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ORIGINAL ARTICLE

A Study of Simulation-Role-Play Strategy on Pre-service Teachers' Academic Performance in Basic Electronics

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ABSTRACT

Achieving deeper and permanent learning has always been the focus of teaching force. This purpose is independent of the teaching level or subject matter. Pre-service teachers' lack of interest and inability to connect learning levels are partly cited for their inability to develop this deeper and permanent learning of science concepts. In this respect, an action research design conducted using a case-study paradigm which included the simulation-role-play teaching strategy was used to teach pre-service teacher the concept of "doping of pure semiconductors" into p-type and n-type semiconductors. This is an area under basic electronics. The result of the non-parametric Wilcoxon Signed Rank Test analysis revealed a statistically significant increase in pre-service teachers' performance level in basic electronics test following an intervention using the simulation-role-play approach. The median score of the performance level also increased from a pre-test score to post-test score. The simulation-role-play teaching approach affected student teachers' learning of basic electronics by 55% which is considered a large effect. Further, when a sample of the pre-service teachers were interviewed, the result showed a positive view toward teaching using simulation approach which converts theoretical knowledge into practical knowledge for deeper understanding and permanent learning. The findings from this study would be helpful to student teachers and tutors in the colleges of education as it offered useful intervention in teaching and learning of doping of pure semiconductors.

KEY WORDS: Basic electronics; generalist teachers; pre-service teachers; simulation-role-play

INTRODUCTION

One of the keys of active learning is the teaching approach adopted for the teaching and learning practices. Effective teaching is an indispensable force for nurturing competence, creativity, and skills among students. Teaching is very important to all categories of learners but arguably more important for student teachers at the college level because they are being trained to teach. Student teachers imitate skills in teaching; hence, teaching should be created in such a way that it will build confidence among student teachers in their future quest as professional teachers (NTC, 2015). Supporting this argument, Hardman et al. (2012) added that prospective teachers pick up skills and develop knowledge from the way; they are being taught by their college tutors. This means that instructors' skills are transferrable hence critical. Instructors transfer certain skills, competencies, values, and strategies that influence prospective teachers positively or negatively in their future teaching practices.

In the light of the role teaching plays in shaping characters and instilling of confidence in learners, teaching must always gear toward developing interventions from perceived problems. This makes teaching prospective teachers pivotal. Teaching prospective teachers at the colleges of education (CoE) level is critical, especially teaching science concepts to generalist student teachers and particularly, and teaching challenging science concept such as concepts of basic electronics. It is therefore important to demystify the science teaching from experiences bringing science teaching from abstract mode to the physical mode.

Science learners in general across the globe are expected to envision science concepts at three levels to learn meaningfully. The "macroscopic" level refers to what is realia in science concepts. The "microscopic" level deals with the atomic and molecular entities, and then finally the "symbolic" level which deals with equations or the more abstract level. Johnstone described these levels as a learning triangle or triplet of chemical education (Johnstone, 1991; Johnstone, 2010). Although Johnstone focused on chemistry education engagements, the application of the triplet of learning chemistry education can also be related to other science fields such as physics education. Hence, learners' inability to relate among the three-learning triangle results in passive learning which makes learning difficult (Hanson et al., 2012). The challenge becomes more critical for prospective primary teachers who have a weak background in science education and are being trained as generalist teachers who are expected to teach primary science. This issue is critical because scholars have established that generalist teachers have difficulties teaching basic concepts in primary science (Appleton, 2003; Fitzgerald & Smith, 2016). Since generalist primary school teachers themselves have weakness in teaching science concepts (Appleton, 2003; Fitzgerald and Smith, 2016), it presupposes that generalist teachers themselves partly have challenges understanding the science concepts when taught at the college level. Appleton (2003) confirmed this claim reporting that most primary teachers who are being trained as professional generalist teachers tend not to focus on the science studies but on non-science studies. These challenges therefore necessitate a teaching and learning approach in science that will facilitate the understanding of science concepts of prospective generalist student teachers and arouse interest in science concepts.

