GENDER DIFFERENCE IN PERCEIVING ALGORITHMIC THINKING IN AN INTRODUCTORY PROGRAMMING COURSE

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Abstract

Algorithmic thinking is considered an important step towards learning to program for novice programmers. In this study, we developed and introduced a PROSOLVE game to enhance the algorithmic thinking skills of novice programmers in an introductory programming (IP) course. The game is based on pseudo code technique. Moreover, the game is web-based and it covers most of the teaching topics of IP course. A survey was conducted to collect students' feedback. The mean values for each survey question were compared by gender. A T-test was performed to determine if there is any significant difference between the mean values of male and female students' survey responses. The result shows that both female and male students appreciated the game-based learning in the teaching and learning process of the IP course. Male students perceived more positive responses compared to female students in most of the survey questions. However, female students perceived slightly more than male students that the game helped them in understanding the programming concepts and learning the problem solving skills. The result of T-test depicts that it is statistically significant because the p-value for equal variances assumed (.028) is less than p = 0.05. Overall, the game promotes algorithmic thinking and discourage programming shortcut ('Problem statement → Codes').

Keywords: game-based learning; algorithmic thinking; programming education; novice programmer; gender.

1 INTRODUCTION

Algorithmic thinking is considered an important step towards learning to program for novice programmers. It helps novices to devise the solution for a given problem statement before start writing the code. On the other hand, the traditional teaching approach in the introductory programming (IP) course focuses more on programming knowledge (syntax and semantics) [1]. Reference [2] found that those students who did not have a background in algorithmic thinking were handicapped in higher education and argued that traditional teaching strategies were inappropriate for students to acquire problem solving skills. Moreover, reference [3] discussed that ‘typical introductory programming textbooks devote most of their content to presenting knowledge about a particular language’ (p. 141). Reference [4] examined programming textbooks and concluded that 6 out of 40 textbooks incorporated problem solving strategies throughout the book. Algorithmic thinking should be offered for the whole semester for novice programmers to acquire program design skills.

In this study, we developed and introduced the PROSOLVE game to enhance the algorithmic thinking skills of novice programmers. The game covers all the teaching topics of the IP course. Hence, it offers algorithmic thinking to novice programmers for the whole semester.

This paper is divided into a number of sections. It starts with a review of the literature, followed by a research question. A brief introduction to the PROSOLVE game is provided. The research methodology used for this study is then described, and research results are reported and discussed. The paper concludes with a summary of the outcomes.

2 LITERATURE REVIEW

Algorithmic thinking refers to solve a problem by developing a set of steps in a particular sequence to achieve a desired outcome [5]. Algorithmic thinking is the thought process which helps to formulate the required steps to achieve the desired result [6]. Reference [7] stated that ‘algorithmic thinking does not require a computer and mathematical thinking and is almost solely dependent on the human’s formalization capacity for abstraction’ (p. 28). Reference [2] argued that algorithmic thinking is a core concept for students in higher education and the traditional teaching strategies did not provide the conceptual framework substantially required for coding and problem solving. Therefore, they suggested incorporating a strategic focus on algorithmic thinking in an education setting.
Algorithmic thinking is one of the core concepts in computer science. Students should be taught this concept as a primary objective of computer science education [8]. Therefore, reference [8] explained how they introduced three examples in programming classes to promote general aspects of algorithmic thinking. This process leads to a deeper understanding of computer science concepts to students.

Reference [9] suggested teaching algorithmic thinking at the beginning of programming education. This process helps students to focus on problem solving strategies without much worry about the programming language [10]. Therefore, a web-based application, PROBSOL, was offered to enhance problem solving skills of novice programmers [11]. The application is based on pseudo-code technique and students did not bother much about the programming language syntax while enhancing their algorithmic thinking. Reference [2] introduced game –based learning in programming education to enhance algorithmic thinking. Reference [12] developed and introduced an online puzzle-based game learning system, TGTS (Turtle Graphics Tutorial System), to help students learning algorithmic thinking skills. Reference [13] introduced an ADRI (Approach, Deployment, Result, Improvement) based approach in an introductory programming course which promotes algorithmic thinking. The first stage (Approach) of the ADRI based approach covers problem solving strategies (pseudo-code and flowchart). Students have to purpose the solution of the given problem statement by using problem solving strategies (pseudo-code and flowchart) before start writing the program in programming language. This process promotes algorithmic thinking in the course.

3 RESEARCH QUESTION

It is evident from the previous section that algorithmic thinking is an important component in programming education. Moreover, algorithmic thinking should be offered at the beginning of an introductory programming course. In this study, we prepared and offered the PROSOLVE educational game to novice programmers in the introductory programming course. We purpose a research question to guide the study and to determine the impact of the PROSOLVE educational game on novice programmers.

