Influence of Robotics-Aided Lessons on Students' Physics Achievement

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Abstract

This research paper aimed to determine the effects of robotics-aided lessons on students' physics achievement using the experimental design. The experimental group was exposed to instruction using the RCX programmable LEGO bricks and pieces, sensors, and motors while the control group was exposed to traditional teaching. The instruments used were Student's Robotics Profile Inventory, Achievement Test, Observation Checklist, and Interview. It was found out that the post-test of students who were exposed to robotics-aided instruction was higher than that of the non-robotics-aided lessons. When the pre-test and post-test were compared, they showed improvement from low to high scores. Moreover, the results of the students' physics achievement using non-robotics instruction during the pre-test and post-test also improved from low to average through their mean scores. Social skills, personal values, and intellectual knowledge using the robots as an intervention in the learning process were developed among the students. The results supposed that positive behaviors motivate students to engage themselves in physics. Defined recommendations were given to schools' administrators, supervisors and teachers in using robotics in their teaching methods and pedagogies.

Keywords: robotics-aided instruction, robotics, robotics technology, achievement, physics strategy

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The Basic Education Act of 2001 emphasized the provision of necessary competencies to develop holistic Filipino learners in literacy, numeracy, critical thinking and learning skills, and desirable values. However, there is a disparity that stems from the unequal access to low quality and marginal relevance of basic education in the Philippines. It was summed up in the 1991 Report of the Congressional Commission on Education that the status of education in secondary schools has been continuously declining especially in physics education. Some researchers stated that due to the broad coverage of science examinations, teachers had little time to collaborate with students in knowledge exploration. Science tests have always emphasized the grasp of physics knowledge but neglected students' development. Teachers have considered that their role is to transfer information rather than to teach.

Student observation and laboratory experimentation are less emphasized in physics instruction. Li, Ni, Li, and Zhang (2011) observed that some teachers have transformed vivid experimental physics into dull calculation, resulting in the very low performance of students in physics.

To raise student achievement, teachers must assess students and use resources to enable them to use the results for improving their learning in day-to-day classroom lessons. Schools empowered to instruct with the shared vision of its grassroots stakeholders have the best chance of attaining the national goals.

Based on the studies of Manseur (2004), robotics starts with the introduction of mathematical concepts, then on kinematics of robot manipulations, followed by elements of dynamics and control that heavily rely on kinematics. Robotics provides computer assistance and is time saving, which is one of the concerns of the researcher.

Correl (2008) mentioned in his study that project-based hands-on learning for robotics-approach gives students the opportunity to put course materials immediately into action. It provides an inspiring and motivational subject to students, and are solvable within the limits of the class. Robotics allows the students to be exposed to the most significant challenges of state-of-the-art advances in science and prepares them to explore studies on industry and science research.

Dias, Browning, Mills-Tettey, Amanquah, and El-Moughny (2007) cited that robotics leads to empowering the younger generations to become creators of innovative technology solutions to problems. They posited that teaching robotics makes teaching multi-disciplinary and excite and inspire students. Hands-on projects expose the students to the challenges, joys, and frustrations of systems development and integration brought about by robotics instruction. They also claimed that robotics plays an influential role in technology education, motivating students to become technical experts in the field of science, and encourage the students to value state-of-the-art research. Matarić (2004) added that robotics is a growing field of science that should be explored.

Theoretical Framework

Science education in the Philippines is in the midst of a twenty-year decline. After two decades of worrisome sinking statistics, both in terms of academic achievement and successful employment, Filipino students remain ill-prepared and incapable of joining the workforce of the future. Citizens and educators alike were shocked by the report on the country's achievement. Studies found that, despite the post-sputnik mindset of promoting science education, the country was experiencing a nationwide shortage of physics teachers and specialists. Filipino schools were not producing the science-oriented graduates that the country needed to remain internationally competitive (Luz, 2009).

Whether Filipino students choose to become scientists or not, they will need skills related to life-related applications on manufacturing and technology to be productive members of the society especially of the economy. The opportunities for all citizens to help by fostering an innovation system that is inclusive and a science educator that serves rather than threatens society are needed. There must be have adequate support, inspiration, motivation, and assistance from the authority (van Mier, Temple, Pelmutter Raichle, & Petersen , 1998).The usage of robots in education offers students multiple learning modes in gathering information (Gardner, 1993).