In Ghana, pre-service generalist teachers generally show a weakness in learning science concepts particularly basic electronics, a topic in the General Physics Course at the CoE. This is based on reports from the main external examining institution, Institute of Education, University of Cape Coast which has shown that basic electronics, as a physics concepts, is a difficult area for students taking the General Physics Course (Course Code EBS 227). During our first semester's lectures with 2nd year primary education (prospective generalist teachers), the first author found that basic electronics was a challenging topic even at the internal assessment level confirming the issue being raised externally. This is because at the external level, for example, questions covering basic electronics in the General Physics Course examination for 2nd Year Generalist College Students had been reported consistently as the most unpopular question between 2018 and 2021. Further, investigation in the General Physics Course examination for 2nd Year Generalist College Students between 2018 and 2021 revealed that questions involving basic electronic were often avoided in the examinations. This perceived difficulty by students if not tackled at the college level may cause students to avoid treating that section of the course content for prospective generalist teachers let alone developing confidence to teach such areas in the primary school science curriculum in the fields.

Fitzgerald and Smith (2016) revealed that the CoE in Australia seems to attract more primary teachers who fear to teach science in the primary schools than those who love it. This is due to the weak scientific background of primary school teachers. From this assertion, it appears that most generalist teachers have a weakness in science from their secondary school education. As such, they often tend to focus on teaching other subjects to the neglect of science lessons, even though they were trained to teach all the subjects in the primary school curriculum. The question that needs to be asked is how can a primary school teacher willingly and confidently teach basic science concepts in the primary school science curriculum if they themselves are not motivated to learn and understand science concepts conceptually? Furthermore, complicating the issue, generalist teachers have no specialism. Meaning, they teach all the content in the primary school science curriculum. Hence, if generalist teachers develop disinterest for science concepts, they may shift the focus of their teaching to teach non-science studies in the classroom. Understandably, this problem identified is not only found in Australia but also pervasive in Ghana.

Although the Ghana Tertiary Education Commission has made provision that all secondary school applicants must obtain a quality credit (at least C6 as a grade) in integrated science (Ghana Education Service, 2021) as part of the minimum requirement for gaining admission into any of the 46 colleges in Ghana, this directive and policy is not being enforced. This is because the admission requirement by the colleges agrees to allow failed integrated science applicant to replace the integrated science with a credit in social studies. This means that a failed applicant in integrated science could still gain an admission to become a primary school teacher (a generalist teacher). This might explain why most studies have revealed that primary school teachers tend to teach more social studies related subject in the primary school curriculum than science. Further, it may explain why generalist teachers show reluctance when it comes to teaching science concepts they perceive as difficult (Fitzgerald & Smith, 2016). To this end, there is a need to give much attention to the teaching and learning of science concepts in the CoE. If this problem persists, it will weaken the scientific foundational knowledge of primary school learners, killing their desires to pursue science-related courses as their future careers. This is significant because the foundation is principal and key in everything.

Due to these challenges, engaging prospective generalist in active learning of doping of pure semiconductors, a topic under basic electronics, a simulation-role-play teaching approach which makes teaching effective as well as promoting conceptual understanding was used (Atalan & Donmez, 2019). Simulation as a teaching approach encompasses basic elements of active learning or skills such as listening, speaking, manipulating, reflecting, and others. Simulation is a type of teaching approach which transforms theoretical knowledge into practical knowledge (Atalan & Donmez, 2019). Understandably, the practical creates a more realistic and a permanent learning environment (Cahyadi, 2007) committed to saving time and resources. Simulation can be viewed from different perspectives. Simulation can be in the form of pure computer-based, augmented computer simulation, and among others. However, for this study, simulation-role-play was used which takes the form of a drama.

