ROLE OF STUDENTS' CONTEXT FAMILIARITY IN DIFFERENTIAL EQUATIONS PROBLEM SOLVING AT PRE UNIVERSITY LEVEL

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ABSTRACT

In this study, role of context familiarity in students' differential equations (DEs) solving was explored at pre-university level. An assessment test containing three self-developed DEs tasks were distributed among 430 students, studying in inter-colleges. Collected responses were analyzed using a scoring rubric containing three main stages (understanding, planning towards the solution and getting answer).Findings revealed that context familiarity positively affected students' problem solving. Students showed better problem-solving skills in physics based problem as compared to biological related problem. Surprisingly, in solving compound interest related problem, students'performance was even better than physics related problem. Beside the positive affect of context familiarity, students have shown lower performance in getting answer and the increasing trend of errors was found in answering to logical questions. From the findings of this study, it may be concluded that context familiarity and contextual based problem solving have great potential to improve differential equation problem solving.

Keywords: *Algebraic Approach, Context Familiarity, Differential Equation, Problem Solving*

INTRODUCTION

Differential Equations (DEs) have prominent role in mathematics. These can correlate real life situations (e.g. motions of heavenly bodies, bridge designs and interactions among neurons) and also provide effective solutions of problems(Arslan, 2010a). Due to their great importance, the study of DEs has been included in various courses in different departments including college level (Blumenfeld, 2006).

Literature reveals that several factors have been identified and reported as major contributing factors for mathematics problem solving as well as differential equation problems(Aisha, Abedalaziz, Ahmad, & Satti, 2018; Ozturk & Guven, 2016). These factors include epistemological math problem solving beliefs, usefulness, self-regulated learning strategies (SRL) and goal orientations(Beghetto & Baxter, 2012; Bibi, Zamri, Abedalaziz, & Ahmad, 2017; Hofer, 1999; Muis, 2004; Polya, 1962; Schommer-Aikins, Duell, & Hutter, 2005; Schommer-Aikins & Duell, 2013). Beside these, it was also revealed that selection and employment of the problem-solving approach (such as algebraic, graphical or numerical) also effect differential equation problem solving. Several studies have proven that algebraic approach predominates in traditional differential equation course, yielding relatively good performance(Arslan, 2010b; Rowland, 2006). Further Arslan (2010b) elaborated that procedural learning in traditional differential equation course confines students to mastering and applying some algebraic techniques. In our previous work (unpublished and under review), it was also revealed that mostly algebraic approaches are being used to solve differential equation problems at pre-university level. However, in applying the similar algebraic problem solving approach, results were different for changed areas (i.e. physics, biological and etc.). This variation in the results had motivated the researchers to further explore this area.

From the literature, several studies were found which had highlighted the positive effect of context familiarity in problem solving (Jairaman, Zamri, & Rahim, 2018; Possi & Milinga, 2018; Yew & Zamri, 2018), particularly mathematics problem solving (Gómez Ferragud, Solaz Portolés, & Sanjosé López, 2015; Heller, Keith, & Anderson, 1997; Kulasegaram, Min, Ames, Howey, Neville, & Norman, 2012; Langtangen & Pedersen, 2016; Ngu, Yeung, & Phan, 2015). According to authors, context familiarity (through direct experience, newspapers, televisions, or standards textbooks) makes problem solving easier than problems with context unfamiliar to the students (Abramovich, 2015; Kulasegaram et al., 2012; Martin, Liem, Mok, & Xu, 2012; Palincsar & Brown, 1988). These findings have provided further directions to interlink differential equation problem solving with the idea of context familiarity. Therefore, in this work, students were asked to solve differential equation tasks using algebraic approach. These tasks were involving different areas/fields. Task 1 was from the biological based problem, whileTask 2 was from physics field and Task 3 was related to compound interest. To measure their problem solving skills and score achievement, a scoring rubric containing three stages were used to analyze the effect of context familiarity.

