Exploration, Engagement and Inquiry in Undergraduate Education: A Case Study of Learning about Science Using LEGO® and Technology

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Abstract: This case study explores perceptions of undergraduate teacher education students, enrolled in an online course, on types of educational experiences that foster engagement in science-related courses and impact their active participation. The use of LEGO® and technology was a vehicle to implement this inquiry. The case study also provides information about faculty practices perceived as positive towards science teaching, student success and increased completion rates of college students majoring in STEM disciplines. Feedback from undergraduate students provided information on how to enhance the teaching of science online. Finally, the value of this case study not only facilitates better understanding on how to increase the number of pre-service teachers interested in STEM teaching but also to increase the number of qualified STEM teachers for public schools that will teach the next generation of K-12 students.

Introduction

Recently, the White House announced funding for a "master teacher' program for teachers who excel in teaching content knowledge and skills in science, technology, engineering and mathematics, known as STEM (Koebler, 2012). In this initiative, teachers are recognized as key in preparing children to be competitive for the jobs of the future, locally and globally. However, it is a known fact, according to Secretary of Education Arne Duncan, that STEM teachers are in short supply in public schools and many of those who teach are not qualified while those who are better-qualified leave for industry-related jobs within a couple of years (cited in Koebler, 2012). Retention is just one factor in having available and qualified STEM teachers. The bigger factor is motivating undergraduate students to pursue STEM-related majors for their college degrees. But before these students can be motivated, they need to be aware that these majors exist and must develop a common understanding of what they are (Brown et al, 2011).

The challenge of recruiting college students in STEM programs begins with the first contact with faculty and the experiences with active, creative and engaging learning activities in STEM-related courses (Smith, Douglas, & Cox, 2009; Appleton & Lawrenz, 2011). Students' perceptions of science in general and learning about science influence how they perform in these college courses. Well-designed, hands-on activities delivered by the teaching faculty influence how students respond to their college education in general as well as in the sciences.

The other challenge explored in this case study was the use of an online course delivery format involving undergraduate teacher education students. Kim and Bonk (2006) reported "online education is becoming an important long-term strategy for many post-secondary institutions" (p. 23). Revere and Kovach (2011) identified that increased use of online learning and related technologies create opportunities for innovative teaching. Further, they stated that appropriate use of technologies "can foster student engagement in the learning process" and "decrease attrition, enhance learning outcomes, and improve student satisfaction" (p. 123). Finally, Garrison (2009) argued online learning could promote collaboration and a sense of community to support student satisfaction and achievement.

The implementation of this project significantly impacted undergraduate teacher education students' perceptions in learning about science in an online learning environment. These education students (mostly early childhood and elementary majors) were enrolled in undergraduate course titled "Integrating Technology into the Curriculum" at a comprehensive university located in southeastern United States in 2013. The course was delivered 100% online.

The potential change in perceptions may help create an interest for students to consider a science-related major. The data collected about educational experiences will inform how students can be active, creative and engaging in learning discipline-specific content and skills. This has numerous implications in designing and developing instructional activities to keep students motivated to learn about science. The project provides opportunities to explore and experiment with contemporary products (LEGO®) and technology to strengthen the links to science-related content. LEGO® products are colorful interlocking plastic bricks that can be assembled or used to construct objects and taken apart to make other objects (Jensen, 2011; Mortensen, 2012). Finally, feedback received from the students provided more information on how these types of content and resources can be integrated and adapted to online course delivery.

This case study reports how the following goals were met:

1. Identify perceptions toward teaching science among college students enrolled in an online educational technology course at a university-level.
2. Explore types of educational experiences that engage students in learning about science.
3. Discuss how to design and develop active, creative and engaging teaching strategies by faculty to support the teaching of science, inquiry and integration of technology into the curriculum.

4. Use and discuss how identified resources promote student success in learning about science, inquiry and integration of technology into the curriculum.