Simulation-role-play appears to be more align to non-science studies. Studies have shown that its role in ensuring conceptual understanding in any subject area cannot be underestimated (Otter, 2020; Caniglia, 2019). More so, simulation-role-play has also been associated with teaching primary and junior high learners who are between the ages of 6 and 12 years (Otter, 2020). To address some of the gaps in the literature, this study focuses on 56 prospective generalist students' teachers whose ages were between 18 and 25 years. Furthermore, the use of

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this simulation-role-play approach to teach doping of pure semiconductors, a topic under basic electronics has been given little or no attention, hence, its application in enhancing the teaching and learning of basic electronics which is perceived as a difficulty area to learn by generalist teachers (Appleton, 2003). Simulation-role-play helps to bridge the gap between student teachers' real-life experiences and physics concepts. This is because the simulation-role-play approach serves as a form of practical activities which places the lesson in a real-life context and this is what removes the abstractness and makes physics concepts less content loaded (Williams et al., 2003), Simulation-role-play has been found to be an active ingredient of improved students' performances, interests, and engagement (Caniglia, 2019).

The overarching question that guided this study was: What is the effect of simulation-role-play in teaching basic electronics to prospective generalist teachers? To fully address that research question, four specific research questions were formulated from the main research question. These questions were:

a. What is the performance level of the student teachers in basic electronics before the intervention?
b. What is the performance level of the student teachers in basic electronics after the intervention?
c. Is there a statistically significant change in the performance level of student teachers in basic electronics after the intervention?
d. What perceptions do students have about the use of simulation-role-play in teaching basic electronics?

Participants

In addressing these research questions, we chose to conduct this study using an action research design in a case study paradigm. The 56 participants were level 200 student teachers studying in a Bachelor of Education (Primary Education) program at a College of Education in the 2021/2022 academic year. This group of student teachers was selected because they were a convenient sample as the first researcher served as a facilitator to this group of student teachers. At the data collection stage, initially, the first author asked student teachers to discuss doping of semiconductors in groups and then do presentations in class as prescribed in the course learning manual. The students were then tested and their examination was marked after the presentations and discussions in class. After the marking, it was found that these students' teachers showed a lack of deeper understanding of the concepts of doping of pure semiconduction. This is because they could not answer the questions satisfactorily. Hence, after a week, the first author decided to teach these same groups of students again, but this time, using simulation-role-play approach. Their performances in the pre-test and post-test were recorded. Data were further gathered when we randomly selected about ten of the students who were willing to be interviewed to seek further clarification and for triangulation of the paper and pen made test. To draw conclusion and make recommendations, we subjected the data gather to analyses and review of results. The next section gives a more detailed approach about the methodology.

The researchers needed to protect the identity of the student teachers and the institutions. To develop trust and to promote the integrity of the research during the process of data collection, student teachers who were interviewed were assured of confidentiality and anonymity. The researcher respected the research site and the participants by not allowing the intervention process to interfere with the school's programs and disturb participants after the study. For data analysis and interpretation, the researcher ensured the anonymity of participants by the use of pseudonyms for individual student teachers. The researcher also provided accurate account of the information from the data collected.

METHODOLOGY

This study's methodology followed three stages. The first stage involved the identification of the problem. The problem was identified during their presentations and subsequent testing of their understanding of doping of pure semiconductors, leading to the formation of N-type semiconductor and P-type semiconductor. This test was described as pre-testing. We realized that student teachers did not understand the concepts of doping of these two types of semiconductors. This was because they lacked the concept of bond formation. Hence, their performance in the pre-test was poor. They also showed little interest in the lesson involving doping of pure semiconductors.

The second stage involves the planning and the implementation of the intervention. According to Caniglia (2019), for simulation teaching strategy in general to be effective, three elements must be present: Preparation, active student participation, and post-simulation debriefing. These elements are critical since it anchors the main purpose for simulation of any type. For this reason, for the first element, a detailed pro forma was planned to be enacted in the classroom as the intervention. It was first enacted on Colleague Tutors in the Science Department as a pilot test. Colleague Tutors in the Department assumed the role of "critical friends" including some of my coauthors. Simulation-role-play was the main teaching and learning approach used for the intervention. These processes served as "the preparation."