RESEARCH OBJECTIVES

The aim of current article is to determine the extent of context familiarity effects on the students'differential equations problem solving. Beside this, students' difficulties and the errors when they use similar approach were also investigated.It is anticipated that the findings of current study will assist educators and researchers with some insightful ideas about the pattern and issues studied in the area of differential equations.

The research questions addressed by this study are therefore:

1. To what extent context familiarity affects the students' differential equations problem solving.at pre university levels?
2. What arethe student's majorerrors when they use similar problem solving approach in different areas (i. e physics, biology, finance and etc.)

METHODOLOGY/RESEARCH DESIGN

To explore how the context familiarity affects the students' differential equations problem solving and the errors arose when they usedsimilar approach in different areas, a self-developed instrument was used.Details of the instrument, population, and samples have been described in the following sections.

Research Instruments

For the current research, an assessment test containing three self-developed differential equation tasks was used.Keeping in mind, the level of the course content and selected population, three non-routine problems containing first order autonomous and pure time differential equations were developed. Although the developed tasks were not complex as like available in literature (for university level). However, sufficient efforts were carried out to give them shape of non-routine problems with adequate hidden data to analyze the full picture of difficulties faced by the students when they were engaged to solve assessment test.

To measure their problem solving skills and score achievement, a scoring rubric containing three main stages (understanding, planning towards the solution and getting answer) was adapted. This scoring rubric was based on analytic scale for problem solving (Charles, Lester, & O'Daffer, 1987). For the current study, each stage had maximum two marks, while each task had total six marks. Detail of the scoring rubric is provided in Table 1.

To ensure the content reliability and validity, the assessment instruments was validated through 4 experts that integrated one mathematician, one psychological educator and two mathematics educators, who were teaching at college and university levels. They were explicitly asked to look into the instrument content and face validities. This group accomplished an anonymous consensus on the instrument reliability and content validity. Besides this, a pilot study was also carried out with the participant of 228 students who had already attended differential equation lessons. These participants were not considered into evaluation within the scope of this study. In addition, responses of the participants demonstrated that the differential equation tasks were suitable for the data collection and eventually for the objective of the study. Further, Cronbach's alpha (a statistical measurement) was used to calculate the reliability of the subscale. Coolican (2014) recommended that this technique can be used to determine the internal reliability of survey instrument to confirm outputs from the measurement are consistent in generating same results at different times.

Data Collection

The target population for the current study was inter level students, enrolled in second year inter-colleges/higher secondary schools in Khyber Pakhtunkhwa (a big province of Pakistan). Sample was collected from students having pre-engineering and science back ground studying in public and government institutes. For more generalized and appropriate random sampling, institutes from both urban and rural were considered. Overall, 430 questionnaires were distributed and ultimately, 394 responses were deemed fit for further analysis. To analyze all the responses, Statistical Package for the Social Science (SPSS) software was used.

Analysis of Differential Equation Tasks

An adapted Analytic scale for problem solving based on scale of Charles, Lester, and O'Daffer (1987) was used to score these tasks. Authors proposed three categories as understanding, planning and getting answer (Charles, Lester, & O'Daffer, 1987). The understanding stage, students needed to interpret or retrieve hidden data. In case of full understanding they were assigned 2 marks otherwise 1. The next phase was planning, in which students had to plan the whole steps, procedures, formulas, and strategies. Students who were successful in their planning phase they were assigned 2 marks otherwise they were considered partial planner and were assigned 1 mark. In getting answer phase, the answer of the task, students who used the correct procedure but not completed the solution or made a sign or unit mistakes they were assigned one marks and vice versa.

The test had maximum two marks for each stage and total six marks for each task. Detail of scoring rubric to assess differential equation problems is illustrated in Table 1.

