ICT Implementation to Improve Rural Students' Achievement in Physics

Dionysios Trikoilis

School Of Education

University of Nicosia

Nicosia, Cyprus

trikilis.d@unic.ac.cy

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Abstract

Due to the challenges of the new era teachers enrich their teaching approaches with the implementation of Information and Communications Technology (ICT) tools. Worldwide literature provides solid evidence underlying the potential of technology for supporting everyday teaching practice, providing an interactive teaching and learning environment. This quantitative small-scale study describes the implementation of ICT in a teaching scenario in high school Physics. The scenario focused on a computer simulation about the uniformly accelerated linear motion and was the outcome of Distance-Based Instructional Coaching (DBIC). The specific DBIC was designed to support the professional development of rural science teachers. The scenario was presented to a class of twenty randomly selected tenth-grade level students of a Greek rural island. The benefits of applying the scenario are outlined not only through the satisfactory statistically significant student outcomes, but also through the student reflection that followed. According to the findings of the study the vast majority of the students enjoyed learning using simulations and scored higher after the attendance of the scenario.

Keywords: Physics, uniformly accelerated linear motion, ICT utilization, rural schools.

INTRODUCTION

New technologies provoke changes in education affecting the ways teaching and learning take place. Especially in subject areas like Physics, new technologies can foster students' intellectual abilities. This is obtained through higher-order thinking, problem-solving, improved communication skills, and deep understanding of the learning tool and the concepts to be taught (Aladejana, 2007). As a result, a lot of countries have taken measures to apply ICT-oriented education policies to emphasize the value of technology inclusion in curriculum documents at all school levels (Agyei & Voogt, 2012).

The inclusion of Information and Communications Technologies (ICT) in school courses requires specially designed long-term teacher training. However, the way teachers are trained in rural areas is a matter of concern due to special challenges such as distance from the training centers, weather conditions, and lack of financial support for travel costs. This quantitative small-scale study examines the effectiveness of simulations use as an interactive ICT tool in improving the teaching of physics in a rural Greek high school classroom context. Specifically, the simulation used was a Physics Education Technology (PhET) simulation. Students and teachers can run (PhET) simulation online or they can download it for free. It is a highly interactive, animated activity which is user-friendly and provides students the ability to explore a wide range of topics in physics (Podolefsky, Perkins, & Adams, 2010). Moreover, it creates a game-like environment that provokes a positive predisposition for students to learn. Thus, it becomes a highly engaging activity for students, making physics an interesting, exciting, and enjoyable subject. Last but not least (PhET) simulation represents concepts and activities which would be impossible in an out-of-date rural physics lab. Due to all these reasons simulations seem to be a useful and interactive resource for the effective teaching and learning of physics. However, little research has been conducted to identify the impact of physics simulation on students' outcomes, especially in a rural context.

This study aims to present the effectiveness of integrating PhET Interactive Simulation-Based Activities in improving rural students' academic achievement in physics, and more specifically to enhance their understanding of the topic of uniformly accelerated linear motion. Thus, the research questions addressed in this study are as follows:

1. How PhET Interactive Simulation on the topic of uniformly accelerated linear motion affects rural students' academic performance?
2. Is there a significant difference in academic performance after the application of the PhET Interactive Simulation in the classroom?

LITERATURE REVIEW

The cognitive theory of multimedia learning is lying on three assumptions (Mayer, 2014). According to the first assumption, learners can organize information into two different cognitive channels, the visual and the auditory channel. The second assumption is that each channel provides a limited capacity for information processing. Therefore, it would be more beneficial if learning environments could stimulate the activation of both the visual and the auditory channels. The third assumption is that to understand new knowledge, learners need to interact actively with learning material. This is possible through the use of immersive learning environments, where learners can affect their learning processes actively and directly. During this learning procedure, the teacher has a lot of responsibilities. He or she plays the role of the facilitator, offering, if necessary, scaffolding, clearing up points of misunderstanding and misconceptions, encouraging students to sort out problems on their own and achieve consensus.

