen if we were to change this variable?*); DQ may also sound like **Scaffolding**: *"does the scale know the difference btw a ceiling or pulley?"];*
MOD = Modeling (provoking thinking; meta-level transaction that explicitly explains or demonstrates the ways of thinking or acting that are part of the disciplinary practice and/or how to use disciplinary tools – i.e., how to use representations & inscriptions (e.g., how to think about free body diagrams or physics equations as a tool that communicate information);
COA = Coaching (coaching of individual students and/or groups, usually involves the teacher circulating the classroom and consulting with students, checking work for accuracy, elaborating, explaining, etc.);
CL = Collaborative learning (all instructional approaches that involve explicitly asking students to work together; includes, inquiry-based instruction, problem based instruction (PBL), Peer Instruction approach, which uses ConcepTest questions with a vote & revote);
Affective:
POS = Positive feedback, empathizing (providing encouragement, telling personal stories, etc.);
NEG = Negative feedback (insulting, demoralizing, etc.)

Instructional Material(s)/ Resources/Artifacts > answers the question: what instructional resource(s) does the teacher use, or initiate use of, to accomplish the instructional goals?

NT = No tool include when the teacher uses no materials and simply talks without the use of any props;
SMT = Static Material/Tools (static artifacts – e.g., ONLY drawing/writing on the CB/WB/SB; PPT slides, viewing of website content);
DMT = Dynamic Material/Tools (MUST involve some change or addition to the available resources, including: modification of existing artifact (e.g., drawing on PPT slide); creation of new artifact (e.g., creating a page in NoteBook; production of graph from graphing software; output from running simulations, dynamic websites);
WS = Work Sheet or printed hand outs used to deliver information, problem solving or turned over for student engagement activity (includes textbook problems; Mastering Physics problems; old exams – i.e., disciplinary artifacts);
Interactive tools
CQ = Clicker Questions (ConcepTest questions, or other multiple-choice questions that require students to vote on the answer);
OIT = Other Interactive tools (includes DALITE, VoiceThread or any other material or tools that collects students responses and creates an artifact that can be displayed to the class)

Media/Technology (teacher or student) > answers the question: what media is the activity unfolding in?

SB = Smartboard [**SB-S =** Smartboard used as a device <u>to show</u> other media; **SB-D** = Smartboard used as an <u>interactive device</u>];
CB/WB = Chalkboard or Whiteboard;
PC = Student Computer [**PC-S =** PC used as a device <u>to show</u> other media; **PC-D** = PC used as an <u>interactive device, this includes the use of clicker technology</u>];
PM = Print Media (includes textbook, work sheets, problems written out on the CB/WB/SB; problems written out in student's textbooks)
PE-ndc = Physics Equipment (with <u>no data collection</u> device attached); **PE-dc** = Physic Equipment (<u>with data collection</u> device – e.g., motion detectors device and graphical readout);

Student Engagement > answers questions: what the students are doing?

AL = Attend and listen; **AW** = Attend and write;
R = Respond [**R-IRE** = Respond to IRE; **R-DQ** = respond to DQ]
OFT = Off Task (includes not attend and talk; sleeping (head on desk);
SQ = Student-generated Question (student generated questions should be numbered (SQ1, SQ2, etc.), student should be identified by location (Table #), gender (g=girl, b=boy), other identify (g1, g2, b1, b2, etc) – e.g., SQ1_T5_g2; or [**SC** = Student-generated Comment];
IW = Individual Work (students working individually on problem solving, or any other individual task);
GW = Group work or discussion [**GW-lab** = students engage in group work as part of a lab that includes: planning, division of labour, data interpretation, etc. (should be coded as additional to LAB-Ex); **GW-CQ** = group discussion as part of Clicker Questions; **GW-PS** = group discussion as part of Problem Solving; includes checking problem solving between students, e.g., "what did you get?"];
HS = Help Seeking (explicit help seeking from teacher or peers);
SPM = Spontaneous peer mentoring;

Note: In any situation where a code doesn't fit O may be used

O = Other (Add descriptions)

APPENDIX D

Questions for Semi-Structured Teacher Interviews

1. How do you characterize learning? How has this characterization changed, if any, in the last few years? Do you attribute this change to any particular event (e.g., ped day activity, new labs, colleagues, journals)?

2. How have you tried to use the new labs to promote your students' learning?

3. What would you like to see in these new labs to further support your efforts to promote your students' learning?

4. What would you say is sufficient evidence of your students' understanding of a particular concept during your class presentation? Has this sense of evidence changed in the last few years? If yes, have you noticed any differences in how your students react/perform/engage as a result of your changed approach to what is evidence of learning? Has this changed as a result of your teaching in the new labs?