Table 1
Detail of adopted scoring rubric for non-routine words problem to assess differential equation problems(Charles, Lester, & O'Daffer, 1987)

Stages	**Scores**	**Characteristics**	**Description**
Understanding	0	Complete misunderstanding	Lack of comprehension problem Not able to identify important given data
	1	Partial understanding	Misinterpreted some part of problem partially understand data, partially understand goals and hidden data
	2	Complete understanding	Ability to take information and to translate it in the mathematical model, fully retrieve given and hidden data and symbolically specify relevant known and un known variables, formulate proper equation
Planning a solution	0	No attempt/ inappropriate plan	Wrong Integration procedure, not able to put constant of integration,
	1	Partially correct plan	Correct interpretation up to a certain point, but strategy remain major flawed
	2	Plan lead to a correct solution	Execute the plane, translate plane into series of appropriate mathematical action, successful findings
Getting answers	0	No answer	Can't execute integration steps
	1	Copying error, computer error	Mathematical/computational error
	2	Correct answer, correct label	Solution complete, No error in answer

Furthermore, students were graded based on the grading system of the Khyber Pakhtunkhwa (KPK), Pakistan. The detail of the grading system is provided in theTable 2.

Table 2
Grading system of the Khyber Pakhtunkhwa (KPK), Pakistan

Marks Percentage Range	**Grade**	**Remarks**
80 % or above	A+	Outstanding
70-79 %	A	Excellent
60-69 %	B	Very good
50-59 %	C	Good
40-49 %	D	Fair
Below 40 %	E	Un-Satisfactory

RESULTS

For the current study, three self-developed tasks were used. In thedevelopment stage, guidelines of Polya (1957) and Schoenfeld (1985) were considered, which had more focused on the distinction between a mathematical problem and a mathematical task. In addition, these tasks were reflecting non-routine based differential equation problems. These three non-routine differential equation tasks were covering different aspects of the differential equations to relate and solve daily life problems. Task 1, task 2 and task 3 were about population growth, projectile motion and compound interest, respectively. Algebraic or procedural based approaches were needed to solve these tasks.

While preparing and analyzing research tasks, their cognitive demands were particularly considered making sure that they must reflect low, moderate, and high levels of complexity. According to Webb (1999) classification system, cognitive complexity level of items is associated with its depth of knowledge rather than ability of students. A low complexity of a question requires students to recall a previously learned concept, whereas, moderate complexity requires more critical thinking, in which students are expected to use reasoning and problem-solving strategies, and bring together skills and knowledge from various domains. In addition, a high complexity question involves solving a non-routine problem that requires multiple steps and decision point. Based on Webb (1999)classification system, each used task was reflecting low, moderate and high complexity level.

Results revealed that, for task 1, out of 394, 2 % of the participants were unable to interpret word problems and due to this, they were unable to understand problem completely, whereas, 8 % participants had shown partial understanding, while 90% have shown reasonable understanding. In the next stage, 4% entirely failed to plane, 13% had partially planed, while 83% have shown reasonable planning skills. In the third stage, 15% entirely failed to get answer, 8% had partially answered, while 77% had given the correct answer with right units.

Analysis of the task 2 showed that 2% of the participants were unable to understand the problem completely, 5 % participants had shown partial understanding, while 93% have shown reasonable understanding. In the next stage, 3% entirely failed to plane, 12% had partially planed, while 86% have shown reasonable planning skills. In the third stage, 14% entirely failed to get answer, 25% had partially answered, while 61% have given the correct answer with right units.

From the analysis of task 3, it was observed that 3% of the participants were unable to understand the problem completely, 3% participants had shown partial understanding, while 94% have shown reasonable understanding. In the next stage, 3% entirely failed to plane, 7% had partially planed, while 90% have shown reasonable planning skills. In the third stage, 10% entirely failed to get answer, 68% had partially answered, while 22% have given the correct answer with right units.