The second element of the second stage involved active student participation as the intervention. For the intervention, the female students role-played the role of pure semiconductors. They identified themselves with any of the pure semiconductors such as silicon (Si) or Germanium (Ge). These pure semiconductors are tetravalent semiconductor since they have four electrons in their outermost shell (Si = 2, 8, 4 or Ge = 2, 8, 18, 4). Hence, the female student teachers held four green pebbles in their hands as their valence electrons. In fact, in the pure state, at 0 K (Zero Kelvin), these semiconductors have equal number of holes and electrons (no major or minor carries) but for this simulation-role-play study, it was assumed that the female teachers had only electrons which was used in the doping process. Their male counterparts on the other hand assumed

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the role of impure atoms. They were either pentavalent atom such as Arsenic (As = 2, 8, 18, 5) which means, they have five electrons in its outermost shell and impure trivalent atom such as Boron (B) has three electrons in its outmost shell. This means the male student teachers who role played the role of impure pentavalent and trivalent atom held five black pebbles and three black pebbles, respectively, in his hands as their valences.

Now, at higher temperature for the doping process, the male student teachers with five valence electrons (Arsenic atom) approached a female counterpart and would want to settle or "fuse" with her, the pure Si or Ge. During the doping process, they pair up their outermost electrons. At this period, the impure pentavalent atom paired with the pure Si with tetravalent atom using their valence elections hence four valence electrons against five electrons, leaving one black pebble (electron) unused, just perambulating, or wandering in the pure Si crystal. Together with the entire student teachers, we described this type of doping as N-type semiconductor or n-semiconductors because of the excess electrons (Major negative carriers). In other words, it has Major negative carries and minor positive carries. Similarly, when a different impurity (a different male student teacher) such as trivalent atom (three valence electrons) combined with the Si and settles in the crystal structure, this time around, the male student teacher shared only three black electrons leaving one hole around the Si crystal to be filled. When this happened, it leaves Major carriers to be holes resulting in P-type semiconductors or p-semiconductors.

The third element was described as post-simulation-role-play and debriefing stage. This third element was also the final stage and involved discussions and an evaluation exercise on the concept studied by the student teachers. Hence, they were tested again using the same concepts but with a different set of question items. This served as the post-test. The test items were scored up to 10 marks just like the pre-test. After the test, seven student teachers were interviewed. There were a series of semistructured interviews to seek their views about this new approach. The next sections discussed the analyses of the results and the views expressed by the student teachers about simulation-role-play being used as a teaching and learning approach.

RESULTS

The analyses were done in relation to the research questions that guided the study. The first research question wanted to determine the performance level of students-teachers before the intervention. Hence, the performance is presented in Figure 1. It could be seen that the performance level of the student teachers in the pre-test was below the average score (mean score = 1.61 and a median score of 1).

The bar graph is skewed to the left (positive skewed). Meaning, most of the participants obtained a low score in the pre-test.

The analyses in relation to research question 2, we wanted to find their performance level after the intervention. The result is presented in Figure 2.

From Figure 2, it could be seen that the performance level improved (mean = 4.64 and a median score of 4). This is because the median score obtained in the pre-test increased from 1 to 4 in the post-test.

Analysis with respect to research question three wanted to determine whether there was a statistical significance difference between the two scores under the two conditions pre-test and the post-test. Since the data gather are non-parametric, Wilcoxon Signed Ranks Test statistics was conducted. The test results are displayed in Tables 1 and 2. With Table 1 showing the percentiles while Table 2 shows the test statistics of z-score.