Information is power. Knowing what type of educational experiences foster engagement in science-related courses is helpful in designing course activities for undergraduate teacher education students. Also, information about faculty practices perceived as positive towards science teaching can lead to student success and increased completion rates of college students majoring in STEM disciplines. The knowledge gained from this case study has fostered actions leading to a potential increase in the number of qualified STEM teachers for public schools to teach the next generation of K-12 students.

Research Questions

This case study provided preliminary answers to research questions focusing on student perceptions, educational experiences and resources at the end of the implementation period of an undergraduate online course focused on integrating technology into the curriculum:

1. What perceptions do these students have on teaching science?
2. What types of educational experiences engage students in learning about science?
3. What strategies used by faculty are perceived by students as positive towards learning about science?
4. What educational resources support successful science learning for college students?

Participants, Course Profile and Data Collection

Participants. Sixteen undergraduate teacher education students that were enrolled in an MEDT 3401 Instructional Technology course qualified to participate in this project. The participants included nine females and seven males with ages ranging from 21 to 28 years old. Finally, participants majored in early childhood education (6), special education (4) middle grades education (4), and secondary education (2).

The online course. MEDT 3401 Instructional Technology is an undergraduate course required for pre-service teachers to take prior to graduation. It is a survey course offered every semester and focuses on various technology-based tools that aspiring K-12 teachers can use to support the teaching of curricular content in language arts, social studies, math and science. Using LEGO® and technology to teach science was one of the hands-on projects completed in the course. Other hands-on projects were completed in the course but focused on different subject areas and technologies.

Data collection. All students completed three pre-activity surveys and three post-activity surveys. Also, the students worked in pairs to create an instructional activity focused on science and using LEGO® with technology. At the end of the activity, students wrote reflection papers about the LEGO® and technology experience.

LEGO® and Technology Experience

The LEGO® and technology experience required students to work in pairs to produce instructional material that supports the teaching of science or science-related concepts. The expected outcome of the educational experience had three components: Lesson, Video Tutorial, and Reflection.

Lesson. For the lesson, the students chose science or science-related concepts covered by a K-12 science curriculum (elementary, middle or high school) and aligned to the Common Core Georgia Performance Standards. After selecting the concepts, the students designed and developed a lesson using LEGO® available from the college. Activity packs were also available for students to use as reference in designing their own lessons.

Video tutorial. After designing the lesson, the students created a step-by-step video tutorial in using and integrating the selected LEGO® materials. Students produced multiple video clips to show each step towards completion of the project and each video clip was about 1-3 minutes in length. Video cameras were made available from the college for students to borrow and use in their projects. Finally, the students created a Wiki as an online space to showcase the lessons, and video tutorials.

Reflection. Students documented their LEGO® design and development experiences by writing a paper for submission to their professor. The following questions served as a guide in writing the reflection paper:

1. Describe and reflect on how the project made an IMPACT on your thinking about teaching.
2. Describe and reflect on how the project made an IMPACT on your thinking about teaching science concepts.
3. If others asked you what you LEARNED from this project experience, what would you tell them in terms of the knowledge/content, skills/applications, and attitudes/dispositions that you acquired?
4. What aspects of the collaboration with your partner(s) did you find CHALLENGING and how did you manage them? What aspects did you find REWARDING?
5. What have you LEARNED ABOUT YOURSELF as a learner at the end of this project experience?
6. What "SURPRISED" you about this project experience? What are your "TAKE AWAYS"? What is your "AHA" EXPERIENCE (positive) in this project that you will always remember?

Findings

Students' perceptions on teaching science. Students were surveyed prior to starting their LEGO® activity on their perceptions on teaching science. Also, students completed the same survey after completing the activity. Using descriptive statistics (mean and standard deviation) from pre- and post-survey data, researchers computed for effect size. Except for one item, "Once I start teaching science, I will find it hard to stop", most of the survey items had small or minimal change from pre- to post-activity (see Table 1).

Table 1. Student perceptions on teaching science.

