

Learning problem-solving skills in a distance education physics course

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Abstract. In this paper we present the results of a study on the effectiveness of combinations of delivery modes of distance education in learning problem-solving skills in a distance education introductory physics course. A problem-solving instruction with the explicit teaching of a problem-solving strategy and worked-out examples were implemented in the course. The study used the *ex post facto* research design with stratified sampling to investigate the effect of the learning of a problem-solving strategy on the problem-solving performance. The number of problems attempted and the mean frequency of using a strategy in solving problems in the three course presentation modes were compared. The finding of the study indicated that combining the different course presentation modes had no statistically significant effect in the learning of problem-solving skills in the distance education course.

1. Introduction

The role of computational physics in the quest to understand and explain the physical world has risen to equal that of physics theory and experiment [1]. This explains the increasing need to introduce computational physics skills to physics learners at undergraduate level [2], if not as early as experimentation is. Almost all the studies on the teaching and learning of computational physics and problem-solving skills were conducted and focused in the traditional face-to-face education [3, 4]. In this work the worked-out example instructional approach was implemented to teach problem-solving skills in a distance education introductory physics course. The aim of the present research was to assess the effectiveness of the worked-out example instructional approach in a distance education environment. The results of this study can assist in the development of the worked-out example instructional approach for effective use in distance education settings.

One of the aims of physics courses is to teach problem-solving skills [5]. This aim is reflected in the learning activities and assessment instruments in physics courses being dominated by problem solving tasks. Research [3] has shown that the explicit teaching of a problem-solving strategy in science courses can also increase success rates in the courses. The present study implemented the explicit teaching of a problem-solving strategy with worked-out examples to teach problem-solving skills in a distance education physics course. The implemented instructional approach had not been tested for effectiveness, however, the components (problem-solving strategy and worked-out examples) were shown to be effective in this regard. The study was conducted on an actual distance education course delivery. There are practically

no authentic studies reported on the learning of problem-solving skills in distance education. Moreover, most of the studies reported, including those focusing on the traditional face-to-face education, are conducted under ideal experimental settings [6, 7].

In distance education the normal teaching and the required learning take place in different locations, and the teaching is facilitated through technology [8]. Distance education delivery modes include (i) correspondence where print as well as information and communication technologies are used, (ii) online where the Internet and computer technologies are used and (iii) face-to-face classes where traditional classroom instructional technologies are used [9]. The effective use of these technologies in the delivery of distance education relies on the sound knowledge of the technology affordances and the appropriate pedagogy for the content delivered [10]. This study investigated the effect of using combinations of presentation modes of a distance education physics course in learning a problem-solving strategy. The research questions addressed in this study are:

- (i) Is there any statistically significant difference in the problem-solving performance between students who use different combinations of the three presentation modes of a distance education course?
- (ii) Is there any statistically significant difference in the frequency of strategy use between students who use different combinations of the three presentation modes of a distance education course?

These questions were also investigated in the study by Selçuk *et al.* [7] in a traditional face-to-face environment using an experimental research design. In the present study the questions are investigated in a distance education environment. The same course content was treated in the three course presentation modes. The research method of the study is presented in the next section.

2. Research method

The study was conducted at the University of South Africa (UNISA) which is a single-mode distance education institution situated in South Africa, Africa. The physics course considered for the study was presented through correspondence, online, and face-to-face modes.

- (i) Correspondence: This was the traditional tuition mode at UNISA. In this learning mode tuition took place through sending (receiving) the course material (study guide and tutorial letters) to (from) the university using postal services, e-mail and telephone.
- (ii) Online: The *myUnisa* learning management system [11] was used for the online presentation of the course material (study guide and tutorial letters). Weekly online course discussions were scheduled on the discussion forum. Participation in the online interactions required access to computer and internet facilities, which could be accessed at the university regional centers.
- (iii) Face-to-face: Two face-to-face discussion classes in the semester were scheduled for the course and the students were informed of the date, time and venue at least one month before the class. The classes were held at different regional centers in the Gauteng Province. The classes focused on problem-solving and students were working individually during the problem-solving activity.

The same course materials were treated in all the three course-presentation modes [12]. The research design, sampling and data collection are discussed next.

2.1. Research Design

The present study investigated the effect of using combinations of correspondence, face-to-face and online presentation modes of a distance education physics course in learning a problem-

solving strategy. The study used a quantitative research method to formulate an answer to the research questions. The *ex post facto* research design was used in the study because it was not possible to either control for extraneous variables or randomly assign subjects to groups [13]. The following three subsections summarize the instructional approach, population and sampling, and data collection, respectively.