The research question being addressed in this study is as follows:

RQ: what is the impact on the perception of gender difference after introducing the PROSOLVE game in the introductory programming?

4 PROSOLVE GAME

The PROSOLVE game is a web-based application and it is based on pseudo-code technique. The main purpose of the game was to promote algorithmic thinking in the IP course. Questions related to all the teaching topics of the IP course are embedded in the game. Figure 1 shows the interface of the game.

Figure. 1: Interface of PROSOLVE game
The game comprises of Random Steps and Solution list boxes as shown in figure 3. The Random Steps list box shows the solution of the given problem statement in a random manner as shown in figure 2. A user can re-arrange the solution steps by clicking the up and down arrows. A number of clicks are recorded and the user can get the right solution by clicking the ‘Get Points’ button. The correct solution for the given problem statement is shown in the Solution list box. The game compares the user solution against the correct solution and award points. The user errors in the solution are shown in Random Steps list box in red color.

![Figure 2: Random Steps List box of PROSOLVE game](image)

The game consists of seven levels. Each level covers a different teaching topic of the IP course. A player can win bronze, silver or gold medal based on the points earned in the game as shown in figure 4. Moreover, the player can win a cup depends on the total points obtained in the game.

![Figure 3: List boxes of PROSOLVE game](image)
5 RESEARCH METHODOLOGY AND DESIGN

The research question was investigated by conducting a survey with students after introducing the PROSOLVE educational game in the IP course. 51 students participated in the survey including 10 male (19.6%) and 41 female (80.4%).

The survey has three parts and consists of 27 closed-ended questions. The first part of the survey consists of demographic questions. The second part includes questions related to programming concepts and course content. The third part of the survey covers questions related to usability of the PROSOLVE game in the IP course. A five-point Likert scale (1=strongly disagree to 5 = strongly agree) is used for questions related to the second and third parts of the survey. An ethical approval was obtained from the college before collecting the data. Students’ participation was voluntary and optional. Data collection was anonymous in the survey.

6 RESULTS

This section describes the result of this study and research question was explored by analyzing the responses of students in the survey.

A statistical method was used to explore this research question. The mean values for each question were compared by gender. The weighted mean was calculated to address the unbalanced population (80.4% female compared to 19.6% male students). A T-test was performed to determine if there is any significant difference between the mean values of male and female students’ survey responses. Table 1 depicts the result of T-test.

The comparison of mean values of male and female students’ responses depicts that it is statistically significant because the p-value for equal variances assumed (.028) is less than p = 0.05.

<table>
<thead>
<tr>
<th>Gender</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>Significance value (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>21</td>
<td>3.8157</td>
<td>.17554</td>
<td>.03831</td>
<td>.028</td>
</tr>
<tr>
<td>Male</td>
<td>21</td>
<td>3.9333</td>
<td>.15916</td>
<td>.03473</td>
<td>Equal variances assumed</td>
</tr>
</tbody>
</table>

6.1 Demographic Details

The demographic details of the respondents are shown in table 2.
Table 2. Demographic details of respondents

<table>
<thead>
<tr>
<th>Major</th>
<th>Information Systems</th>
<th>37.3%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Computer Science</td>
<td>41.2%</td>
</tr>
<tr>
<td></td>
<td>Software Engineering</td>
<td>21.6%</td>
</tr>
<tr>
<td>Degree</td>
<td>Bachelor</td>
<td>52.9%</td>
</tr>
<tr>
<td></td>
<td>Advanced Diploma</td>
<td>3.9%</td>
</tr>
<tr>
<td></td>
<td>Diploma</td>
<td>43.1%</td>
</tr>
<tr>
<td>Age</td>
<td>Under 18 Years old</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>18 to 28 Years old</td>
<td>94.1%</td>
</tr>
<tr>
<td></td>
<td>29 to 44 Years old</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>45 Years old or above</td>
<td>2%</td>
</tr>
<tr>
<td>Gender</td>
<td>Female</td>
<td>80.4%</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>19.6%</td>
</tr>
<tr>
<td>Prior programming experience</td>
<td>Yes</td>
<td>29.4%</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>70.6%</td>
</tr>
</tbody>
</table>

6.2 Programming Concepts

Respondents’ perception in understanding programming concepts after introducing the PROSOLVE game in the IP course is shown in figure 5. Moreover, figure 5 depicts a comparison of mean values by gender for this set of questions.

Figure 5 depicts that male students perceived better than female students in ‘focus only on problem solving skills’, ‘understanding programming structures’, ‘learn the course contents’, ‘develop skills that apply to my academic career and/or professional life’ and ‘develop confidence in the subject area’. On the other hand, female students perceived better than male students in ‘understanding the programming concepts’, ‘learn the problem solving skill (pseudo-code)’, ‘design a program to solve a certain task’ and ‘participate in the course activity in ways that enhanced my learning’.
The second part of this section covers questions related to the teaching topics of the course as shown in figure 6.