Simulations are the most explored category of instructional software used in physics education (Esquembre, 2002). According to the literature, simulations reflect the key elements of constructivism and advocate the type of teaching approach that is purposed to be a highly student-oriented process (Hofstein & Lunetta, 2003). Computer simulations in physics teaching promote interactivity among students and provide students the space to explore a wide range of topics (Podolefsky, Perkins, & Adams, 2010). Besides, they offer new educational environments that aim to enhance Science teachers' instructional flexibility and to enhance students' active engagement (Jimoyiannis & Komis, 2001). The way and manner in which simulations are used in the classroom, the design features, the support structures put in place, and the alignment of the simulation-based activities with the intended curriculum are four rigorous parameters for the effectiveness of simulations (Bell & Smetana, 2008). Therefore, teachers have an important role to play since the way they integrate simulations into their teaching practices may vary and, consequently affect the anticipated learning outcomes. Because of this, a teacher should follow proper training to be able to choose and implement teaching strategies that foster students' meaningful learning.

Professional development is a major issue for teachers in rural schools. Research has reported feelings of geographical isolation, professional isolation, and social isolation for such teachers (Hellsten et al., 2011). Teachers' professional development is mostly provided in the capital cities of each state following a "one size fits all" model to teacher preparation. However, this type of development is not adequate for the needs of rural schools (White et al., 2011). Moreover, rural teachers have to experience a lack of teaching resources, insufficient instructional materials (McCoy, 2006), as well as out-of-date classrooms and labs (Marlow & Cooper, 2008). Literature indicates that the link between the availability of facilities and resources on the one hand, and student learning experiences on the other, is very strong (Barrett et al., 2007; UNESCO, 2008). Therefore, these deficiencies have a negative impact on how and what children learn (Welch et al., 2007).

Distance-based instructional coaching (DBIC) could address rural teachers' professional development effectively (Kunz, Nugent, et al., 2013). Research reports that teachers who participated in DBIC describe positive experiences and shifts in teaching practices as much as teachers who received school-based instructional coaching (Gentry, Denton, & Kurz, 2008). With the evolution of web-based video conferencing technology, many features of school-based coaching are enabled in DBIC including classroom observation, synchronous video-conference coaching, and file sharing. Therefore DBIC has the potential to promote communication and collaboration among rural teachers and connect them to high-quality resources, providing them a sustainable model to enhance their professional development (Rock et al., 2009).

METHODOLOGY

The study aimed to investigate the effectiveness of integrating PhET Interactive Simulation-Based Activities in improving rural students' understanding of the topic of uniformly accelerated linear motion. For this purpose, a scenario focusing on a computer simulation about the uniformly accelerated linear motion has been utilized. This scenario was the outcome of a three-month Distance-Based Instructional Coaching (DBIC) for a group of physics, chemistry, and biology rural teachers. The DBIC model used in the study was delivered via a Web-based video conferencing platform. The platform enabled real-time video conversations between teachers and the coach. Additionally, the members of the group were allowed to share their screens and send files to each other. Teachers had the opportunity to actively engage in learning, to examine and improve their instructional practices (McGatha, 2008). The DBIC ended with a final assignment. Every participant had to develop and present a teaching scenario implementing ICT.

Data Collection

Two sets of data were collected from twenty randomly selected tenth-grade level Greek rural students. The first set was collected before the attendance of the scenario through a relevant assessment sheet to measure the knowledge already acquired about acceleration. The second set of data was gathered after the attendance of the scenario. To compare the two means of these data sets a paired samples t-test was conducted.

The Participants

The population of the study was 92 tenth-grade students at a Greek rural high school. The sample of the study consisted of twenty tenth-grade students selected applying simple random sampling. In this sampling method, each member of the population has an equal chance to be selected. It is the most straightforward of all the probability sampling methods. For the application of this method, a complete list of every member of the population has been created and a number from 1 to 92 has been assigned to each one. A random number generator produced 20 numbers corresponding to the 20 students of the sample. Sixty percent of the participants were boys and forty percent were girls. No control applied for any other criteria such as academic level of students, family socioeconomic status, parents' educational level, etc.