Survey Item	Pre-Mean	Pre-SD	Post-Mean	Post-SD	Cohen D	Effect Size	Change
22. Once I start teaching science, I will find it hard to stop.	3.375	1.7633	4.9375	1.7843	(0.8809)	0.4031	Medium
11. Science makes me feel stupid.	3.1250	1.7984	2.2500	1.2500	0.5650	0.2719	Small
5. Knowing how to teach science is a necessary skill for me.	5.3750	1.7275	5.1250	1.9961	0.1339	0.0668	Small
6. I like teaching science.	4.6250	1.4523	4.7500	1.8540	(0.0751)	(0.0375)	Small
7. Teaching science concepts make me nervous.	3.3750	1.7984	3.6875	2.0530	(0.1619)	(0.0807)	Small
8. I feel confident with my ability to teach science concepts.	4.9375	1.4348	4.8750	1.6910	0.0399	0.0199	Small
9. I like teaching science as part of my work.	4.7500	1.3919	4.3125	1.8947	0.2632	0.1305	Small
10. I wish I could teach science more frequently.	4.1875	1.6286	4.3750	1.7275	(0.1117)	(0.0558)	Small
12. A job using science concepts would be very interesting.	4.1250	1.9325	4.2500	2.1937	(0.0605)	0.0302	Small
13. I don't expect to teach science concepts much in my work place.	2.2500	1.4361	2.5625	1.7309	(0.1965)	(0.0978)	Small
14. I'm not the type to do well with teaching science.	2.3750	1.2686	2.3125	1.0440	0.0538	0.0269	Small
15. Working with science-related concepts is boring.	2.6875	1.5297	2.2500	1.2990	0.3083	0.1524	Small
16. Learning about science is a worthwhile and necessary subject for all prospective teachers.	5.5625	1.2732	5.4375	1.4987	0.0899	0.0449	Small
17. It is important to know how to teach science in order to get a job.	4.5625	1.8361	4.8750	1.6536	(0.1789)	(0.0891)	Small
18. I know that if I work hard to learn about science, I will do well.	5.7500	1.2500	5.4375	1.6190	0.2161	0.1074	Small
19. I am able to do as well teaching science concepts as my peers or classmates.	4.8750	1.7984	5.0000	1.6583	(0.0723)	(0.0361)	Small
20. I think teaching science will be difficult for me.	3.0000	1.6956	2.9375	1.7843	0.0359	0.0180	Small
21. Teaching science makes me feel uneasy and confused.	3.0	1.7321	3.0625	1.7843	(0.0355)	(0.0178)	Small

Qualitative data was also collected from the students' reflection papers. For example, one student stated, "*This project helped me see that science is not something that can be simpl*[y] *stated in one word answers but something that takes exploration and questioning to find the answer or answers*." (S8)

*Educational experiences***.** Students were asked to choose from a list of educational experiences that engage them in learning about science. The top educational activities that engage students in learning science are hands-on activities (12), in-class exercises (12), small group activities (10), lecture (9), project-based assignments (8), in-class discussions (7) and one-on-one tutorial (7). Early childhood education students' top picks were hands-on and in-class activities. Middle grades education student identified small group activities. Special education students picked hands-on activities and one-on-one tutorial.

Table 2. Educational experiences that engage student in learning about science.

SCIENCE	Early Childhood Education	Middle Grades Education	Secondary Education	Special Education	Total
Hands-on activities	5	3	1	3	12
In-class exercises	5	3	1	2	12
Small group activities	4	4	---	2	10
Lecture	4	3	1	1	9
Project-based assignments	3	3	1	1	8
In-class discussions	3	2	---	2	7
One-on-one tutorial	2	2	---	3	7

Also, using the same list, students were asked what strategies used by their faculty to help their learning in science courses. However, in reviewing the data collected from open-ended questions of the survey, students reported that most of the teaching strategies used in their college science courses were lectures. The data reported a limited number of active, creative, and engaging strategies, such as, hands-on, experiments, labs, and in-class activities and discussions.

