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Scaling Up Socio-Technological Pedagogies

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

ABSTRACT

This research was divided into two themes. The first examined the effects of teaching and learning environment. The second examined the effects of such environments on the adoption by teachers of student-centered active teaching. The results of Study 1 indicate that the teaching approach is essential. Students who received an active learning pedagogy achieved better conceptual gains in physics. Also, students in active learning pedagogy were more willing to take the opportunities offered by new environments compared to their peers taught with traditional pedagogy. However, the socio-technological framework on its own does not seem to have any effect per se on conceptual learning. Study 2 shows the positive impact of socio-technological environment for teachers willing to make the jump to the active learning approach. Finally, Study 2 indicates that teaching approaches are strongly related to a change in the ways students' approach learning (i.e., greater self- regulation of their learning).

introduction

In 2006 the Ministère de l'Éducation, du Loisir et du Sport (MELS) began its effort to change the face of science education by instituting approaches to teaching that are based on years of research in the fields of educational psychology and the learning sciences -- known as the Québec Education Program (QEP). These changes include making teaching more student-centered, providing students with greater opportunities to learn through their own investigations and doing so while working with peers. Such pedagogical approaches have been called "active learning" and are informed by social-constructivist theories of learning[1]. More recently, there is growing interest in designing classroom environments to enhance the benefits of the educational reform by providing facilities that allow students to work together in more natural and regular (ongoing) fashions.

Interest in changing pedagogical approaches and changing the design of traditional learning spaces is a growing concern both at the local level as well as internationally. Heralding the growing acceptance of such thinking a *New York Times* article entitled "At M.I.T., large

[1] Active learning includes the following activities related to types of implementations of this pedagogical approach: Think-Pair-Share (Peer Instruction teaching approach); Analysis and problem solving (Problem Based Learning (PBL), Project-Based Learning, Learning by Design (LBD), Inquiry-Based Instruction approaches; less structured activities (j*ust-in-time-teaching*, reflective journals, other writing).

lectures are going the way of the blackboard" (Rimer, January 13, 2009) reported on the redesign of classrooms and lecture halls at American Ivy-league universities. Examples of these projects are 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).

While there is a growing body of evidence showing the efficacy of active learning pedagogies we continue to face many unknowns regarding how to change teaching and learning practices. Additionally, there is still little research into the efficacy of the new learning environments and how they might be best used to enhance the learning experience of students. The objective of this project thus was twofold: (1) to investigate whether and how student-centered Active Learning (*SCAL*) pedagogies influence students' conceptual understanding of introductory physics; and (2) to investigate how teachers take up these new pedagogical approaches and use the new physical spaces and technology (*Socio-Tech* environments).

Problem Statement

This study took a system's approach to identify problems at the level of the student and at the level of the teachers that relate to both the implementations of new pedagogical approaches as well as the use of technology and new designs to learning environments.

At the level of the students

Until recently student-centered active learning pedagogies have been limited to a number of factors. A major area of interest has been the experiences of elementary or secondary school students in urban sectors of the USA (e.g., Blumenfeld, Fishman, Krajcik, Marx & Soloway, 2000). When students from higher education have been included, this research generally has been conducted at ivy-league school such as Harvard University where students are high achievers (Crouch & Mazur, 2001). As this pedagogy begins to be scaled up into general practice new and important issues come into play. For instance, what are the implications of this pedagogy on the different segments of the student populations – high and low prior knowledge, gender differences, and so on.

An important feature of this new thinking about instruction is the redesign of learning environments and the use of technology as a way to facilitate student-student collaboration. While these changes are intuitively appealing there is little formal research in this area.

Consequently, we need to understand more about the impact of active learning pedagogy in higher education. 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?

At the level of the teachers

Preparing and supporting teachers in their efforts to add new pedagogical approaches as well as use new technologies and new environments that offer different opportunities for learning is no small feat. Dillenbourg and Fischer (2007) argue that it would be simplistic to think that the teacher's roles in student-centered instruction as merely changing from "the sage on the stage" to "the guide on the side." In fact, these new pedagogies require a redefining of what the teacher does. The literature suggests that instead of “telling” teachers are expected to “model” and support, or “scaffold,” the type of thinking that is part of the discipline of study – a process that is called *cognitive apprenticeship* (Collins, Brown & Newman, 1987).