The Procedure

The title of the specific scenario used for this study was: "The concept of acceleration in uniformly accelerated linear motion" and was developed especially for the teaching needs of the tenth grade. Before the application of the teaching scenario students were provided with a short description explaining its' stages:

- At the first stage, students responded to a relevant assessment sheet that concerned the knowledge already acquired about acceleration. In this way, the first results were collected which are represented in Figure 1 and Table 1 as Grade_1.
- The second stage of the project included the projection of relevant audiovisual material to stimulate the interest of students and to connect the taught concepts of linear acceleration with topics from everyday life (e.g., sports, car racing, space travel).
- At the third stage, students were introduced to the PHET simulation for the linear uniformly accelerated motion which is available at https://phet.colorado.edu/en/simulation/legacy/moving-man. The teacher presented the basic concepts, the technical features for the use of the simulation and provided several examples. After that plenty of time was granted for questions and answers and extra information was given for the students to get familiar with the software environment.
- At the fourth stage, the students were provided with a worksheet on the topic of the uniformly accelerated linear motion. They had to work in groups to answer the worksheet in forty-five minutes. The worksheet consisted of 15 questions that the students had to answer collaboratively utilizing elements of the simulation. The worksheets were evaluated in the (0-20) scale which is the official evaluation scale in Greek schools. The next day the teacher provided feedback for every group of students.

- The fifth stage took place a week after the application of the scenario and the students were asked to answer the same assessment sheet. In this way, the second results were collected which are represented in Figure 1 and Table 1 as Grade_2. After the completion of the assessment sheet, the students were asked to evaluate the whole scenario. They were given a set of the following "emojis": 😃 (very happy – excited), 🙂 (happy – satisfied), 😐 (neutral), 🙁 (disappointed – expected something else), 😟 (very disappointed). The students had to select only one "emoji" and answer the question "Which of the following faces better expresses your feelings about this teaching scenario?". Their answers are represented in Figure 2.

RESULTS

The sample of the study was 20 tenth-grade students at a Greek rural high school. All of them were students of the tenth grade, 15 or 16 years old. Sixty percent of the participants were boys and forty percent were girls. The data obtained from the quantitative analysis revealed that the application of the scenario had a positive effect on the students' academic achievement regarding the specific physics topic. Figure 1 shows evidence of the change in scores after the attendance of the scenario. More specifically twelve students (60%) scored higher compared to the first assessment, 3 students (15%) scored the same compared to the first assessment and 5 students (25%) scored lower. A remarkable finding is that after the scenario intervention three more students scored 20, which is the highest score on the scale. Table 1 presents the mean score for the first and the second assessment, as well as the standard deviation for each one.

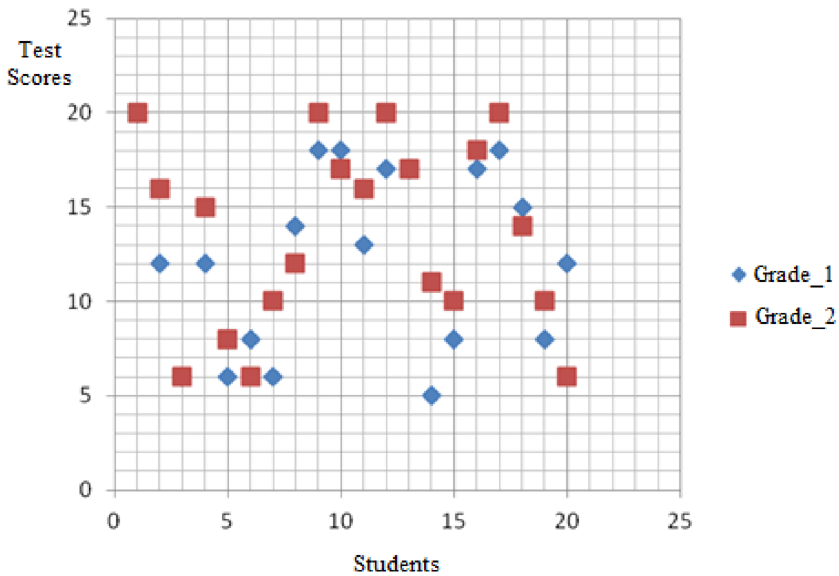

Figure 1. *Representation of Test Scores Before and After the Intervention*

Table 1. *Grades from the Assessment Sheets*

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Grade_1	12.5000	20	4.92576	1.10143
	Grade_2	13.7000	20	4.84605	1.08361