From Tables 1 and 2, a Wilcoxon Signed Rank Test revealed a statistically significant increase in performance level in basic electronics test following an intervention using simulation-role-play approach, $z = -5.824$, $\rho < 0.001$ with a

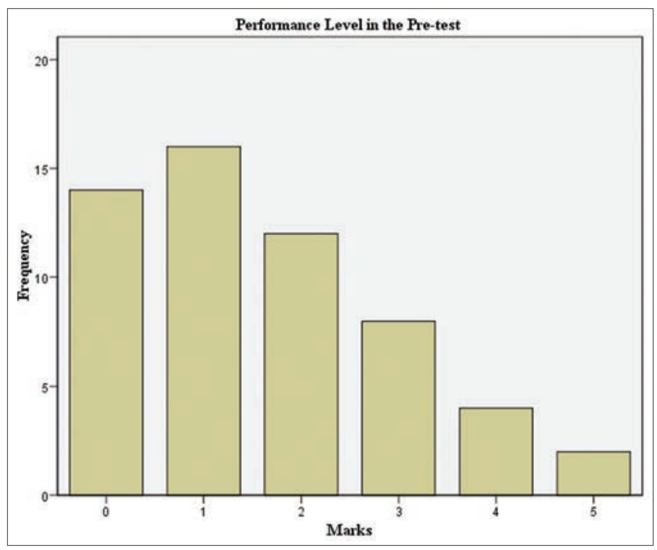

Figure 1: Performance level in the pre-test in basic electronics of student teachers

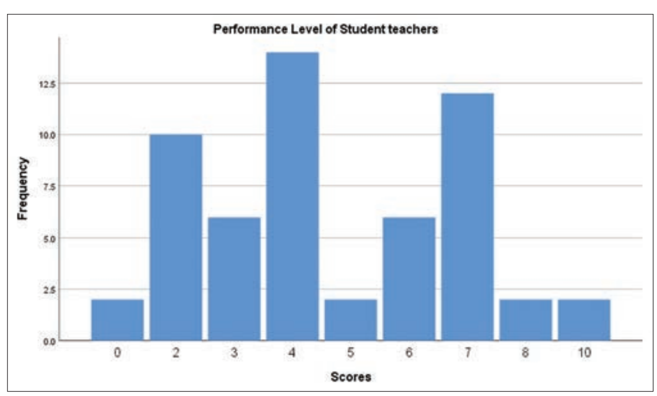

Figure 2: Performance level in the pre-test in basic electronics of student teachers

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Table 1: Percentile rank of the median score

Test	n	Percentiles		
		25th	50th (Median)	75th
Pre-test	56	0.25	1.00	2.75
Post-test	56	3.00	4.00	7.00

Table 2: Test statistics showing the z-score

Test	Statistics[a]
Z	−5.824[b]
Asymp. Sig. (2-tailed)	0.000

[a]Wilcoxon Signed Ranks Test, [b]Based on negative ranks

large effect size (r = 0.55). The median score on performance level also increased from a pre-test score (Md = 1) to post-test score (Md = 4). The effect size was considered large because according to Cohen's (1988) criteria, an effect size greater than 0.5 is classified as a large effect size. For this reason, it could also be seen that the simulation-role-play teaching approach on student teachers learning basic electronic was influenced by 55% which is considered as large effect.

Analysis of research question four also wanted to find out about student teachers' view about teaching doping of semiconductors, a concept in basic electronics, using simulation-role-play approach. The views of the seven students were recorded and transcribed verbatim.

Here were some of the views expressed by these student teachers:

Facilitator (F): Why do prefer simulation-role-play teaching approach to group discussions and the presentation?

> Student teacher (St) 1: I prefer the simulation-role-play to presentation using slides because the simulation-role-play approach made me understood the lesson.
> St. 2: I prefer the simulation-role-play approach because it gave me a clear understanding of what doping of pure semiconductors works. I saw how the doping was done physically.
> St 3: The simulation-role-play because; it is well understood. It came with some form of drama which re-enforces understanding.
> St 4: Simulation-role-play approach is very simple, clear, and explicit.
> St 5: When the discussion method was used, I did not understand but during the simulation-role-play, I was able to grasp the concept so well.
> St 6: Even though the discussions were detailed and more, the level of understanding was not down to my level. Unlike teaching using simulation-role-play approach.
> St 7: I prefer simulation-role-pay approach because; it takes time to explain the concepts easily.