Furthermore, the literature suggests that the teacher’s role is to *orchestrate* classroom activities without being at the centre of the instruction (Fischer & Dillenbourg, 2006). In doing so they are expected 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).

Accomplishing such changes raises many important and urgent questions related to the skills and capabilities required by teachers to effectively use student-centered active learning (SCAL) pedagogies. For instance, what does it mean to use active learning pedagogy in teaching? Equally important is the culture of teaching and the beliefs teachers have about their role in the classroom.

The world of teaching is steeped in tradition and a culture of teaching whereby many believe that a teacher-centered approach is best. The sentiment being that if it worked for me it will work for my students. Recent studies, however, have begun to show that teacher-centered approaches have an adverse impact on students’ approach to learning (Biggs, Kember & Leung, 2001; Kim & Branch, 2002; Trigwell, Prosser & Waterhouse, 1999) – these results coming from the aggregated data of the class and not from individual students.

Furthermore, research tells us that it is difficult for teachers to change their practice and face many obstacles in the process (Laferrière & Gervais, 2008). These include the development of deep understanding of the key tenets of social cognition and the contradictions that arise between their own experiences of learning and this new paradigm.

Research Questions

Questions arising from such research relate to the process of preparing and supporting teachers as they gain the skills, experience and expertise to effectively use the student-centered Active Learning pedagogies and new physical spaces/technology. Broadly speaking, this research was divided into two studies and looked at the following questions:

Study 1: What is the impact on learning when students are taught with Student-Centered Active Learning (SCAL) pedagogies; what impact does the new physical spaces/technology (Socio-Tech environment) have on this learning? In particular, which is more germane to students’ conceptual learning, pedagogy or physical spaces/technology?
Study 2: How do teachers come to use active pedagogies and the new physical spaces/technology effectively?

Methods

To make this section easier to read we will describe each study and its results before moving on to the next. We start with Study 1.

Study 1

It was divided into two parts – part A & B. Participants in both parts of Study 1 were first year Cegep Science Program students enrolled in the introductory physics course Physics NYA-Mechanics and between the ages of 17 – 19 years. While the gender distribution was somewhat different in each section overall there was approximately 50 percent males and females in the study.

Part A was a comparison between two pedagogical approaches (student-centered Active Learning and Traditional Instruction) taught in two different types of learning environments (Conventional and Socio-Technological). This comparison between groups was assessed using the *Force Concept Inventory* (FCI; Hestenes et al., 1992). The FCI is a 30 item test and is "the most widely used and thoroughly tested assessment instrument" in physics (McDermott & Redish, 1999).

In this study FCI data from three years were aggregated - F08, F09 and F10. The total number of students participating in part A was 407.

The FCI data were analyzed using the statistical procedure called an ANCOVA, an analysis of covariance. Results from these analyses allow for comparisons between groups while accounting for prior knowledge differences (i.e., what students know before instruction). Simple conceptual knowledge gains are calculated as the differences between pre-test and post-test scores. This study used a normalized gain, which is defined as follows:

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

Part B was a qualitative case study designed to investigate how students instructed with the two pedagogical approaches (student-centered Active Learning and Traditional Instruction) in the same Socio-Technological environment perceived their learning experience. The data for this study were collected using targeted interviews from 34 students from both the SCAL pedagogy and the traditional pedagogy with an equal number of male and female students. The interviews were analyzed using a mix of qualitative analysis involving emergent coding techniques and discourse analysis to extract common themes and understandings.

Results Study 1

Part A results. Analysis of the FCI data showed that students have increased conceptual gains when taught with a student-centered Active Learning (SCAL) 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 have less productive effects (see Figure 1).