Table 1 shows that all 20 students of the sample completed the first and the second assessment. Additionally, there is a difference between the grades of the students obtained in the first and the second assessment. As it is presented, the mean score for the pretest assessment is 12.5 whereas the mean score for the posttest assessment is higher, 13.7. As far as the standard deviations are concerned they are approximately equal SD = 4.9 for the pretest and SD = 4.8 for the posttest. This result addresses the first research question. According to Table 1 rural students' academic performance on the topic of uniformly accelerated linear motion is positively affected by the PhET Interactive Simulation. PhET simulation environment and its' interactive features helped them enhance their learning of the subject matter.

The second research question investigated the significance of the difference in academic performance after the application of the PhET Interactive Simulation in the classroom. Because the group of students was the same for the pretest and the posttest, a paired samples t-test has been conducted to compare the two means. The statistical significance level was set at 0.05 and the results of this t-test are shown in Table 2.

Table 2. *Paired Samples t-test Results*

Paired Samples Test									
		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Err Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Grade_1 Grade_2	-1.20000	2.44088	.54580	-2.34237	-.05763	-2.199	19	.040

As Table 2 demonstrates there is an average difference between the two scores (Mean=-1.2). This finding explains the difference regarding the scores for the pretest (M = 12.5, SD = 4.9) and the posttest (M = 13.7, SD = 4.8). The test statistic has a value of t = -2.199 with df = 19 for the degrees of freedom. The p-value corresponding to the given test is p = 0.040. Because the p-value is less than the statistical significance level (0.05) it can be concluded that there was a statistically significant average difference between the pretest and the posttest. According to this finding, there is a significant difference in academic performance after the application of the PhET Interactive Simulation in the classroom. Students scored significantly higher after the application of the scenario. PhET Interactive Simulation has the potential to enhance students' learning with physics concepts even in a rural context.

During the teaching, the participation of the students was enthusiastic, without substantial obstacles. The "Vygotsky scaffolding" took place while weaker students learned by collaborating and working with more advanced students in each group to achieve their learning goals. At the end of the teaching scenario, the students were asked to make an evaluation and express their feelings through a set of "emojis". The results of their evaluation are shown in Figure 2. The majority of the students (60%) stated that they felt very happy and excited. Some of them (30%) felt happy and satisfied whereas the minority (10%) had neutral feelings. A remarkable finding is that none of the students selected the "emoji" corresponding to "disappointed – expected something else", or to "very disappointed".

