AC 2010-1822: USE OF SITUATED COGNITION AND CONSTRUCTIVIST THEORIES TO TEACH MOVEMENT SCIENCE IN BIOMECHANICS

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Use of Situated Cognition and Constructivist Theories to Teach Movement Science in Biomechanics

Abstract

It is estimated that students now graduating will pursue as many as five careers in their lifetime. This puts increasing pressure on instruction to expedite a student’s ability to transfer what they have learned in the classroom to many applications. Many times the learning experiences students have in the classroom become isolated and limited because of the lack of context in which the learning experience occurs. With this in mind, a Movement Science in Biomechanics course was designed to enhance learning experiences by tying the course objectives to the context of clinical applications. According to situated cognition theory, students learn best by doing what experts in that field are doing. Activities were designed based on the typical activities in a motion and gait laboratory including kinematic analysis using inertial sensors and goniometers, kinetic analysis using a force plate, and muscle activity using electromyography technology.

Each activity was introduced as a goal-based scenario in which the groups constructed the necessary knowledge needed to solve a problem in their own way and justified their solution through a report and/or presentation. Scenarios included characterization and optimization of a golf swing, ground forces associated with an ACL tear, and muscle recruitment and activity during cycling. Problem scaffolding based on constructivist theory was necessary to develop the skills and schema to solve the scenarios without cognitive overload. To do this, students were divided into subgroups in which they became “experts” with one of the skill sets and technologies. Collaborative groups were then comprised of several different “experts” that worked together to solve the goal-based scenario. Dependence on each of the group member’s expert skills encouraged individual accountability within the group. The groups pursued a research question of their own for their final project which was based on multiple technologies and skills sets learned throughout the class.

Students’ pre- and post- test performance on statics and force concept inventories were compared. Perceptions of learning gains and expert experience were assessed through student interviews and surveys. We will report on these results and discuss implications and limitations on learning through constructed contextual knowledge based on situated cognition and constructivist theory.

Introduction

Study Abroad Program Description

Movement Science in Biomechanics was taught as part of a study abroad program that took place during a Maymester session of 2009 in Brussels, Belgium. This 5 week program
incorporates six hours of instruction divided between a technical elective (Movement Science in Biomechanics) and a humanities course based on the culture and history of Belgium and the corresponding area. Students are housed in a long term living facility in downtown Brussels and attend classes at a university within the city. The cross-cultural course is taught by a professor associated with the Belgian university while the technical elective is taught by the sponsoring university’s faculty. Students attend the biomechanics class three hours a day, three days a week, usually from 9 am to 4 pm.

Course Description

Movement Science in biomechanics is an application based course for sophomore to senior level students which applies principles and concepts of biomechanics, including statics, dynamics, and physics to motion analysis. Within the course students are expected to utilize various bioinstrumentation to collect and analyze data for various human motions and apply biomechanics concepts to quantify and characterize these motions.

Description of Students

Nineteen students from the sponsoring university participated in the Movement Science in Biomechanics class. Within the class, the majors included: 14 bioengineering, 2 mechanical engineering, 1 computer science, 1 civil engineering, 1 chemical engineering. All students had completed their sophomore year and 1 student had completed their junior year classes. There were 6 females and 13 males. All students had taken at least one semester of physics. The bioengineering students had taken statics the previous semester (Spring 2009) along with the mechanical engineering students and civil engineering students. The computer science student and chemical engineering student had not taken statics. One of the mechanical engineering students had taken a combined statics/dynamics class and the civil engineering student had taken but not passed dynamics. Two of the bioengineering students had also taken biomechanics in during the Spring of 2009. From survey results, all students but two had a positive overall attitude toward their engineering department. The other two were neutral.

Theoretical Framework

The theoretical framework for this was based on situated cognition theory and constructivism. Situated cognition theory suggests that knowledge is a matter of competence related to a valued enterprise and that knowing is a matter of participating in the pursuit of such enterprises. Meaning therefore is the ability to experience the world and have a meaningful engagement into it. Ultimately, this is what learning is to produce. The purpose of this in-class activity was for the students to have a meaningful engagement of their prior learning toward a real world experience. Two main attributes of this theory were used in the design of the in class demonstration: anchored instruction and authentic activities. Anchored instruction has been used as a means of implementing the conditions of situated learning. A situated context based on an objective question is provided for a more complex and realistic problem.
The students must rely on their prior knowledge to lead them through the problem solving process, leading them to answer the objective question. The students pose questions to decide what information they already know, what information they will need to find, and how to group this information together. Considering the classroom as a learning community, the emphasis is on distributed expertise in which the students come to the learning task with different interests and experiences. As a learning community, students offer their experiences as a way of sharing meaning and understanding of the activity as a means to answering the objective question.