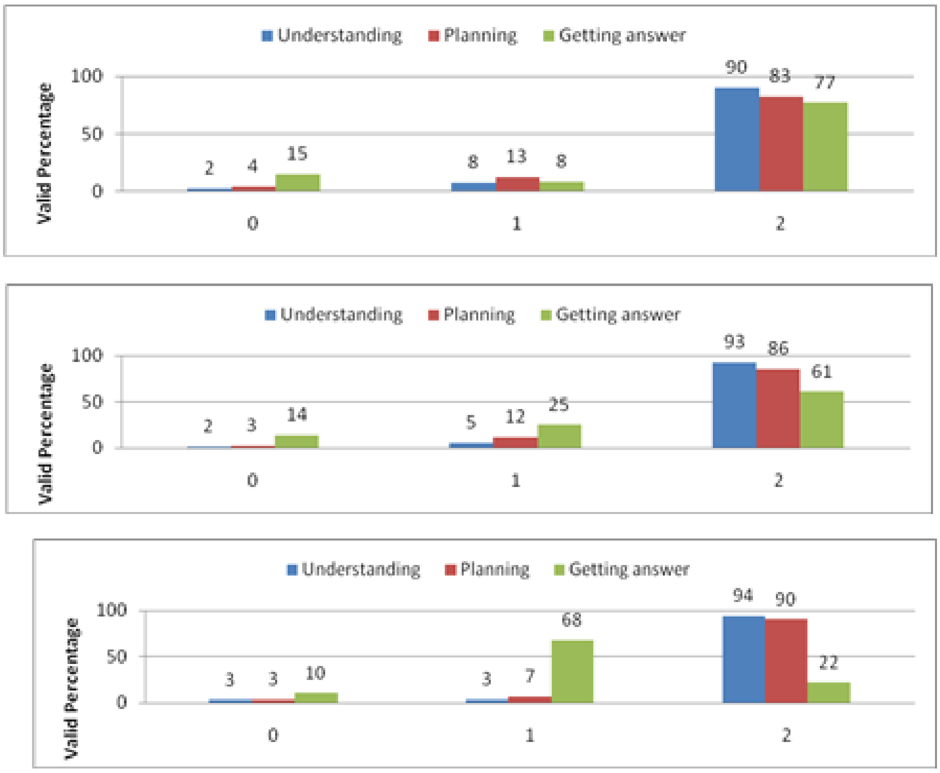

Figure 1. Findings in terms of percentage success of students while they engaged in DE problem solving

DISCUSSIONS

In all of the tasks it was asked to find the explicit general solution followed by initial value solutions. However, the nature of the problem was different. Task 1 was from the biological based problem interrelating population growth of bacteria while task 2 was from physics field related to projectile motion. Task 3 was related to compound interest.For these tasks, algebraic or procedural based approaches were needed to solve.

From the analysis of the task1 and task 2, it was revealed that during understanding and planning phases, results were improved in task 2 as compared with task 1. However, in getting answer phase the trends were seen opposite to previous phases' findings.

Overall findings showed high performance in both of these tasks, which were well supporting the previous studies, claiming that algebraic approach predominates in traditional differential equation course, yielding relatively good performance(Arslan, 2010b; Rowland, 2006). Further Arslan (2010b) elaborated that procedural learning in traditional differential equation course confines students to mastering and applying some algebraic techniques. Performance trend was different in first two phases (understanding and planning) as compared with last phase.

For the task 3 (compound interest), similar positive trend was notice. Students showed very high percentage 94% and 90% both in understanding and planning phases respectively. However, at final phase, only 22% were able to give the correct answer with right units. In this task, researcher asked a logical question about function increase, decrease after algebraic calculation. Since the logical questions need high level of understandings, critical thinking and some more tricks to be solved properly. In procedural based learning, less attention is given toin-depth understandings and critical thinking therefore logical part was not solved properly (Figure1). Due to same reasons, earlier,Camacho-Machín, Perdomo-Díaz, and Santos-Trigo (2008) proposed that teaching activities must be revised to promote students' understandings and they able to utilize several different systems in which they may reflect on different aspects linked to concept itself, procedures, the solution methods and connections and meaning among these representations.