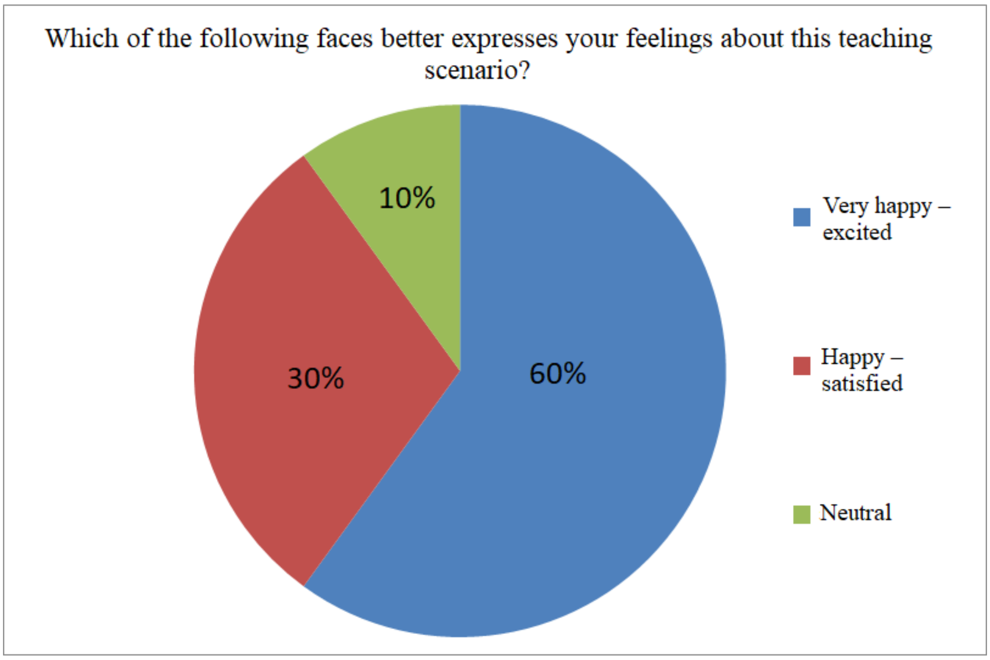

Figure 2. *Students' Responses about their Feelings*

CONCLUSIONS AND DISCUSSION

This study aimed to present the effectiveness of integrating PhET Interactive Simulation-Based Activities in improving rural students' understanding of the topic of uniformly accelerated linear motion. According to the findings of this small-scale quantitative research, rural students' academic performance can be affected positively by the PhET Interactive Simulation. This can be justified by the significant difference in their academic performance before and after the teaching intervention.

This finding aligns with the study of Batuyong and Antonio (2018). Their study focused on the effect of PhET® Interactive Simulation-based Activities in electromagnetism on the performance and learning experiences of two hundred tenth-grade students. They found that the implementation of simulation in the teaching procedure enhances students' participation and enthusiasm during the classroom activities and discussions. They also concluded that students improved significantly their Physics academic performance. A more recent study with a sample of 83 seventh-grade students also concluded that the PhET interactive simulation-based activities improve significantly the academic performance of students (Mallari, & Lumanog, 2020). The study also underlines that students who participated were very active, highly motivated, and challenged while doing interactive activities in class.

The added value of the scenario that has been used in this study is more in the cognitive clarification of the concept of acceleration. Students clarify the difference between acceleration and speed. So through speed racing, they understand that a body can have low speed but high acceleration, and vice versa. Besides, they understand that a body can be immobile, but still have acceleration. These findings reconstruct the misconceptions that have been formed by students from the first years of their lives (Gardner, 1991). Additionally, the simulation experiments presented provided a virtual environment in which the student had the opportunity to safely investigate and conduct a variety of experiments in a short time by changing the values of the available parameters (Podolefsky, Perkins, & Adams, 2010). The prompts for predicting the outcome of the experiment sharpen the student's critical ability as he tries to combine and cope with more complex problems. In this way, students understand that the deceleration, which reduces the measure of the speed of the moving man, can also work as an accelerator after zeroing his speed. These activities can contribute to a deeper understanding of the algebraic sign and the vector character of certain physical quantities.

However, the scenarios alone are not a driving force to change the teaching method and integrate ICT into science teaching. Teachers themselves need to be convinced of the learning benefit that will result from their use. This could be obtained with the proper training. In this direction, rural teachers can be helped by Distance-based instructional coaching (DBIC). DBIC can foster rural teachers' professional development effectively overriding the issues of limited resources and access to coaches (Lee et al., 2018). Moreover, research reports that teachers who participate in DBIC describe positive experiences and shifts in teaching practices that in turn improve student achievement.

In this direction, small internal collaborative networks can be formed between rural teachers who teach the same subject. The school counselor of the specific subject can play the role of the group coach. Initially, the members of the group can set their goals. This point is the starting point of action research. Under the coach's supervision, each member monitors and observes the other's teaching, methods, and practices. This observation will lead to reflection and self-monitoring in which each member of the network takes responsibility for creating personal meaning. This meaning will be re-shared and evaluated with his colleagues.

REFERENCES

Agyei, D. D., & Voogt, J. (2012). Developing technological pedagogical content knowledge in pre-service mathematics teachers through collaborative design. *Australasian Journal of Educational Technology, 28*(4), 547-564. https://doi.org/10.14742/ajet.827.

Aladejana, F., (2007). The Implications of ICT and NKS for Science Teaching: Whither Nigeria. Ile-Ife: Complex Systems Publications, Inc.