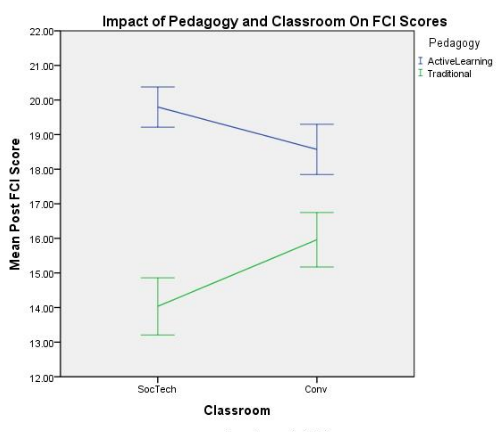

Figure 1. Active learning (blue line) generates more conceptual gains than traditional pedagogy (green line). The socio-tech environment produces optimal conceptual gains only in conjunction with an active pedagogy. In the presence of traditional teaching methods, socio-tech environment is less effective than the traditional ones.

Another interesting finding is that those who benefit most from student-centered Active Learning pedagogies are the students with lower prior knowledge. These results counter the argument that SCAL pedagogy works mainly with high performing students in elite institutions, such as Harvard and MIT students.

What more can be learned about the role of the environment? While the results above shows a relationship between pedagogy and classroom environment more questions remained. For instance, we were interested in understanding whether space alone (Soc-tech environments vs. Conventional classrooms) had an impact on learning. Specifically, is learning affected by the opportunities available in the physical environment? And are the differences between students' incoming knowledge a factor? To answer that question we compared the FCI results of students in Soc-tech environments to students in Conventional classrooms (i.e., isolating space from pedagogy). These results showed a marginal increase in conceptual gains for students with high incoming-knowledge, whereas, students with low incoming-knowledge showed a marginal decrease. These findings raise some concerns that need to be addressed with regard to physical design. At the extreme, it tells us that we need to pay more attention to supporting certain kinds of students. At the minimum, it tells us that the space alone may produce counterintuitive results when pedagogy is not considered. Either way this issue requires further study.

Part B results. Analysis of the focus group interviews uncovered several important differences between students taught with a student-centered Active Learning pedagogy (SCAL groups) and those taught in a traditional teacher-centered pedagogy (Traditional groups). These differences can be classified into three categories: (1) beliefs about in-class learning; (2) beliefs about learning physics; (3) beliefs about the role of the teacher.

1. Beliefs about in-class learning

This category was subdivided into two categories: (a) teacher-authority and (b) shared-authority. The analysis showed that students taught in the student-centered Active Learning pedagogy, compared to peers in the teacher-centered traditional pedagogy, were less likely to view learning as merely the responsibility of the teacher. Additionally, they were twice as likely to view learning as a process that requires their participation and interaction with peers. In other words, the student-centered Active Learning students saw it as their responsibility to collaborate with others and they valued the opportunity for peer teaching.

This can be seen in their comments. For example, one student expressed how trying to explain or defend his understanding of a physics concept to his peers was critical to his learning. Another student recognized the wider effect of these classrooms when he noted the global applicability of building group interaction skills early on.

2. Beliefs about learning physics

The beliefs about learning physics category was classified into four sub-categories: (a) views learning physics as learning about processes and procedures (*process*), (b) spontaneously relates physics to real world phenomena (*real world*), (c) believes that it requires their personal effort to learn physics (*requires effort*), and (d) believes that understanding physics as increased by having access to a variety of experiences in the classroom (*experientially mediated*).

(a) *Processes*: results showed the student-centered Active Learning students were less likely to view physics as mainly about processes. Meanwhile, students taught with teacher-centered traditional instruction saw this as a major component of learning physics.

(b) *Real world*: during the interviews students taught with student-centered Active Learning pedagogy spontaneously mentioned occasions when they took the opportunity to apply what they had learned in their course to situations outside of classroom. This type of unprompted recollections of applying physics to real life was not present in the conversation of the teacher-centered traditional pedagogy students. Such results are consistent with other research that tells us that with traditional instruction, generally, students tend to isolate what is learned in science class from what experiences in their daily lives (e.g., Entwistle, 2010).

(c) *Requires effort*: this topic was identified as a separate category because of the frequency with which the student-centered Active Learning students commented on the need to work hard. Additionally, they mentioned how they learned by engaging in the classroom activities, and saw the benefit of this extra effort. The students in the teacher-centered traditional groups generally did not talk about putting out effort to learn. A reasonable explanation for this difference is that the SCAL students were becoming more self-regulating in recognizing how they learned and the kinds of effort necessary to learn deeply.

