Learning about STEM in the ICT Environment – The Case of the Sound, Wave and Communication Systems Course

Nayif Awad

Sakhnin College,
Ben-Gurion University of the Negev

awad_nayif@yahoo.com

Moshe Barak

Ben-Gurion University of the Negev

mbarak@bgu.ac.il

Abstract

Teaching science, technology, engineering and mathematics (STEM) content is full of opportunities and challenges. This study presents the case of the development and evaluation of an integrated learning program of science, technology, engineering and mathematics (STEM) for a Sound, Waves and Communication Systems course. The research aimed at exploring the student teachers' achievements and motivation (in terms of interest and self-efficacy) to learn science and technology. The instruction method relied heavily on the extensive use of information and computer technologies (ICT). The conceptual framework for the use of ICT comprises four principles: Contextual learning, Active learning, Social learning, and Reflective learning (CASR).

The participants comprised two groups of 25 student teachers each in an academic college for teachers' education in northern Israel. Data collection tools included holding observations in the classes, administering an attitude questionnaire before and after the course, and conducting a final comprehensive exam.

The findings indicated that the participants managed to learn the subject fairly well and showed a high motivation level to learn scientific-technological subjects. However, the student teachers' self-efficacy to learn new scientific subjects remained relatively low.

In conclusion, on the one hand, this research highlights the CASR instructional framework as being effective for promoting STEM learning through ICT. On the other hand, it might require a combination of ICT instruction with student-centered methods such as PBL in order to develop student teachers' self-efficacy.

Keywords: ICT, Sound waves, STEM, Student teacher.

Introduction

Teaching integrated programs in science, technology, engineering and mathematics (STEM) is becoming increasingly important in scientific education (Brown et al., 2011). However, a significant proportion of teachers have only little content knowledge and pedagogical knowledge that are required to teach these subjects in the ICT environment (Barak, 2014).

To address these challenges, a STEM program for teaching a Sound, Waves and Communication Systems (SWCS) course in a rich ICT-based environment was developed. The program was offered to student teachers in a regional college as part of their teacher education program. The research aims at exploring the cognitive and affective factors affecting student teachers' successes and motivation in learning the SWCS course.

Literature Review

Conceptual Framework for Using ICT in STEM Education (CASR)

In order to construct a conceptual framework for the use of ICT in STEM studies in school, Barak (2006) proposed a framework based on four instructional principles that were derived from multiple learning theories (Johnson & Aragon, 2003). These principles are singled out and described below.

Learning is Contextual: Curriculum and a teaching methodology should be tied to the child's experiences and interests as well as to physical and social contexts in which learning takes place (Dewey, 1944).

Learning is an Active process: People learn better through their own experience than through passive acceptance of information provided by others or through technical means. Consequently, educators should see computer technologies as a means of knowledge discovery and construction, rather than of knowledge transfer or its passive acceptance (Salomon, 1998).

Learning is a Social process (Vygotsky, 1978): Learning is intimately associated with the process of discourse between the learner and other people – teachers, peers, family members and casual acquaintances.

Learning is a Reflective process: In order to enable pupils to learn from experience, it is important to encourage them both as individuals and groups to reflect on their own experience (Flavell, 1976).

The Sound, Waves and Communication Systems Course

The course is designed to provide junior high school students with the following scientific concepts: transitive wave, longitude wave, period (T), frequency (f), wavelength (λ), amplitude (A), sound velocity (v) and sound propagation on different materials or states of matter. The course also addresses technological concepts such as a sound system, microphone, speaker, amplifier, analog to digital conversion and digital sound.

The use of ICT was at the center of the course. Strong emphasis was paid to the use of computerized tools such as simulation and sound editing software, as is shown in Figure 1.

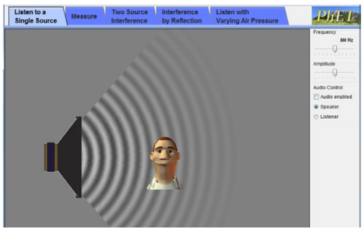

Figure 1. Simulation of sound wave propagation

Instruction Method

Most of the class sessions in the course comprised:

- *Teacher's presentations and demonstrations* of basic theoretical principles using rich presentations and animations for 20-30 minutes.
- *Student's engagement in problem-solving tasks* with a strong emphasis on carrying out experimentation using simulations and sound-editing software for 45-60 minutes. Figure 2 shows an example of a light-based microphone experiment. As a result of a person's sound waves inside a cup, the light source vibrates. The small changes in the distance of the light source are absorbed by a light cell and cause changes in electrical signals that are recorded using the Audacity software.