Educational resources. This project used LEGO® and technology as potential educational resources to support successful teaching of science to college students. Students, as project participants, were asked to reflect on their experiences of developing instructional activities using LEGO®. Further analysis of the qualitative data from student reflection papers generated several emerging themes that supported the use of LEGO® as educational resources as well as the value of this project in exposing students to science teaching.

LEGO® as instructional tools

… it opened my mind up to teaching educational concepts using other stuff besides typical classroom equipment. I always looked at LEGO®'s as nothing but a toy and now I look at them as an instrument that can be used to teach several different science concepts. (S3)

When I first started thinking about how to teach simple machines I thought about objects that could be experimented with that we might find outside however I started thinking about how something as simple as inclement weather could ruin such plans. Using the LEGO® activity however helped me see that a science concept such as simple machines can be taught within the classroom while using something as simple as LEGO®. This project also helped me see the value of having students complete an activity that is hands-on and how this experience can have a deeper and more impactful learning experience for the student. (S8)

I learned about the LEGO® WeDo kit and how it works. I learned how it could be used to incorporate creativity and collaboration into the curriculum. I learned how to use resources to help guide me in areas where I was not confident in my content knowledge. I also learned that I shouldn't completely abandon my science knowledge due to the fact that I am an English/ Social Studies teacher. It is important to utilize as many areas in the curriculum as I can to familiarize myself with areas where I am weak. This project showed me the areas that I need work. (S9)

Teaching Science Concepts and Principles

When first approaching this assignment, we couldn't see how it would help in the education field, but throughout the project we saw how it could make learning about science concepts fun. Most children love LEGO®, so we knew that by incorporating something fun into the curriculum, it would definitely peak their interests. If the future school we work in has the resources for us to use like this one, we fully intend to take full advantage of them. (S1)

Teaching science concepts has always been something that students really liked doing during class especially when they can have fun while doing them. This projected helped me to see how science concepts can easily be made fun for the students. (S3)

This project impacted the way I thought about teaching science concepts by making me see that science can be very fun and interesting. It does not all have to be about lectures or copying notes and watching boring videos. Science can be fun and very hands-on and interactive. (S6)

I remember facts and information well but I do not have the head for equations and doing chemical experiments. If anything at all this project has made me want to teach science less. (S7)

… forced me to evaluate my teaching of science concepts. I have not had any science classes in quite some time, as I am concentrated in English and Social Studies; therefore, I found it challenging to confidently construct a lesson.

Without adequate content knowledge in this subject area, it made it much more difficult to create a lesson much less actually implement[s] *the lesson. This project forced me to evaluate my science knowledge and possibly brush up on my content knowledge.* (S9)

Integrating Technology to Science Teaching

After we met up and finished everything, when going back to school, we were able to tell our classmates (who are not in this course) how this project was useful. It showed us a way to teach many different scientific concepts in a fun and entertaining way, it gives teachers a chance to integrate the use of technology into the curriculum, and it is also a way to help student build good team building skills. (S1)

I personally learned how to better incorporate technology into my lesson plans. Unless it is a Promethean, brain pop, or PowerPoint presentation I have not had a lot of experience with it. I definitely had a different attitude towards this type of software before using it. I felt nervous and even had moments of frustration and panic. After finally figuring it out however I felt that it wasn't so bad. (S2)

I would tell others that educational technology is really expensive, and unless that cost of technical aids is subsidized by the county, there is very little chance a person on a teacher's salary can afford to bring aids and educational tools on a classroom scale of 30 or so students. (S4)

As a whole coming away from this project it would seem that the 'aha' moment for us would be how beneficial it could be to incorporate technology in some way with our classes. It also enlightened us on how technology can be incorporated with the use of projects, but not only to teach new ideas, but to also reinforce some of the knowledge they have, while also promoting a creative thinking environment. (S5)

I learned that there are a lot of skills you need to know in order to be successful in science, such as… building techniques, computer skills, scientific vocabulary, video/recording skills, and many more. (S6)