(d) *Experientially mediated*: once again this topic was identified because of comments that arose more frequently in the student-centered Active Learning pedagogy groups. They talked about the benefit of the frequent demonstrations and classroom activities that called for their participation. In this instance there was specific reference to the value of the new physical spaces/technology (i.e., the Socio-Tech environment), which allowed these types of demonstrations and interactions to occur easily. Students in the teacher-centered traditional instruction did not make such comments.

3. Perception of teacher category

There were twice as many mentions of this factor in the student-centered Active Learning pedagogy groups compared to the teacher-centered traditional pedagogy groups. The SCAL pedagogy students more frequently 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.

Study 2

Study 2 was separated into three parts:

- Part A: a case study narrative documenting the professional development of a student-centered Active Learning pedagogy teacher;
- Part B: a case study involving several teachers who taught in the Socio-Tech environment; and included a qualitative analysis comparing and contrasting differences between these teacher's self-reported perceptions with the field observations of their classroom teaching; and
- Part C: a case study of interviews on the use of the new environment.

Participants in Study 2 were six teachers. The majority was male. They fell into two groups in regard to their teaching experience: (1) 3- 5 years, and (2) 10 - 15 years. All six taught a section of the introductory physics NYA course scheduled into the new physical spaces/technology (Socio-Tech environment). All six teachers could be described as attempting to implement some aspects of active learning in their classrooms. However, most teachers were not actively taking part in formal pedagogical development toward these ends.

The data collected for Study 2 include: classroom observations, teacher interviews and the *Approaches to Teaching Inventory* (ATI) questionnaire (Trigwell & Prosser, 2004). The ATI has been used to investigate the relationship between teaching and learning and has two scales: (1) the conceptual change/student-focused (CCSF); and (2) information transmission/ teacher – focused (ITTF).

Results Study 2

<u>Part A:</u> 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 a set of guidelines that we relay in the conclusion of this article. We believe these will help others in their professional development.

<u>Part B:</u> based on the self-reported answers to the ATI questionnaire the six teachers were categorized on the two scales mentioned above (see Figure 2). Generally, the six teachers did not score high on either scale, with one exception. Most interesting was that those teachers who scored higher on the CCSC scored low on the ITTF, and vice versa. Thereby creating a way to quantify the observed differences between teachers. The data collected from the classroom observations was coded and those results highly corrects with these student-centeredness scales for these six teachers. Thereby supporting the use of the ATI as a way to assess teacher's pedagogical approaches.