5. What would you say is sufficient evidence of a student's understanding of a particular concept during your assessment measure?

6. How would you characterize yourself as a teacher? i.e., what's the most important aspect of your job?

7. After 2 years of teaching in the new labs, have these new spaces changed your teaching in any significant ways?

APPENDIX E

NYA-06 Fall 2010 planning sheet (morning)

Week # & day	Planned Material	Active components	Assigned work	Post/handout	Due	What was done & comments
1						
Wed (L1)	• Course intro ~~& addendum~~ • RW instructions • Show them First Class	• Had them work in groups of 4 to define what physics is and answer a couple of questions.	• Read 1.1-1.9 • RW: 1.7-9 (vectors, components, unit vectors and +-) • ~~FC act:~~ Ask them to read FC articles in welcome message (not an ass.)	• HO: course outline & ~~addendum~~ • HO: RW info • HO: FC info • HO: Ch.1 photocopy	none	• Intro went OK but it was a bit too long before getting to the active part (I switched things around for the afternoon class (NYA-04) and it was much smoother). Also, I'm not sure how useful the activity was – except that it was an activity. Again the afternoon question (is theory proven fact or hypothesis?) was much better. Despite this, the discussion went very well. The lab room (7A.2) is a joy to be in and the students take so easily to discussion with each other. This class reminded me of section 10 from F08. • **Note in hindsight: Next time you have to force them to use FC. Force them to post something up so that they get used to it and get on the system right away otherwise they don't start off on the right foot.**
Fri	• FCI & Talk about research & distribute consent forms. • Ch.1.1-5 (esp. models, conversions & sig figs) & Ch.1.7	• Clicker Q's	• none	• HO: vector worksheets	RW: 1.7-9	• The FCI went well and this time I was able to find clickers that worked (usual set were not working). The clickers went really well and the discussions were good. It's hard to tell because I was only estimating votes in section 04 the previous day but it seemed as though this group had more difficulty with the MC questions – they re-voted on several of them.

Week # & day		Planned Material	Active components	Assigned work	Post/handout	Due	What was done & comments
2	Tue	• review addendum • Ch.1.7-10 (do 7.10 only briefly) – ***FINISH CH.1*** • Show them MP	• Clicker Q's • Worksheet (vectors from Knight) ~~• OISE Q's as pre-activity…~~	• MP tutorial • Ch.1 MP Assign • RW: Ch.2.1-3	• HO: course outline Addendum • Post: Ch.1 ppts & vector worksheet sols.	~~FC act.#1~~	• **Finish Ch.1** • OISE stuff not ready yet – put 3rd OHIO-03_vectors:vectors Q in ppt. as clicker Q. ~~• Add OISE the first set of (4?) online OISE questions to RW#3. Have OISE Q's due 1 hour before class…~~ • Finished vectors and ch.1. It took a while to go over the addendum and show them MP but it went well enough.
	Wed (L2)	• Ch.2.1-3	• ILD: Motion detector and 2m track (cart without fan, with fan, on slope etc.) ~~• Clicker Q's~~ • Worksheet (graphs from Knight)	• none	• HO: Prediction sheets for ILD • HO: Graphs worksheet	RW: Ch.2.1-3	• I started by tying up a couple of loose ends: - Told them to be patient with MP – it's not perfect - Showed them my proposed office hours and asked if it seemed good for them – and for only one or two it looked ok. - Reminded them about consent forms. - Had them predict what they got on the FCI using clickers and then told them what the average actually was (they predicted about 70% and actual was about half that). We then discussed the need to be ready to change their pre-conceived notions of how the world works. • The ILDs went really well. First I showed them a cart moving at constant speed and explained how the motion detector works. Then I had them predict what would happen if: 1) the cart was released from rest with the fan on, 2) the cart was pushed towards the detector with the fan resisting, and 3) I showed them a video of Usain Bolt vs Tyson Gay sprinting. They handed all 3 prediction sheets in. I started the lecture notes but didn't get to clickers - only had time to get to workbook exercises (handed out Knight worksheets) but didn't do them in class. There was a lot of info in this class and they seemed a little overwhelmed at the end with graphs and the subtleties of motion.