2.2. Instructional Approach

The course considered for this study was a distance education semester course. The course was the calculus-based first-level physics mechanics course. The course was presented through correspondence as well as online using a learning management system. Two face-to-face classes were organized as a learner-support measure. The course was divided into four learning units with each unit scheduled to be treated over three weeks. A pacer was set for the course completion. The instructional approach for the course involved the (i) direct explanation of the prescribed problem-solving strategy, (ii) modeling of the problem-solving strategy through worked-out examples, (iii) independent practice of the strategy through formative exercise problems and (iv) provision of immediate feedback for attempts to formative exercise problems [7]. For each course unit students were required to first study the summary of the mechanics concepts, laws and principles covered. Three worked-out examples and three formative exercise problems were assigned for each course unit. The format of the solutions of the worked-out examples was consistent with the prescribed problem-solving strategy and the solution rubric. The example and exercise problems were taken from standard mechanics textbooks [14, 15]. The summaries of the mechanics concepts, laws and principles were discussed with the instructor, or tutor. However, the solutions to the exercise problems were constructed by the students without assistance.

Heller *et al.* [3] have designed a problem-solution rubric based on a sound problem-solving strategy. This solution rubric has been well researched and is adopted and adapted for use in this study. These authors also designed a tool for determining the difficulty level of a physics problem based on the familiarity of problem context, cues and information given, explicitness of the question, number of possible approaches as well as number of equations to solve. According to this tool the most difficult physics problem has a difficulty rating of six (6) while the least difficult has a difficulty rating of one (1). The example and exercise problems were chosen to be of difficulty rating 3 or less.

2.3. Population and Sampling

The target population was all the students registered for the first-level mechanics physics course. Research [16] has shown that demographic and situational factors can affect learning, including in distance education. In this study the target population was treated as a homogeneous group. However, it was noted that the target student population consisted of males and females with ages between 18 years and 50 years, the majority of whom resided in South Africa. Some of the students were employed in various economic sectors while others were not employed. All the students were familiar with information and communication technologies (computer, cellphone) and had used instant-messaging and e-mail services. Also, based on the admission requirements, the students were familiar with distance education technologies and were proficient in the language used in the course presentation. However, the students were used to the traditional face-to-face teaching, which differed from the distance teaching and learning in this course.

All the students registered for the course were invited to participate in the course by taking part in the online course activities as well as attend the face-to-face class of the course, in addition to the traditional correspondence tuition. Three main subgroups of students in the course were identified based on whether the students participated in the online part and/or face-to-face class of the course. As a result, a stratified random sampling technique [17] was used to identify

groups of students depending on the additional participation mode in the learning activities of the course. Few students participated in the face-to-face classes as well as the online components of the course [18] which resulted in all the participants in these learning modes being selected for the study. However, a simple random sampling technique [17] was used to select a proportional number of students using the correspondence learning mode only.

2.4. Data Collection

The research data were obtained using researcher-designed criterion-referenced tests with ten (10) closed problems as test items. The problems were testing the knowledge and understanding of physics concepts at various levels of Blooms taxonomy of learning objectives [19]. Primary and secondary data were collected to answer the research questions. Primary data consisted of (i) solutions to the formative practice problems, (ii) the number of problems solved, and (iii) the frequency of strategy use in solving problems in the summative examination. Secondary data consisted of (i) participation in the correspondence, online and face-to-face learning activities. All necessary permissions were obtained before collecting the data. Several measures were taken to increase the validity and reliability of the data collection instruments as well as the results.

The problems to be solved were selected from a standard internationally published physics textbook [15] used in previous official formative and summative assessment tests in the course. In addition, a test consisting of problems with deep similarity characteristics to the problems in the assessment tests was given to students registered for the course in the previous semester. This helped improve the clarity and comprehensibility of the problems in the tests. The same rubric used to assess solutions to the formative practice problems was used to assess solutions to problems in the formative and summative assessment tests. The tests were moderated by an internal physics expert for face validity and content validity. Also, the tests were marked by an external marker and the marked tests were moderated by two internal physics expert. The results are presented and discussed in the next section.

3. Results and discussion

The target population consisted of 179 active students in the course. Only 19 students legitimately participated in the online and 19 students attended the face-to-face class. After trimming the face-to-face class group was reduced to 15 students. Therefore, the sample size was restricted to 45 students, 15 in each group. No matching in the sample was done because this would have further reduced the already small sample size. The summative assessment test consisted of ten problems and was to be completed in two hours. The solution rubric of Heller *et al.* [3] was adopted in this study to assess solutions to problems from the formative and summative assessment tests. The rubric has been widely researched and modified over the years [20]. This rubric divides the problem solving process into five categories and provides simple grading mechanism for each category. The rubric is in line with the assessment policy of UNISA and is consistent with best assessment practices. Only problems of difficulty level between 2 and 4 [3] were chosen for the domain-referenced researcher-designed tests. To simplify the analysis of the results the number of problems with complete solutions (out of ten) and the frequency of strategy use were categorized as shown in Table 1.

The summative test was evaluated by two physics experts and the evaluated test was further assessed by the researcher. The inter-rater ratio [13]

$$R = \frac{\text{Number of actual agreements}}{\text{Number of possible agreements}} \quad (1)$$

can be used as a measure of consistency in the evaluation of the test. A value of $R = 0.65$ was obtained for the number of problems with complete solutions in the summative assessment

test. The results for the problem-solving performance are given and discussed in the next two subsections.

Table 1. Categories of problem-solving performance measures considered.