This study aimed to determine the influence of robotics-aided lessons on students' physics achievement. Specifically, this study sought answers to the following questions:

1. What is the level of students' physics achievement in the pre-test is of: (a) robotics-aided instruction, and (b) non-robotics-aided instruction?
2. What is the level of students' physics achievement in the post-test of: (a) robotics-aided instruction, and (b) non-robotics-aided instruction?
3. Is there a significant difference in the students' physics achievement in the pre-test between robotics-aided instruction and non-robotics-aided instruction?

4. Is there a significant difference in the students' physics achievement in the post-test between robotics-aided instruction and non-robotics-aided instruction?
5. Is there a significant difference in the students' physics achievement between the pre-test and the post-test of; (a) robotics-aided instruction, and (b) non-robotics-aided instruction?
6. Is there a significant difference in the students' physics achievement in the mean gain scores between robotics-aided instruction and non-robotics-aided instruction?

Methodology

This study ascertained which teaching strategy in physics would be more useful —that of exposing the students to robotics in teaching or having the teacher discuss the concepts with the students without using the robotics.

Since this study intended to find out whether the robotics would cause a change in the physics achievement of the learners, the experimental research design was used. The pre-test - post-test control group design that allowed the researcher to determine the effects of the treatment by comparing results was used. The qualitative approach was also used. This research method provided additional data that quantitative analysis cannot supply, such as the depth of the students' appreciation of the intervention. Qualitative data and analysis supplemented the quantitative data and their analysis.

Participants

The participants in this study were the 74 fourth year regular public high school students taking physics as a subject in Jalandoni Memorial National High School during the academic year 2013-2014. The students were ranked based on their average in Science I, II, and III final rating general point average (GPA). Two separate rankings were made-one for the males and another for the females. This manner of distributing the participants was done to ensure that the groups were equivalent in both male and female ratios and more or less equal in their intellectual capacity. To ensure that the two groups are comparable at the start of the intervention, pre-test was given.

Before the study was the conduct of the study, 37 students who were clustered in the robotics-aided instruction were given a profile questionnaire to gather data on how the students would be exposed to robotics and computer. This will determine the possible cause of their achievement. The questions were categorized on computer exposure, location, and knowledge in learning robots. This profile guided the researcher in ascertaining the extent of knowledge of the participants in manipulating the robots through some of the fundamental principles and ways of using them in teaching physics with robots. The assumption was that the students had no prior experience programming or building robots. It helped the researcher in identifying the respondents as to which group they will belong in the entire span of the intervention.

Materials

LEGO mindstorms. LEGO and MIT Media Laboratory developed a robotic construction kit. The package contained an RCX programmable LEGO brick and numbers of LEGO pieces, sensors and motors. The RCX brick is programmable to signal power motors, stimulate light bulbs, and receive feedback from sensors. Transferring program messages from the computer is through infrared. It is a way of transmitting energy, from a tower that is connected to the computer running the programming software, to a panel on one side of the brick (Bers, Ponte, Juelich, Viera, & Schenker, 2002). The semiconductor inside the LEGO brick is then able to perform many functions on its input and output ports. The treatment group was given a container of LEGO Bricks identical to those available virtually in the software.

ROBOLAB. This is a software tool that accompanies the LEGO Mindstorms construction Kits and was developed by the partnership between Tufts' Center for Engineering Education Outreach, LEGO Education, and National Instruments (ROBOLAB). It is software with a user interface based on symbols that represent various pieces of the LEGO Mind storms hardware. Data recorded and reported by students went through software called Investigator. Working with robotics engages students to active designing and helps in applied computer technology within a constructionist philosophy (Bers, et al., 2002).

Lesson plans. Robotics-aided instruction plans were made and presented to a panel of experts who validated the reliability of the material for further development by giving their comments and suggestions on each lesson. The recommendations made by the experts were consolidated and followed. The lessons prepared for both groups were similarly based on the coverage of the lessons in Mechanics. The difference between these classes was the treatment. The two categories were taught using different approaches, one with the use of robotics in teaching while the other group, without the use of robotics. In making the lesson plans, the researcher utilized the 2002 Basic Education Curriculum Sample Lesson Plans, Physics textbook, and Teacher's

Manual prepared by the DepEd. Ten instruction plans were developed by the researcher. The lessons were the following: a) Vector and Scalar Quantities, b) Distance and Displacement, c) Speed, d) Acceleration, e) Newton's Second Law of Motion: Law of Acceleration, f) Newton's Third Law of Motion: Law of Interaction, g) Momentum and
Impulse, h) Law of Conservation of Momentum, i) Circular Motion, j) Work and Energy, and k) power. These lesson plans were presented to a three-member jury for face and content validations.