Week # & day		Planned Material	Active components	Assigned work	Post/handout	Due	What was done & comments
	Fri	• Ch.2 – motion graphs, velocity & accel. • Show them VoiceThreads.	• Worksheet (graphs cont.) • Clicker Q's	• RW: Ch.2.4&5 (NB: 2.4 they only have to be able to use those equations not derive them) • Uncertainty reading (prep for Lab quiz).	• Post VoiceThread info • Lab #1 (inclined plane) and +- instructions. • 1st half of Ch.2 ppt notes.	MP tutorial	• OISE stuff not ready yet. • Worked on graphs and did clicker questions. They really responded well to the clicker questions and it despite my saying it twice they talked a fair bit before voting the first time. ~~• Need to find/develop a tutorial for DataStudio~~ ~~• VoiceThread activity: Have students analyze video clips ….~~VoiceThread stuff not ready yet.
3	Tue	• Ch.2.4&5 (1D constant accel & free-fall) – ***FINISH CH.2*** • Free-fall (Moon) video & Freefall Demo	• Clicker Q's • Solve problems	• Ch.2 – part 1 and 2 MP Ass.	• Procedure for solving kinematics Q's	Ch.1 MP Ass. RW 2.4&5 ~~DataStudio tutorial~~	• Solve 3 long questions • **Finish Ch.2** • Didn't finish ch.2 – only got through the clicker Q's and the first problem (throwing keys up). Class was OK – I was tired, some of my clicker slides were giving me troubles, and I could have been better using the SmartBoard (need to scroll down as I'm doing the problem). Students were low energy too (due to me, the material or them??) but the clicker slides where they have to pick the list of knowns and unknowns based on the reference frame are important.

Week # & day	Planned Material	Active components	Assigned work	Post/handout	Due	What was done & comments
Wed (L3)	• Lab exp.#1 Quiz (including uncert.) • Lab exp #1: Puck on inclined plane	• Lab exp.	~~• Uncertainty Assign.~~ •	• Post Ch.2 ppts & alternative sols to class problems		• Group lab report #1: focus on graphs, data tables and analysis. Have them find the Sci. Student Handbook on FC and use the instructions to make graph #1. • The lab went very well – they seemed to be prepared and had no trouble getting started. They worked very well in groups. They were efficient and seemed to be delegating tasks within groups effortlessly. I didn't have to push any of the groups to get going. I don't know if it's the fact that these are reform kids but they seem stronger when it comes to doing experiments – especially at drawing graphs (they were really good!). • Before the end of the lab period I showed them VoiceThread and asked them to have a look at the video (Jet, car & bike drag race) I have uploaded for them and comment over the weekend.

Continued ………

APPENDIX F

Teacher Questionnaire Related to Impact of New Lab/Classroom Space Fall 2009

New physics labs F09 Questionnaire

Teacher's name: ______________________________ January 2010

This questionnaire is designed to assess your experiences and opinions about teaching in the new Physics Labs 7A.2 and/or 7A.6.

1. Did you teach in **BOTH** of the new physics labs 7A.2 and 7A.6? (check box)	Yes		No	
1a. If yes, would you say that the teaching and/or lab experience was equal in both labs? (check box)	Yes		No	

1b. If no, in which lab did you prefer teaching or giving labs? (check box)	7A. 2		7A. 6		Neither

1c. What would you say is the biggest difference between the two labs?

2. If you taught only in **ONE** of the two labs, which lab was it?	7A.2		7A.6	
3. Whether you taught in both or one of the labs, did you enjoy the overall experience of teaching in this new environment?	Yes		No	

3a. If yes, what particular features of the labs did you most enjoy? (circle answer)	The new technology: Smartboard & screens	The physical design: Seating arrangement	Both technology & design

Please elaborate:
3b. If no, what particular features did you dislike?
4. How does the new lab compare to teaching in traditional labs?

5. How does teaching in the new lab differ from giving a lab in the new labs?		
6. What were the major adjustments you had to make in teaching in these new labs?		
7. Did you attend the Ped Day workshop on how to use the Smartboard technology?	Yes	No
7a. What was the most useful aspect of this workshop?		
8. Did you attend any Ped Day workshops on how to use new pedagogies such as collaborative work, or peer-to-peer instruction?	Yes	No
8a. What was the most useful aspect of the workshop?		
9. Did you request any other pedagogical advice to help you teach in the new labs and encourage your students' interacting with each other and with your course materials?	Yes	No
9a. If yes, what help or suggestions did you get?		
10. What other help might you need to improve the use of the new technology or the new pedagogical potential of your students' learning in the new lab design?		
11. What did you as a teacher notice about the students' learning in these labs?		
12. What other experiences (anecdotes), advice or general comments about teaching in the new labs, or any of the classrooms, are you willing to share?		