Improving Teaching Strategies

If the resources were available, we would definitely use this to have students research certain animals and the habitats. After completing this assignment, we would have them present what they learned and their LEGO® project. Not only would students learn a lot, but they would also have the opportunity to enjoy what they are learning/researching. (S1)

… made an impact on my thinking about teaching by showing just how much technology can be incorporated into a lesson. (S2)

It made me realize how important it is to explain all parts of a lesson because the foundational parts of a science lesson are so important to the complex takeaways that a student has. I also realized that it is imperative to thoroughly explain yourself as the educator as well as what your expectations are as not to confuse students. (S4)

… making me realize that there are ways that you can really make students interact with one another through projects and activities. (S6)

… it helped me realize just how important hands-on activities are for children especially in elementary schools. (S8)

Value of the Project

This project had a lot of information on procedures, steps, and building. It introduced students to many science concepts that they are not normally used to doing without them even realizing because they were having fun. (S2)

From doing this project I learned that the students have to have some knowledge about what they are about to learn to start applying concepts to experiments. I thought that finding the content for the project would be hard but it was easy after I thought of the concept I would be teaching. Applying science concepts to toys and games can be easy. The teacher just has to think the experiments out good and be very detailed with the directions. (S3)

… impacted my thought process on teaching in a secondary environment as it forced me to seriously consider my methods of evaluation. It forced me to think on how best I should assess their knowledge from a lesson without getting them as not to warrant a simple parrot of information back to me. (S4)

"The best thing that we feel we took from this project is the experience gained in collaboration between teachers. It also brought to light some of the interesting ways in which technology can be incorporated to the modern classroom. (S5)

… made an impact on my thinking about teaching by pushing me to think creatively. (S9)

Challenges and Implications

All students who participated and completed the LEGO® and technology activities reported that the learning experience was valuable. The qualitative data suggested that the vast majority of the participants expressed positive feedback on the project

implementation as well as having meaningful experiences. The result was consistent with the exploratory focus of the project. Given that the participants were pre-service teachers, it is important that the experience demonstrated options on what they could do when asked to teach science concepts that will engage their future students. Further, anecdotal comments made to the instructor captured the need for more types of these activities in undergraduate education courses.

Several challenges were encountered during the implementation of the various activities. First, about sixty (60) students were expected to enroll in the targeted sections of the university course. However, less than twenty (20) students registered for the course. The low number of participating undergraduate students served as a limitation in making generalizations on the outcomes of the case study.

Second, due to changes in the course management system, there were communication issues between the students and the professor on what to do initially. Students surprisingly informed the professor that they were not familiar in working in a fully online learning environment. This resulted in more efforts taken by the professor to prepare students and get them started with their projects. The professor's feedback identified the need for a visual-based orientation to be provided to students prior to starting the project.

The participants reported that the things they learned from project implementation included new knowledge, skills and dispositions related to teaching science and teaching in general. Participants identified various benefits of completing the LEGO® and technology project especially in planning a lesson, teaching science concepts, integrating technology, and using non-traditional instructional tools.

Based on these initial findings, it is recommended that a second project implementation should be completed to confirm several outcomes generated by the first project. Also, it is important to increase survey completion to enhance reliability and validity of the instruments used. By doing another project implementation, it will be an opportunity to refine the instructional process for creating LEGO® products and using technology that are aligned with the Common Core standards for science. Finally, it will be an opportunity to better prepare undergraduate students to do online work as well as collaborate with their peers.

Conclusion

Participating in this project expanded the researchers' understanding of the benefits and challenges of teaching science or science-related concepts using contemporary products (LEGO®) and technology to undergraduate students. The experience enhanced knowledge of students' perceptions toward teaching science of the principal investigators and students. Working with undergraduate students has facilitated the exploration of various types of educational experiences that engage them in learning about science and learning at a distance. The researchers had an opportunity to learn how active, creative and engaging strategies could be designed and developed to support the teaching of

science, inquiry and technology integration at a distance. Finally, the exposure to resources (LEGO®, technology) was useful in rethinking the delivery of content to promote student success in learning about science, inquiry, technology integration, and distance education.

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