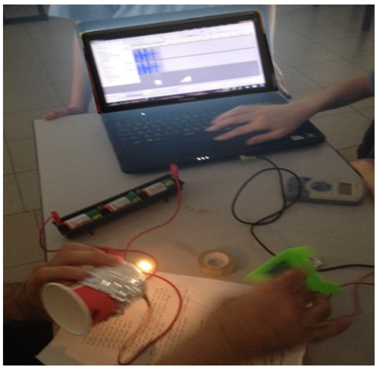

Figure 2. Recording and analyzing a sound wave using the Audacity software

The Research

Research Questions

The questions guiding this research were:

1. To what extent can student teachers in an academic college learn advanced scientific-technological subjects such as sound, waves and communication systems in an ICT-based environment? What are the factors that promote or impede this learning?
2. How does the course affect students' motivation in terms of interest, self-efficacy beliefs about studying scientific-technological subjects and desire to use ICT for learning?

Settings

The participants comprised two separate groups of 25 student teachers each (total n = 50). The student teachers studied a one-semester course (14 weeks of two hours each) as part of their studies for a B.Ed. in science and technology education in an academic college for teacher education. The student teachers had no prior knowledge of the subjects addressed in the course.

Methodology and Data Collection Tools

We used a concurrent triangulation mixed method design to investigate pre-service teachers' STEM engagement, achievements and motivation when learning the SWCS course (Creswell, Clark & Gutmann, 2003). A mixed method was chosen because it can take advantage of both quantitative methods (large sample size, trends, generalization) and qualitative methods (small sample size, details, in depth), and offset the non-overlapping weaknesses of one method with the strengths of the other method (Creswell & Clark, 2007, p. 62).

The quantitative data collection tools included:

- *Final comprehensive exam*: The exam was about the main subjects that the students learned in the course: sound waves, electrical amplification systems and digital sound. The exam contained 10 multiple-choice questions and five open questions about factual, procedural and conceptual knowledge. In order to ensure the distribution of the questions into different knowledge types, the exam was validated by an experts' panel comprised of three academic researchers (PhD) in science and technology education.
- *Attitudes towards learning STEM questionnaire*: The questionnaire comprised 12 Likert-type items spread over three categories: motivation and interest in learning science and technology; desire to learn in an ICT-based environment; and self-efficacy beliefs about learning new topics. Students were asked to mark their answers on a four-level Likert scale. Cronpach's alpha test was performed to check the reliability (internal consistency) of the answers in each category. The questionnaire was administrated pre and post the course.

The qualitative data collection tools included:

- *Lecturer's documentation:* The first author of the current article served as a lecturer in the classes. At the end of each class session, he documented the student teachers' activities in class in his diary, including comments, informal talks and other special events.
- *Class assignments:* Analyzing the participants' answers to three class assignments that they answered during the course.
- *Students' interviews:* Conducting six semi-structured interviews with groups of two student teachers about their engagement in the course at the middle and end of the course. Each interview lasted between 10-20 minutes.

Findings

Due to the limited scope of this article, findings focus on students' achievements and attitudes toward learning STEM in the ICT environment.

Student Teachers' Achievements in Learning the Course

Using Simulation and Sound Editing Software

Students in the course were engaged in inquiry and in solving problems using simulations and computer programs, for example, exploring the effect of changing variables conditions in the simulation, as shown in Figure 3, and checking the quality of the microphone, as shown in Figure 4.