Test Instruments

Students' robotics profile inventory. The Robotics Inventory was used to gather data on how the students were exposed to robotics and computer. The inventory was shown to experts for content validation using the Eight-Point Criteria for Content Validation by Good and Scates (1973). This was then pilot-tested to students of Santa Barbara National Comprehensive High School.

Achievement test. The researcher constructed a 150-item test guided by the scope and sequence outlined in the regular public high school Science and Technology IV (Physics). It covers the topics in Mechanics. A table of specification was made to ensure that the items reflected a representative distribution of concepts and computational and problem-solving skills on the topics of mechanics using the Trends in Math and Science Survey (TIMSS). The comments, suggestions, and recommendations of the evaluators for the improvement of the instrument were considered. In the final revision of the test, the items were reduced to 60 items only for both pre-test and posttest. After the test had been validated, it was pilot-tested to 63 randomly selected comparable students of Santa Barbara National Comprehensive High School who were not the participants of the study. Using Cronbach Alpha, the Achievement Test in Physics was now composed of 60 items with a reliability value of 0.726.

Observation checklist. An observation checklist on the on-task and off-task behaviors of the students was made. The list determined in which part of the lesson the students showed the most interest, where they had actively participated, the quality of participation of members, and frequencies of the on-task and off-task behaviors. The observation checklist was content-validated by experts. This observation checklist was used by the observers who were requested to observe both groups. Instructions on the utilization of the observation checklist were clarified to the observers beforehand.

Interview schedules. To determine the students' feedback and reaction towards the use of robotics, the researcher conducted interviews. The researcher asked the students by groups using interview guide questions which were presented and validated by experts. The students also filled out the interview guide questions to determine their individual responses.

Results and Discussions

Before the experiment was conducted, a pre-test on mechanics was administered to both groups. The results reveal that the pre-test on both robotics-aided instruction (*M*=17.62, *SD*=3.35) and non-robotics-aided instructions (*M*=17.49, *SD*=3.33) was low. The standard deviations which ranged from 3.33 to 3.35 indicate that the respondents in each category were homogeneous with 0.02 differences. This shows a narrow dispersion of the means for each group. This further indicate that the students in both robotics-aided instruction and non-robotics-aided instruction groups had a similar background on the lesson on mechanics and the same level of achievement before they were exposed to the treatment.

After the actual teaching for eight weeks, both robotics-aided instruction and non-robotics-aided instruction groups were given the post-test. The mean scores of the robotics-aided instruction group's level of achievement (*M*=31.76, *SD*=4.36) was higher compared to the non-robotics-aided instruction group (*M*=30.16, *SD*=4.27). It shows that the students exposed to robotics-aided instruction may have acquired a deeper understanding of the concepts in mechanics. With this knowledge the students became more flexible in their approach in answering the test compared to the students in the non-robotics-aided instruction group. The standard deviations which ranged from 4.27 to 4.36 indicate that the respondents in each category were homogeneous. This is indicated by the narrow dispersion of the means for each group.

The students' physics achievement using robotics-aided instruction during the pre-test and post-test after eight weeks of teaching improved from low to high as shown in their mean scores (*M*=17.62 and *M*=31.76), respectively. Moreover, students' physics achievement using non-robotics-aided instruction during the pre-test and post-test also improved from low to average as shown in their mean scores (*M*=17.49 and *M*=30.16), respectively. It shows that the students were diverse in their achievement in mechanics. This may be attributed to the effect of the intervention. Leri (2003) emphasized that using technology is the students' vehicle to meet their needs successful learning. The implementation of a constructivist-driven science curriculum is evident. This structure can be used to increase academic achievement for both the individual and for the year level. This research has greater implication on the school level, district level and beyond. The connection between the instructional orders in constructivist projects, this structure may begin to be the norm.