To distinguish between an authentic activity and a school activity, an authentic activity is most simply defined as the ordinary practices of the culture of interest. The culture of interest in this case was the biomechanics that would take place in a motion and gait analysis laboratory. Because this activity took place within the classroom, contextual features were needed to most closely resemble this culture such as the force plate, electronic goniometers, electromyography (EMG) sensors, and inertial measurement units (IMU’s) which are comprised of accelerometers, gyroscopes and magnetometers. Students participated in the experiment to collect data as they would in the approximated culture. Observers took on the role of scientists, analyzing and discussing what methods could be invoked to correctly model the observations. In this way, the demonstration more closely resembled the actions of participants in that culture. The student takes on a role of participant or observer and then communicates back to the learning community in the interest of answering the objective question. It should be mentioned that there have been efforts to use similar efforts in a large classroom environment through the “SCALE-UP” project although there are limitations due to equipment availability and in simulating a laboratory environment.

According to constructivist theory, students construct new knowledge by trying to make sense of new experiences. The students test different mental models or structures till one emerges as an appropriate fit. As conflicting experiences occur, the student adjusts the mental model to encompass this new experience (Perkins, 1991a). The more conflicting experiences that are encountered, the more generalized the model becomes to include more abstract situations. Learners must have some viable way of testing their observations with the world around them which usually comes in the form of teachers and more advanced peers (Matthews, 2003). In this class, the team members would consult their “expert” in the group to make sense of the data collected and observations with the various measurement devices. Through discussion, report writing and presentations, the students revise their mental models to reflect their understanding of the related concepts.

Figure 1: Students became “experts” with particular technology to share with future groups.
Activity Design

Students were first divided into groups to become “experts” with a particular measurement device or technology (Figure 1). Each group did an activity which allowed them to explore the functionality and capability of the devices and apply it to a simplified biomechanics application. Students in the IMU expert group attached an IMU to a golf club to identify what data was collected for different translations and rotations and characterized the functionality and capability of the IMUs. The other expert groups conducted similar activities with their prospective devices in order to master the skills necessary to use the devices in future activities.

These expert groups were then divided up into other groups so that there would be at least one “expert” for each device in their group (Figure 2). Each group project focused on a particular technology or measurement device application. The following activities were included in the class: characterization of a golf swing, anthropometric assessment of a patient with a lower limb implant, quantification and characterization of an ACL rupture, muscle activity and recruitment during cycling and a final research project chosen by the group. To help with accountability, the “expert” was responsible for explaining the use of measurement devices and help with data collection and analysis. Each group member would have a turn being the expert with a particular technology.

Results and Discussion

Pre and Post tests were given for the Statics Concept Inventory (SCI) and for the Force Concept Inventory (FCI). A reflection group was also conducted after the course to observe students perception of learning gains and assessment of their expert experience. There were no significant differences between the SCI and FCI pre and post tests which may be expected due to the small class sample size and the contextualization of the course compared with the abstract nature of the concept inventory. The results of the reflection group provide better evidence of the effect of teaching with situated cognition theory and constructivist theory.

Students were asked to participate in a reflection discussion group at the end of the following semester to try and capture associations between the previous Movement Science course and following work experiences and classes. The goal of the reflective discussion group was to...
assess students’ educational experiences to their overall professional formation. This protocol followed a four step accidental competency discourse where students are asked to recall positive or negative experiences which are then analyzed for learning outcomes. The four step strategy consists of the following four steps: Situation, Affect, Interpretation, and Decision (SAID). The first step starts with providing prompts to the students to elicit the positive or negative experiences (Situation, S) and to get the students to elaborate on what actually happened. The next step was to ask the students how it affected (A) them personally. The students were then asked to interpret (I) what they learned from the experience and finally asked to decide (D) what they would do to become a better engineer because of the experience.

Five students participated in the discussion group consisting of four bioengineers and one mechanical engineer. Three of the four bioengineers were female and the other two participants were male. In this paper, the following will be used to reference the various students.