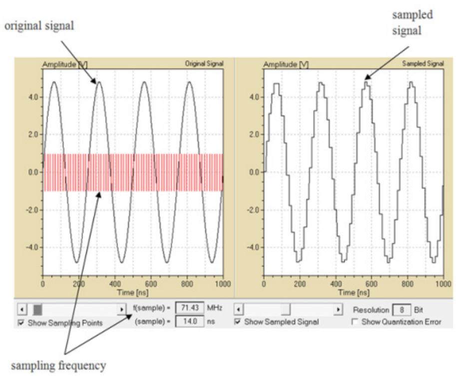

Figure 3. Simulation of sampling a sound signal

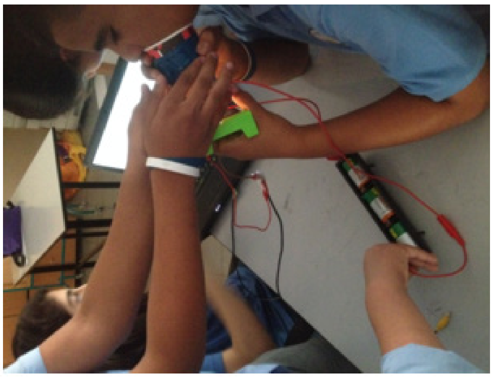

Figure 4. Students' team work in checking a microphone using the Audacity software

Asking Scientific Questions and Participating in Class Discussions

About one-third of the 14 course sessions combined teacher’s presentations and class discussion. The researcher’s diary showed that about 75% of the students participated actively in a class discussion at least once. They expressed their viewpoints, and tried to conduct a scientific dialogue and provide scientific explanations. A significant portion of the discussions extended to broader issues beyond the main subjects of the course. Below are examples of questions that students asked in relation to different subjects.

- *Sound waves carry energy:* Is it possible to heat objects with sound?
- *Sound velocity:* If a person talks near a fan, do sound waves propagate faster?

The findings show that SWCS subjects might arouse students' curiosity and increase their desire to question relevant issues.

Answering a Final Comprehensive Exam

The final comprehensive exam was conducted to explore student teachers’ achievements in learning scientific-technological subjects. To ensure the reliability of scoring the students’ exams, the researcher with another science lecturer together checked three exams of low, middle and high achieving students, and determined how to evaluate the students’ answers. The average total score (on a scale of 0-100) in the second class was 74.72 (n =50, SD = 12.10). The highest score was 100 and the lowest was 40. More specifically, the average score for the declarative knowledge questions was 74.50 (SD = 18.97), for the procedural knowledge questions 78.20 (SD = 26.99) and for the conceptual knowledge questions 74.72 (SD = 12.10). Very similar scores were received in the first class as well. The findings show that student teachers can learn advanced subjects and acquire factual, procedural and conceptual knowledge, with priority to procedural knowledge.

The Student Teachers' Attitudes towards Learning STEM

Forty-three out of the 50 students answered a questionnaire aimed at examining how participation in the course affects their attitudes towards learning STEM. The students submitted their answers before and after learning the course. A paired-sampled t-test to compare mean scores between the pre and post answers was conducted. In order to examine the extent to which the average scores of the students’ answers to the questionnaire indicate a positive or negative orientation, a t-test was performed to compare the means of the answers to the category in the pre and post questionnaires with the middle-scale value of 2.5. The findings are presented in Table 1.

Table 1. T-test to compare pre and post answers to attitudes towards learning STEM questionnaire (N = 43)

						T – test (Pre-Post)	
Section	**Category**	**Phase**	**Cronbach's alpha**	**Mean**	**Std. Deviation**	**T**	**Sig.**
A	Motivation in learning science	Pre	0.603	3.5875#	.29553	.127	.900
		Post	0.799	3.5750#	.41438		
B	Desire to learn in ICT-based environment	Pre	0.433	2.9000#	.39236	-4.067	.001*
		Post	0.644	3.3000#	.48395		
C	Self-efficacy beliefs	Pre	0.884	2.4625	.51475	1.126	.274
		Post	0.707	2.3000	.50393		

# $p<0.05$ relative to the middle-scale value of 2.5. * $p<0.05$ relative to pre-post difference.

The findings show the following:

Section A: Results were significantly higher than 2.5 both in the pre and post.

Section B: Results were significantly higher than 2.5 both in the pre and post. In addition, the results in the post were significantly higher than in the pre.

Section C: Results in the pre and post were around 2.5.

In addition, the interviews with the students were a major source for hearing the participants' views directly. The interviewers were asked about ICT learning in the course. For example, *how do you evaluate the simulation role in your learning process?* On average, 10 of the 12 interviewees in each round of interviews agreed that ICT played a central role in this course. The students' answers related to different aspects, such as visualization – abstract concepts can be 'seen,' having a chance for multiple trials with control sense, and a less cognitive load.