Differences in the Pre-test Mean Scores of Students Exposed to Robotics-aided Instruction and Non-Robotics-aided Instruction

The *t*-test results reveal no significant difference in the students' physics achievement scores on the pre-test between robotics-aided instruction and non-robotics-aided instruction, $t(72)=0.174$, $p=0.86$. The physics achievement of both groups' —the robotics-aided instruction and the non-robotics-aided instruction— were comparable at the start of the experiment. It shows that at this point since 2003, science and technology is still in its reformation. Students had not gained in-depth understanding of science concepts using TIMSS ways of acquiring knowledge since their pre-test scores were low or maybe they were not yet exposed to those types of questions. According to former DepEd Undersecretary Miguel Luz (2009) in a research paper for the Philippine Institute for Development Studies, scores focus on shortages in inputs instead of outcomes. The dilemma that the agency faces in balancing immediate demand for action versus the long lead times needed for outcomes to materialize.

Active learning practices have a more significant impact on student achievement including their background and prior achievement. Students are most successful when they are taught how to learn as well as what to learn. Out of this inference, the agency must start to develop ways of teaching physics and the other sciences.

Differences in the Post-test Mean Scores of Students Exposed to Robotics-aided Instruction and Non-Robotics-aided Instruction

After the students were exposed to different intervention, to determine whether there is significant difference in the post-test mean scores between groups, the researcher subjected the mean scores of their post-test to a two-tailed *t*-test for independent samples set at 0.05 level of significance.

The result reveals that there is no significant difference in the students' physics achievement on the posttest using robotics-aided instruction and non-robotics-aided instructions t $(72)=1.59$, $p=0.116$. Papert (1980) mentioned that this forces students to pursue have more flexibility in terms of what and how they intent to gain. Environments may also provide scientific tools that aid students' exploration when schools are not capable or willing to use them for these purposes. Technical instruments give complex ideas that enable construction and must be utilized for the purpose of giving children different contexts in which they can experiment.

The descriptive results seem to show that the robotics-aided instruction group had better achievement as indicated by their numerically higher mean scores than the non-robotics-aided instruction group. Wagner's (1998) groundbreaking study showed that robots offered students a superior means of learning complicated concepts.

Differences in the Pre-test and Post-test Scores of Students Exposed to Robotics-aided Instruction and Non-Robotics-aided Instruction Groups

The analysis of pre-test and post-test data provided information about the curricular program as a whole as well as the students involved in the study. Attainment results favoring the intervention group demonstrated the significance of the difference in achievement between treatment groups. To determine whether or not there were significant differences in the pre-test and post-test mean scores between groups, the researcher subjected the mean scores in their pre-test to a two-tailed *t*-test for independent samples set at 0.05 level of significance.

Table 1

Differences in the Pre-test and Post-test Scores of Students between Robotics-aided Instructions

Category	N	Pre-test Mean	Post-test Mean	*t*-value	MD	2-tailed .Prob
Robotics-aided instruction	37	17.62	31.76	*22.15	14.14	0.000
Non-Robotics-aided instruction	37	17.49	30.16	*19.55	12.68	0.000

Note: $*p < 0.01$

It is essential to provide an educational environment that provides effective strategies for teaching and that raises optimistic attitudes towards scientific and technical topics. Some strategies that have been proven to be effective in teaching mathematics and science to a varied group of students are small-group lessons, cooperative learning, inquiry approaches, and activity-based instruction (Clewell & Campbell, 2002). In such manner, robotics instruction proved to be one of the strategies that allow students to experience quality education in acquiring knowledge.

Differences in the Mean Gain Scores Between Robotics-aided Instruction and Non-Robotics-aided Instruction

To find out if there were significant differences in the mean gains in the achievement test scores of students in mechanics using robotics-aided instruction and non-robotics-aided instruction, the researcher utilized the t-test for independent samples. The result of *t*-test shows no significant difference in the mean gains between robotics-aided instruction and non-robotics-aided instruction groups $t(72)=1.60$, $p=0.113$. But the mean gain scores of the robotics-aided instruction group are numerically higher than those of the non-robotics-aided instruction group. The robotics-aided instruction had a better effect on students' achievement scores on mechanics than the non-robotics-aided instruction group. This technology has appreciated welfares that would enhance the students' educational experience. It can engage children in hands-on interactions with their tools, and it can promote a deep understanding of the principle involved in their work. During the after-school setting fosters a positive environment for the implementation of robotic technology; it also has limitations (van Mier, Tempel, Pelmutter, Raichle & Petersen, 1998).