Category	Number of Problems	Strategy use
A	8 or more	6 or more
B	5, 6 or 7	3, 4 or 5
C	4 or less	2 or less

3.1. Number of problems solved

The results for the number of problems attempted in the summative examination are presented in Table 2 for the three groups. The number of problems with complete solutions N_p as well as the mean score M_p for each category and each group is given in the table. It can be seen from this table that students in the correspondence group generated more Category A solutions (53% with a mean of 52) than students in the face-to-face and online groups. On the other hand, students in the face-to-face and online groups generated more Category B solutions, 73% and 60%, respectively, with the corresponding mean of about 40. In general the performance of the face-to-face and the online group are similar but lower than that of the correspondence group. The results for the correspondence group follow the same trend as in the formative assignments (not shown) while the face-to-face and online results follow a different trend. This indicates that combining correspondence with face-to-face or online can increase the learning of problem-solving skills in a distance education course.

Table 2. The number of problems solved (N_p) and the mean score (M_p) for the course-presentation modes.

Category	Correspondence		Face-to-face		Online	
	N_p	M_p	N_p	M_p	N_p	M_p
A	8	52.4	3	39.7	4	59.5
B	3	33.0	11	39.1	9	42.7
C	4	34.2	1	21.0	2	20.0

One-way analysis of variance was used to further investigate the performance of the students presented in Table 2 for the number of problems solved. The F statistic and p -value for the three groups were calculated with a 95% confidence level ($\alpha = 0.05$) assuming equal variance in the groups. The results are given in Table 3. The calculated p -value is 0.583, and the F statistic value is 0.547 with a critical value $F_c = 3.2199$. Therefore, the analysis of the descriptive data indicate that combining the learning modes had no statistically significant effect on the number of problems solved ($F < F_c$, $p > 0.05$). However, this finding should be treated with caution since there was no control for extraneous variables.

Table 3. Inferential statistics for the number of problems solved.

Source	df	SS	MS	F	p	F _c
Between groups	2	4.044	2.022	0.547	0.583	3.2199
Within groups	42	155.2	3.695			
Total	44	159.2				

3.2. Frequency of strategy use

The frequency of strategy use was determined from the number of problems with complete solutions. The results obtained from the summative assessment test for the three categories of the three groups show that the face-to-face group had a higher frequency of strategy use, Category B solutions (87%), than the correspondence and the online groups, which had more Category C solutions (80% and 53%, respectively). However, unlike the correspondence and the online groups, the face-to-face group had no Category A solutions. The results for the correspondence and online groups appear very similar. For further analysis of these results, descriptive statistics for the frequency of strategy use were calculated and the results are shown in Table 4. In this table the sample size (N_s), the maximum value (Max), the range ($Range$), the mean (Mf), standard deviation (SD) and standard error (SE) are shown. It can be seen from the table that of the three groups, the face-to-face group had the lowest $Range$ (3), the lowest SD (0.9) and the lowest SE (0.2). The results for the correspondence and online groups also appear similar.

Table 4. Descriptive statistics for the frequency of strategy use.

Group	N _s	Max	Range	Mf	SD	SE
Correspondence	15	9	9	1.9	2.2	0.6
Face-to-face	15	5	3	3.3	0.9	0.2
Online	15	10	10	3.2	2.8	0.7

Table 5. Inferential statistics for the frequency of strategy use.

Source	df	SS	MS	F	p	F _c
Between groups	2	19.733	9.867	2.187	0.125	3.2199
Within groups	42	189.467	4.511			
Total	44	209.2				

One-way analysis of variance was used to further investigate the descriptive statistics of the frequency of strategy use presented in Table 4. The F statistic and p -value for the three groups were calculated with a 95% confidence level ($\alpha = 0.05$) assuming equal variance in the groups. The results are given in Table 5. The calculated p -value is 0.125, and the F statistic value is 2.187

with a critical value $F_c = 3.2199$. Therefore, the analysis of the descriptive data indicate that the use of the blended-learning approach had no statistically significant effect on the frequency of strategy use ($F < F_c, p > 0.05$). However, this finding should be accepted with caution since there was no control for extraneous variables. Conclusions are presented in the next section.

4. Conclusion

The objective of this research was to investigate the effectiveness of the three delivery modes of distance education in learning problem-solving skills in a distance education physics course. A problem-solving instructional approach that involved the explicit teaching of a problem-solving strategy and worked-out examples was implemented in the course. The *ex post facto* research design with stratified sampling was used for the study. A sample of 45 students with 15 in each stratum was considered. The number of problems solved and the frequency of strategy use in solving problems were assessed for each of the course presentation modes. These problem-solving performance measures were compared between the three modes. Small differences in the means were observed in the problem-solving performance of the three groups of students. However, no significant difference was found in the effectiveness of the three presentation modes. It should be noted that extraneous variables were not controlled for in the study. Therefore, the results must be treated with caution. However, the finding of the study is consistent with the findings of [21]. Nonetheless, further investigations are required to verify the results. The finding of this study suggests that learning may be affected less by the type of technology used in teaching and learning in distance education.

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