<table>
<thead>
<tr>
<th>Student Name</th>
<th>Student attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student A</td>
<td>Female, Bioengineering, torn tendon in leg</td>
</tr>
<tr>
<td>Student B</td>
<td>Male, Mechanical Engineering, Internship</td>
</tr>
<tr>
<td>Student C</td>
<td>Female, Bioengineering, reference to gait analysis laboratory field trip</td>
</tr>
<tr>
<td>Student D</td>
<td>Female, Bioengineering, Interviewed for Co-op</td>
</tr>
<tr>
<td>Student E</td>
<td>Female, Bioengineering, Internship</td>
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</tbody>
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Several of the students discussed the benefit of visualization of the course activities in future classes, particularly when there were no visualization tools. Students were able to construct their own mental models for future applications. During the discussion group, Student D discusses taking biomechanics the semester after the study abroad class. She states

“[student C] and I appreciated the hands-on of the study abroad class. The [teacher] does derivations on the board but are hard to understand. When you can see your class mate twisting on the force plate…you can see data…it like helps you understand it…[I]t’s hard but having the background of the biomovement class has helped me…I really understood the stuff we did this summer. I would say the hands-on really helped for retaining [new classwork].”

This evidence showed the relevance of teaching the course using situated cognition theory and to allow the students to construct their own mental models through active learning activities.
Students also discussed how they were more confident with the subject matter outside the classroom and were able to apply it in “everyday” situations. Student A recalled tearing a tendon in her foot during the summer after the study abroad class and going to the doctor’s office. She elaborated that:

“I could visualize how my foot was twisting when I tore the tendon. I made the podiatrist go up to the board to explain how my tendon was formed. It was just nice to talk to the doctor as a student in his practice.”

This student was particularly shy and this interaction showed a change in her confidence with the subject matter. During the study abroad class, this student had trouble taking a leadership role when playing the “expert.” Changes in self efficacy relative to the course material translated into self-confidence outside the classroom.

After reflecting on job experiences including co-operative education and internships, students discussed major transformations in their outlook on their education and how they would change their approach to learning. This brought up discrepancies in the classroom environment and suggestions for future classes based on situated cognition and constructivism. For example, Student B had an internship immediately following the study abroad course. He comments on his internship experience and the changes in his outlook toward school because of the experience in his internship.

“It made me realize why I’m going to school. I was with a small group of engineers. …they would be way over my head….they would use concepts so broadly to describe everything around me…I could only pick up key words and remember definitions. I felt so in the dark”

He was asked to (D) decide what he had done to become a better engineer because of it. Student B states:

“It made me always look at the big picture and how everything connects. Instead of just mindlessly plugging in numbers….take a step back and ask why is it happening. ….see a car passing by and wondering where the energy is coming from…you can apply [these concepts].”

When asked what improvements could be made to the next summer class, he writes:

“have students explain why they are taking certain steps at solving problems, make sure everyone in the group is on the same page, if one student cannot explain the first step verbally then they true don’t understand the concept.”

Student B not only shows how the work experience changed his outlook on his education but how important it can be to provide this type of situating learning environment in the classroom.
Conclusions and Future Work

It is important to focus on bringing the transformational process from academic preparation to the work environment into the classroom. Co-operative education and internships often are not required and usually take place later on in a student’s academic career. If some of the transformations that students experience through co-operative education and internships can be brought into the classroom, it might help change student motivation and mental models to more appropriately adapt their learning to transfer to the work place. This gives support to learning theories that focus on situated cognition and constructivism where the learner must approximate those social and intellectual interactions that can cause these transformations in outlook. This movement science in biomechanics course provides evidence how situated cognition learning theory and constructivism can affect student learning and their application to future learning by helping to retain knowledge and adapt mental models for better application and transfer to different contexts.

Future work looking at further analysis of SCI and FCI concept inventory analysis to look at specific concept knowledge by item analysis. Future assessments may look at the transfer of conceptual knowledge in different domains and context. For example, how does rotating reference frames through space applied to the human body transfer to rotating protein molecules in different orientations and conformations. Additional assessments to differentiate between the expert and non-experts knowledge throughout the activities will also be added for future classes.

Additional reflection focus groups will focus on interviewing co-op or internship students to get additional feedback on how to improve the classroom setting to more accurately reflect the workplace environment. As educators, this study demonstrates the relevance of encouraging students to construct their own understanding in a situated cognition learning environment to more likely provide authentic learning experiences similar to a work environment so that they may make the transformation sooner to become a lifelong learner.

References

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SCALE-UP Approach in Statics, Dynamics, and Multivariable Calculus”, in *ASEE Annual Conference and Exposition* (Honolulu, HI, 2007).