Conclusions

The achievement scores of the students in the pre-test of both groups—the robotics-aided instructions and non-robotics-aided instruction—were low. These indicate that the students in the secondary level have not yet maximized their learning to full capacity in achieving higher performance. Engaging students in technological advancement, exposing them to higher-order thinking skills (HOTS) and TIMSS questions, and advancing science experimentations and inquiry-based approaches their chances at success in learning. The achievement scores of students in post-test of robotics-aided instruction were high while those under the non-robotics-aided instruction were average. It is acceptable that using robots in physics instruction has an edge in presenting topics that give students more in-depth grasp of concepts and ideas that they usually find hard to absorb. In addition, robotics is one of the many possible interventions that may be considered to enhance the technological perspectives of students in physics.

The students' physics achievement in both groups— the robotics-aided instruction and the non-robotics-aided instruction— were comparable at the start of the treatment. It indicates that students' scientific mobility and awareness are the same. It also means that the readiness of learners to the intervention is varied based on their profiling and initial achievement but not enough to maximize the learning outcomes of the groups. Primary scientific competencies among students were not attained as well.

After the intervention, there is no significant difference in students' physics achievement on the post-test using robotics-aided and non-robotics-aided instruction was found. It implies that the two instructional approaches can supportto the teaching and learning process, since they are not detached from the students' achievement after the intervention. It also assumes that both approaches have the same level of influence on students except that robotics-aided instruction has a higher mean. Therefore, robotics provides an additional strategy and innovation in teaching physics as a technological discipline.

However, there are significant differences in students' physics achievement between the pre-test and post-test of both groups. It confirms the major change in the progress that defines the effectiveness of both approaches that robotics can compete with the usual methods teachers use in introducing physics concepts. Diverse inquiry approach and activity-based instruction with robotics can initiate better acquisition of concepts through manipulation and actual situational conditions.

The mean gain between robotics-aided instruction and non-robotics-aided instruction had no significant differences. The maximum expected effect of the intervention does not strike deeper on students maybe because of factors that were not included in this study. It can be deduced that perhaps hands-on interactions with robotics to promote deep understanding of physics principles were not maximally met to influence students because of the limited time. Robotics-aided instruction has higher outcomes that somehow affect students' learning.

Most importantly, social skills, personal values, and intellectual knowledge using the Robots as an intervention in the learning process are developed among the students. It supposes that positive behaviors motivate students to engage themselves in physics.

Recommendations

The use of robotics in lessons has a motivational effect on teaching physics. The high physics achievement using robotics-aided instruction may be considered in teaching physics and other related science subjects.

In exhausting such strategy, teachers need to consider the ratio of robots to students and their time to study and manipulate the technology, especially in programming.

Robotics kits are very expensive. The Department of Science and Technology (DOST), an agency responsible for the development of science and technology in the country, may consider possible ways of producing robotics and its advancements. Create available low-cost robots and supplementary software in as many schools may be created. Awareness within the teaching professions must be elevated. Integrating robotics in academic education and vocational training may be considered. Appropriate physics laboratory room with robotics facility in every school is recommended if they want to include robotics in their instruction for experiment and discovery purposes.

The robotics-aided instruction made by the researcher is only limited to some topics in mechanics. Teachers are encouraged to explore more on mechanics and other branches of physics like electromagnetism, optics, acoustics, and electronics in integrating robotics motivated lessons to improve the teaching-learning environment in the classroom.

School administrators and even the DepEd may consider the use of technology for instruction in their respective institutions as a norm. It is known that some students are deprived to some extent of computer and technological exposure. It is suggested that when students enter high school they must have a computer subject as part of their curriculum so that they would have formal training in computer handling and operations. Science supervisors and coordinators may take part in initiating programs and practices for robotics teachers in enhancing their skills, interests, and dynamics towards the manipulation and use of robots in classroom settings.

Robotics competitions for students have to be encouraged by providing avenues for robotics learning, promotion, and dissemination, to help attain quality education in the country. Parents may also assist in giving support, funding, and equipment to support their children's interest in robotics and for them to consider computer science and engineering as careers. It can help them realize that they play a significant role in their children's education.

Future researchers may conduct similar studies in the field to determine other factors that would contribute to significant differences in the students' physics achievement scores using robotics-aided instruction. They may consider the length of the treatment, number of robotics instruction used, and year level of pupils in the K to 12 curricula. It is also encouraged that other areas of science may come up with robotics education.

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