Barrett A, Ali S, Clegg J, Hinostroza EJ, Lowe J, Nikel J, Novelli M, Oduro G, Pillay M, Tikly L, Yu G (2007). Initiatives to improve the quality of teaching and learning: A review of recent literature. EdQual Working paper no. 11. Bristol: EdQual.

Batuyong, C. T., & Antonio, V. V. (2018). Exploring the effect of PhET® interactive simulation-based activities on students' performance and learning experiences in electromagnetism. *Asia Pacific Journal of Multidisciplinary Research, 6*(2), 121–131.

Bell, R. L., & Smetana, L. K. (2008). Using computer simulations to enhance science teaching and learning. In R. L. Bell, J. Gess-Newsome, & J. Luft (Eds.), *Technology in the secondary science classroom* (pp. 23-32). Washington, D. C.: National Science Teachers Association Press.

Esquembre, F. (2002). Computers in physics education. *Computer Physics Communications, 147*(1-2), 13-18.

Gardner, H. (1991). *The unschooled mind: how children think and how schools should teach*. New York: Basic Books Inc.

Gentry, L. B., Denton, C. A., & Kurz, T. (2008). Technologically-based mentoring provided to teachers: A synthesis of the literature. *Journal of Technology and Teacher Education, 16*(3), 339– 373.

Hellsten, L. M., McIntyre, L. J., & Prytula, M. P. (2011). Teaching in Rural Saskatchewan: First Year Teachers Identify Challenges and Make Recommendations. *Rural Educator*, *32*(3), 11–21.

Hofstein, A., & Lunetta, V. N. (2003). The laboratory in science education: Foundations for the twenty-first century. *Science Education*, *88*(1), 28-54.

Jimoyiannis, A., & Komis, V. (2001). Computer Simulations in Physics Teaching and Learning: A Case Study on Students' Understanding of Trajectory motion. *Computers and Education, 36*(2), 183–204.

Kunz, G. M., Nugent, G. C., DeChenne, S. E., Houston, J., & Pedersen, J. (2013). Meeting rural science teachers' needs: Professional development with on-going technology-delivered instructional coaching. Paper presented at the American Educational Research Association, San Francisco, CA.

Lee, S. C., Nugent, G., Kunz, G. M., Houston, J., & DeChenne-Peters, S. (2018). Case study: Value-added benefit of distance-based instructional coaching on science teachers' inquiry instruction in rural schools. *Journal of Science Teacher Education, 29*(3), 179-199.

Mallari, R. L., & Lumanog, G. D. (2020). The effectiveness of integrating PhET interactive simulation-based activities in improving the student's academic performance in science. *International Journal for Research in Applied Science and Engineering Technology*, *8*(9), 1150-1153.

Marlow, D., & Cooper, M. (2008). *The MetLife survey of the American teacher: Past, present, and future*. (Report No. ED504457). New York, NY: Metlife.

Mayer, R. E. (2014). Cognitive theory of multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd ed., pp. 31–48). New York, NY: Cambridge University Press.

McCoy, L. P. (2006). Southern rural public schools: A study of teacher perspectives. *Qualitative Report, 11*(4), 749–763.

McGatha, M. (2008). Levels of engagement in establishing coaching relationships. *Teacher Development, 1*2(2), 139–150. doi:10.1080/13664530802038147

Newton, L.R., & Rogers, L., (2003). Thinking frameworks for planning ICT in science lessons. *School Science Review*, 84(309), 1-8.

Podolefsky N. S., Perkins K. K., & Adams W. K. (2010). Factors promoting engaged exploration with computer simulations. *Physics Review Special Topics - Physics Education Research, 6*(2), 020117.

Rock, M. L., Gregg, M., Gable, R. A., & Zigmond, N. P. (2009). Virtual coaching for novice teachers. *Phi Delta Kappan, 91*(2), 36–41.

White, S., Lock, G., Hastings, W., Cooper, M., Reid, J., & Green, B. (2011). Investing in sustainable and resilient rural social space: Lessons for teacher education, *Education in Rural Australia, 21* (2), 67-78.