Follow up Questionnaire _Winter 2011

New physics labs Questionnaire

Teacher's name: ___________________________ Winter 2011

This questionnaire is designed to assess your experiences and opinions about teaching in the new Physics Labs 7A.2 and/or 7A.6.

<table>
<tr><td colspan="2">1. Did you teach in the new physics labs 7A.2 and 7A.6 this past year (2010-11)?</td><td>Yes</td><td></td><td>No</td><td></td></tr>
<tr><td colspan="2">2. Did you enjoy the overall experience of teaching in these new environments?</td><td>Yes</td><td></td><td>No</td><td></td></tr>
<tr><td>2a. If yes, what particular features of the labs did you most enjoy?</td><td>The new technology:</td><td>The physical design:</td><td colspan="3">The technology & the design:</td></tr>
<tr><td colspan="6">Please elaborate:</td></tr>
<tr><td colspan="6">2b. If no, what particular features did you dislike?</td></tr>
<tr><td colspan="2">3. Since the availability of the new labs (2009-11), have you taught in the old labs?</td><td>Yes</td><td></td><td>No</td><td></td></tr>
<tr><td colspan="6">4. After having two years of these new labs, how do these new labs compare to teaching in traditional labs?</td></tr>
<tr><td colspan="6">5. What were the major adjustments you had to make in teaching in these new labs, if any?</td></tr>
<tr><td colspan="2">6. Since having the new labs and technology (e.g., Smartboard, Pasco lab equipment) have you had any workshops in your department or Ped Day (or other opportunities) on how to use or benefit from the use of these technologies?</td><td colspan="2">Yes</td><td colspan="2">No</td></tr>
</table>

6a. If yes, what was the most useful aspect of these workshops or opportunities?		
7. In the past year have you attended any workshops or other opportunities to learn about pedagogies that might add to your teaching and the learning experiences of your students?	Yes	No
7a. If yes, what was the most useful aspect of these events?		
8. In the past year have you requested any other pedagogical advice to help you teach in the new labs and encourage your students' interacting with each other and with your course materials?	Yes	No
8a. If yes, what help or suggestions did you get?		
9. What other help might you need to improve the use of the new technology or the new pedagogical potential of your students' learning in the new lab design?		
10. After two years of teaching in these new spaces, do you have any general or specific thoughts on the usefulness of such environments? In other words, what might you wish to share with others who are thinking of implementing such changes to their teaching spaces?		

APPENDIX G

Coding Key for student interviews

Epistemic beliefs about teaching		Epistemic beliefs about physics						Affective beliefs
teacher authority	shared authority	Describes the ways that students view the discipline of physics.] This includes the following:						describes the ways students view their teachers. This includes the following:
Describes the ways students view the role of the teacher and listening to him/her as being the voice of authority within the classroom. This will include the following:	Describes the ways students view their participation in the classroom and their shared role in their learning. This will include the following:	physics is about process	physics is visual	physics is about the real world	physics is about learning formulas	learning physics requires work	physics is experiential ly mediated	
the need to listen to the teacher (hear, listen, explain)	the need to participate in the classroom and particularly work with others to create understanding (interact with other, work in groups)	the belief that learning physics is about steps to solve a problem; about a process (following steps to solve problem, etc.)	the belief that physics is different from other sciences and math (physics is visual, etc.)	belief that physics is about the real world (understand ing how the world works, how things work, etc.)	learning formulas to pass exams (exams, quizzes, etc.)	the belief that learning physics requires doing hard work (practicing problems, trying hard to understand, etc.)	the belief that learning physics is bound up experiential activities	the need for the teacher to capture your attention the need for the teacher to be enthusiastic, finding multiple ways to relate the material, to reach students (interactive, wants you to succeed)

the need to see and record what the teacher is saying (taking notes, seeing what is written, facing the teacher)	the need for conversation and discourse as part of the learning process (freedom to ask questions, discussion, knowing what you don't know) (metacognitive)			spontaneous (un aided) noticing that physics in their day-to-day lives.				
depending on the teacher to determine what is important (telling, waiting for teacher, putting thing together)	the need for multiple sources of knowledge particularly experiential learning (watching /participating in demonstrations, time to practice)							
teacher *makes* the students understand	teacher *helps* the students to understand							
ownership of learning is handed over to teacher, students express an "it's not on me" sentiment.								

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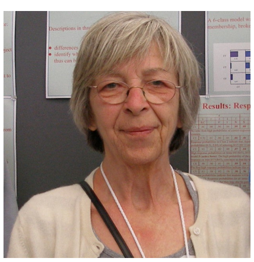

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The End