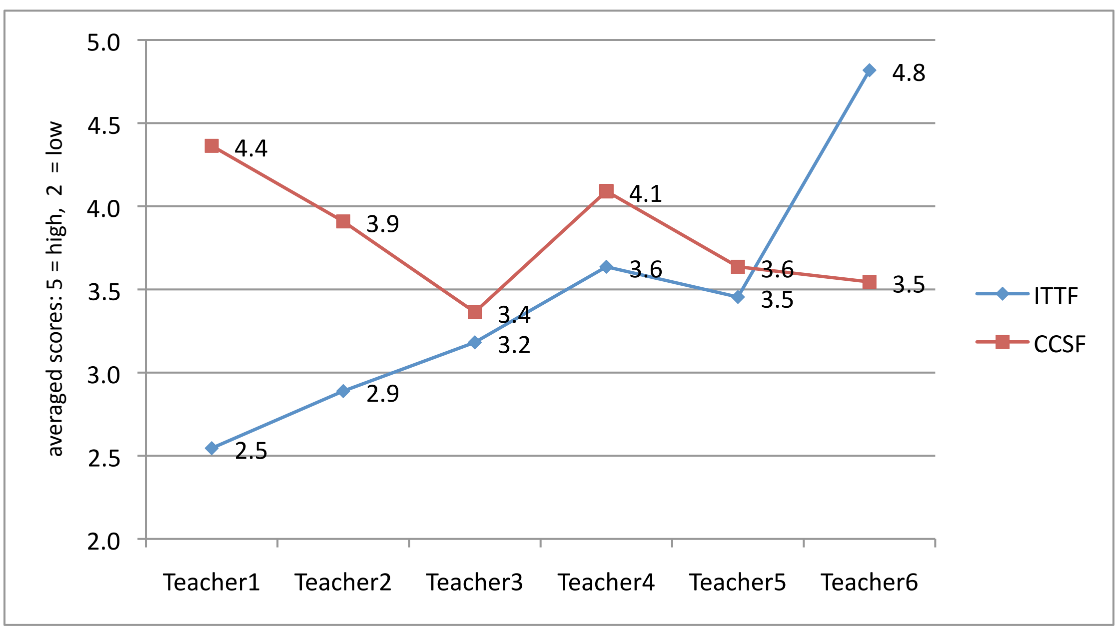

Figure 2. Self-reporting of the 6 teacher on the extent of their approach to teaching - student-centered approach (CCSC) or the teacher-centered approach (ITTF). As the ITTF increases the CCC decreases.

Implications of the Approach to Teaching Inventory (ATI). The results of the ATI were highly correlated with several factors. First, the ATI rankings correlated highly with the coded observations of these teachers classroom practice. Thus supporting the validity of the ATI as a way to assess teacher's approach in a given context.

Second, the ATI correlated highly with students' physic conceptual knowledge gains (FCI normalized gains). That is, teachers' self-report of how student-centered their practice is correlates highly with students' conceptual learning.

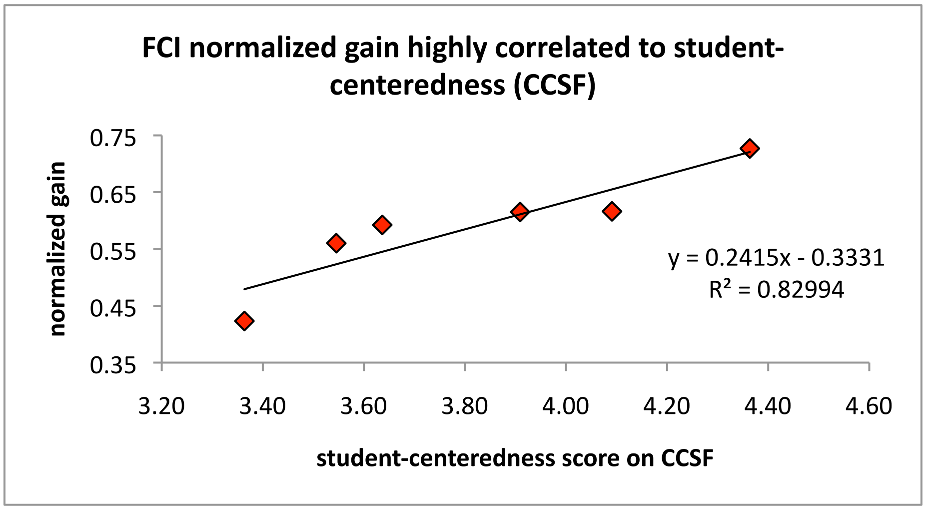

Figure 3. High correlation between students' conceptual gains and the teacher's self-reporting on the ATI student-centeredness scale (CCSC).

This result is surprising but is consistent with the growing body of evidence that shows student centered Active Learning pedagogies improves students' conceptual knowledge gains (Trigwell, 2010). Furthermore, these findings give us courage to continue the effort to explore further the relationship between teaching and learning. As Trigwell states, we need to continue to reassess how we "define good teaching."

Part C: analysis of the interviews showed that the new physical spaces/technology (Socio-Tech environment) had a positive impact on over half of the six teachers. The layout and technology of these new spaces encouraged and supported those teachers in their efforts to change their pedagogy.

CONCLUSION

This study studied simultaneously the impact of active learning pedagogy and use of new socio-technological environments by teachers and students. A variety of research methods were used to investigate and answer the research questions, which also helped to triangulate our results.

The main findings show that we cannot simply change classroom environments but need to focus on changing pedagogy. In essence, pedagogy is paramount to improving learning. The role played by the new physical spaces/technology is to complement and amplify aspects of the student-centered active pedagogies. These environments help students become more aware of how they learn and how they can benefit from learning with others. In the process making students more self-regulating.

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 the teacher to keep in mind when designing for student-centered active learning:

- Designing lectures: 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.
- Designing demonstrations: 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.
- Designing collaborative activities: 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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