To summarize, these findings indicate that the students' desire to learn STEM subjects in an ICT environment increased significantly. In addition, the students expressed nearly the same high level of motivation at the course's beginning and end. However, the students self-efficacy did not develop.

Discussion and Conclusions

The findings of this study indicate that student teachers can deal successfully with learning a relatively complex and interdisciplinary subject spread over a number of areas in science and technology. The main factors that contributed to learning were the combination of the teacher's explanations and the students' learning in a rich technological environment. In addition, choosing topics related to the students' world, such as sound amplification systems and digital sound, were a key factor in fostering motivation in learning the theory and conducting computerized experiments.

The main factors that contributed to learning relates to the fact that students made rich use of ICT throughout the course. The students were involved in problem solving through student-led assignments and also in team work using simulation and sound editing software. In addition, the use of ICT was made according to well-defined recommendations, for example, using the simulation after acquiring basic knowledge in the subject, and only when they are directly related to the curriculum and on condition that they have additional significant contributions (Hoffler & Leutner, 2007; Mayer et al., 2001).

As mentioned in section 2, the conceptual framework for fostering learning with ICT was based on four instructional principles, namely, Contextual learning, Active learning, Social learning, and Reflective learning (CASR). The contextual and active learning were dominant in students' ICT learning as previously described. However, social and reflective learning still must be supported in the ICT environment. Sharing thoughts, cooperation and knowledge construction through personal connection with other people, besides developing student teachers' reflection, might be promoted in an online environment (Jonassen et al., 2000).

Despite the advantages that ICT might bring to learning, the findings show that student teachers' self-efficacy beliefs to learn new subjects remained limited with no significant change. This important outcome requires an in-depth investigation and raises serious questions about several issues such as factors that might hinder the student teachers' self-efficacy development, and conditions or ways that might contribute to or increase student teachers' self-efficacy.

References

Barak, M. (2006). Instructional principles for fostering learning with ICT: teachers' perspectives as learners and instructors. *Education and Information Technologies*, *11*(2), 121-135

Barak, M. (2014). Closing the gap between attitudes and perceptions about ICT-enhanced learning among pre-service STEM teachers. *Journal of Science Education and Technology*, *23*(1), 1-14.

Brown, R., Brown, J., Reardon, K. & Merril, C. (2011). Understanding STEM: current perceptions. *Technology and Engineering Teacher*, *70*(6), 5-9.

Creswell, J. W. & Plano, C. V. L. (2007). *Designing and conducting mixed methods research*. Thousand Oaks, California: SAGE Publications.

Creswell, J. W., Clark, V. L. P. & Gutmann, M. (2003). Advanced mixed method research designs. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social and behavioral research* (pp. 209-240). Thousand Oaks, CA: Sage.

Dewey, J. (1944). *Democracy and Education*. New York: Free Press. (Original work published in 1916).

Flavell, J. H. (1976). Metacognitive aspects of problem solving. In L. B. Resnick (Ed.), *The nature of intelligence* (pp. 231-236). Hillsdale, NJ: Erlbaum.

Hoffler, T. N. & Leutner, D. (2007). Instructional animation versus static pictures: a meta-analysis. *Learning and Instruction, 17*(6), 722-738.

Johnson, S. D., Aragon, S. R., Shaik, N. and Palma-Rivas, N. (2000) Comparative analysis of learner satisfaction and learning outcomes in online and face-to-face learning environments. *Journal of Interactive Learning Research, 11*, 29-49.

Johnson, S. D. and Aragon, S. A. (2003). An instructional strategy framework for online learning environments. In A. Aragon (ed.), *Facilitating Learning in Online Environments*, New Directions for Adult and Continuing Education, S Jossey-Bass, San Francisco: 10, 31-44.

Mayer, R. E., Heiser, J. & Lonn, S. (2001). Cognitive constraints on multimedia learning: when presenting more material results in less understanding. *Journal of Educational Psychology*, *93*, 187-198.

Salomon, G. (1998) Novel constructivist learning environments and novel technologies: some issues to be considered. *Research Dialog in Learning and Instruction*, *1*(1), 3-12.

Vygotsky, L. S. (1978). *Mind in Society*. Harvard University Press, Cambridge, MA.