Figure 6. Teaching topics

Figure 6 shows that male students depict more positive responses compared to female students in most of the areas of teaching topics except ‘design an algorithm’. Both female and male students show equal response in ‘selection structure (if statement)’.

6.3 PROSOLVE Game: Usability

The last part of the survey covers questions related to usability of the PROSOLVE game in the IP course as shown in figure 7.

Figure 7. Usability of PROSOLVE game

The mean values of male students are better for all the questions in this part of the survey (except for the question ‘is effective to learn programming’) compared to female students.

7 DISCUSSION

The result of the students’ survey shows that both male and female students appreciated the PROSOLVE game in the teaching and learning process of the IP course. The game helped students
to grasp the precise concepts of programming domain. It also focuses on students’ cognitive gain and engagement in programming. Moreover, it plays an important role in developing students’ affective engagement in the course. This finding is consistent with the references [2][12] who also advocated that game based learning promoted algorithmic thinking skills in programming education.

Female students perceived slightly more than (0.2%) male students that the game helped them in understanding the programming concepts and learning the problem solving skills. This finding is consistent with [14] who suggested that female students appreciated web-based learning in programming education.

The survey result depicts that male students show more positive response compared to female students in perceiving algorithmic thinking in the course. Reference [15] suggested that it may be due to self-confidence which is lacking in female students compared to male students. This finding is consistent with [16] who concluded that male students were more confident than female students in learning programming after introducing a new teaching approach in an introductory programming course.

The game emphasizes the presentation style ('Problem statement → Solution plan → Codes') and discourage programming shortcut [17] ('Problem statement → Codes'). Students have to devise the solution of the problem statement by using problem solving strategy (pseudo-code) before start writing the code. This process promotes deep learning and algorithmic thinking skills among IP students. Moreover, it helps students in understanding the given problem statement. This finding is consistent with [18] who proposed the ADRI based approach in the IP course to discourage programming shortcut.

The game emphasizes students that program design is also an important step besides language features and program comprehension in programming education. If students understand the given problem statement in a proper way, it will be easy for them to achieve the objectives of the program. This finding is consistent with [19][20][21].

The game covers all the teaching topics of the IP course. Students practice algorithmic thinking for the whole semester which promotes deep learning of the programming concepts. Moreover, this process promotes practice among students. Reference [22] argued that ‘practice is considered an important step in grasping the precise concepts of computer programming for novices’ (p. 1). The game also provides basic understand of different programming structures to novice programmers.

Most of the students agreed that the game helped them in preparing the IP exams. This process motivates students in learning programming education and thus helpful in reducing high failure and dropout rates in computer science. Reference [23] concluded that ‘decisions about majoring in computer science and related fields are often determined by a student’s success or failure in the introductory course. If a student drops out, fails, or passes with a struggle, that student is unlikely to enroll for a follow-on course.’ (p. 97).

Most of the students agreed that the game is an effective way to learn programming. Instructors should prepare the teaching materials which incorporate different teaching methods to engage students in the learning process. Moreover, most students perceived that the game motivated them to learn programming and engaged them as active learners in programming activities. This process helps computer science and related departments to retain students. Reference [24] concluded that ‘the technology integrated tools emphasis on student interest in order to develop their academic performance.’ (p. 2).

Students also suggested incorporating the game-based learning for advanced courses of programming. The game can also be treated as an additional teaching tool in the IP course. Further, it provides a question bank to the IP instructors. The game is web-based and easy to use which helps students to focus more on algorithmic thinking skills.

8  CONCLUSIONS

Gender differences were examined in the introductory programming (IP) course after introducing the PROSOLVE game in the teaching and learning process of the course. The game is web-based and easy to use. It is based on pseudo-code technique. The game covers all the teaching topics of the IP course.
A survey was conducted to determine the students’ perception about the PROSOLVE game in the IP course. Male and female students’ responses were compared in the survey for each question to determine the gender differences. The comparison depicts that male students were more satisfied compared to female students in most of the questions of the survey. It may be due to lack of self-confidence in female students compared to male students [15]. On the other hand, female students perceived slightly more than male students that the game helped them in understanding the programming concepts and learning the problem solving skills.

The game promotes students’ algorithmic thinking and program design skills, students’ cognitive gain and affective engagement, and discourage programming shortcut (‘Problem statement → Codes’). It encourages students to follow the proper presentation style (‘Problem statement → Solution plan → Codes’) while devising the solution for the given problem statement.

Overall, both female and male students appreciated the PROSOLVE game in the teaching and learning process of the IP course. They suggested incorporating the game-based learning in advanced courses of programming.

REFERENCES