The impact of the simulation-role-play on student teachers in learning outcome is further discussed in the next section with reference to relevant related literature.

DISCUSSIONS

It is important to emphasize that what is simple and logical to tutors during a teaching and learning process may be a complex task for learners. To support this claim, a study by Anderson and Bodner (2008) revealed that teaching and learning are not synonymous. This means that a tutor can teach their best lesson and yet their students may produce their worse learning outcome. This is because meaningful learning did not take place. Until students are able to integrate the new knowledge into their cognitive structures, meaningful learning cannot take place (Dwyer and Childs, 2017; Greeno et al., 1996; Mayer, 1996). Furthermore, tutors and student teachers' experiences are different.

As indicated, the objective of this study was to determine whether simulation-role-play had any statistical change on these student teachers' learning outcomes. In line with this objective, the introduction of simulation-role-play approach revealed a statistically significant increase in student teachers' performance in a basic electronics test following an intervention using simulation-role-play approach, $z = -5.824$, $\rho < 0.001$ with a large effect size ($r = 0.55$). The median score on the performance level increased from a pre-test score (Md = 1) to post-test score (Md = 4). The effect size was also considered large because according to Cohen's (1988) criteria, as an effect size greater than 0.5 is classified as a large effect size. Further, it could also be seen that the simulation-role-play teaching approach influenced these student teachers' learning of basic electronic by 55% which is considered a large effect (Cohen, 1988; Pallant, 2020).

This result is in consonance with Talan (2021) who conducted a meta-analysis on the effect of simulation on academic performance and found a large effect ($g = 0.759$) with a standard error of 0.075 over a large sample size of 7,575 participants. This pivotal study revealed that the effect of simulation on students "academic performance did not differ in terms of subject areas, teaching levels, or application of times but only differed in terms of sample size. Meaning, the impact of simulation as an approach of teaching cannot be underestimated. The teaching approach of simulation remains relevant across several fields of studies and learners" grades (Talan, 2021). This is because after Talan had re-analyzed and synthesized 91 studies, he concluded that, although the studies were heterogenous in structure, the simulation teaching approach was highly effective based on Thalheimer and Cook's (2002) calculation and interpretations ($0.75 < d < 1.10$). Several studies which examined the effect of simulation as a teaching strategy on students' academic achievements have shown that simulation as an approach had a large positive effect size on students' academic achievement (Akkağıt and Tekin, 2012; Chen et al., 2013; Talan, 2021; Tanel and Önder, 2010; Taşlıdere, 2015).

It should be noted that other studies found no significant effect of simulation on students' academic achievement (Bayram, 2019; Bıçak, 2019; Ünal, 2017). The difference could be adduced to the implementation process of simulation (Caniglia, 2019). This is because the element of preparation, active student's involvement, and post-simulation debriefing are critical components in ensuring positive significant outcome. Besides, teacher factors such as motivation and students factors such as attitudes toward the course may influence the learning outcome. In this respect, it is important that teachers adopt or adapt Caniglia's (2019) implementation strategy in ensuring success.

Although the size of the student teachers who were interviewed for this study was small, the views expressed by participants showed a positive perception to the simulation-role-play teaching strategy as very helpful. It can be that focus group discussions could have improved the number of the pre-service teachers who would be willing to express their views on the issue as this is known as "group-effect (Krueger & Casey, 2000)."

CONCLUSIONS

The results from this study's intervention of using simulation-role-play approach in helping students to understand doping of pure semiconductors, a concept in basic electronics, showed that it was successful, in part, in addressing student teachers' needs and challenges of learning the perceived difficulty of this basic concept in electronics. This study is therefore consistent with relevant literature.

In the future, further studies could look at the applicability of simulation-role-play on pre-service teachers' academic performance in terms of gender, scope (sample size), attitude toward the teaching strategy, or teaching other science course area such as General Chemistry course at the College level.

ETHICAL STATEMENT

This study was granted ethical clearance by the Research and Publication Committee of Abetifi Presbyterian College of Education, Abetifi-Kwahu, Ghana.

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