Taken as a whole, students showed good performance in task 1, task 2 and task 3. The reason of good performance in the solving tasks may be attributed to context familiarity. Several studies have well highlighted the positive effect of context familiarity in mathematics problem solving (Heller, Keith, & Anderson, 1997; Yew & Zamri, 2018). According to authors, context familiar to majority of introductory students through direct experience, newspapers, televisions, or solving standards textbook are makes problems solving easier than problems with context unfamiliar to the students(Abramovich, 2015; Kulasegaram et al., 2012; Palincsar & Brown, 1988).

In the present case, students have shown better performance during understanding and planning phases of task 2, as compared with task 1. However, in getting answer phase the trends were seen opposite to previous phases' findings. This might be attributed to context familiarity. Because most of students were from pre-engineering group, in which taught proportion of physics and mathematics was greater than biological; therefore findings supported the context familiarity hypothesis and students shown better problem solving skills in physics based problem. In similar context, Rowland and Jovanoski (2004) have reported that students with physics background were able to recognize dv/dt as representing acceleration and recognized that they have to find out an equation for acceleration instead of velocity. Rowland (2006) further elaborated that students thought in term of rate of change resulted into better problem solving. Similar results are reported by Arslan (2010b). In the third phase, opposite trend in getting answer, may be due to the complex nature of answer, calculation errors and different units involved for the task 2 (Bottge, Heinrichs, Chan, Mehta, & Watson, 2003; Camacho-Machín, Perdomo-Díaz, & Santos-Trigo, 2012; Rowland, 2006; Rowland & Jovanoski, 2004).

For the task 3 (compound interest), students showed very high percentage 94% and 90% both in understanding and planning phases respectively. These findings also supported the concept of context familiarity. Interest or compound interest is more frequently term related to economy, banking or finance. In general students get more familiarity through social media, newspapers, televisions, or solving standards text books. Therefore, they showed better performance in early two phases of Task 3. Again, at the, at final phase, only 22% were able to give the correct answer with right units.This might be occurred due to calculation errors and different units involved for the task 2 (Rowland, 2006; Rowland & Jovanoski, 2004).

A few students were not successful in all of these three tasks. These results are consistent withCamacho-Machín, Perdomo-Díaz, and Santos-Trigo (2012), who claimed that several students possess the conceptual resources such as, differentiation, integration, and algorithm to solve differential equation, etc.), but they cannot exploit these resources efficiently. Severe problems in mathematics are sometimes referred to as dyscalculia; a specific learning disability affecting the acquisition of arithmetic skills in an otherwise normal child (Shalev, Manor, Kerem, Ayali, Badichi, Friedlander, & Gross-Tsur, 2001). Likewise, Schwanebeck (2008)explained that student's success or failure is sometimes depends on their persistence and attitudes toward the task, because high ability students shows more positive feelings towards word problems as compared to lower ability students while measuring their success.

From the critical analysis of all tasks, it may be concluded that algebraic approach with context familiarity can be effectively used to for differential equation problem solving. Teachers should emphasized on contextualizing learning using real world problems or authentic environment examples are also an important pillar in constructivist pedagogy (Abdulwahed, Jaworski, & Crawford, 2012).
Overall, to improve differential equation problem solving in the developing countries such as Pakistan, context familiarity and contextual based problem solving must be given attention. These would be an additive to existing different methods including novel pedagogies (such as collaborative learning, inquiry/problems/discovery based learning), mathematical software packages (Mathematica, Maple), and online tools (Wikis and web based courses).

CONCLUSION

In this study, role of context familiarity in students' differential equations solving was explored at pre university level. An assessment test containing three self-developed DEs tasks was distributed among 430 students, studying in inter-colleges.

Findings revealed that students have shown better problem solving skills in physics related problem as compared to biological based problem. This might be attributed to context familiarity. Because most of students were from pre-engineering group, in which taught proportion of physics and mathematics was greater than biological; therefore findings supported the context familiarity hypothesis and students shown better problem solving skills in physics based problem.Surprisingly, for the Task 3 (compound interest), students have shown very high percentage 94% and 90% both in understanding and planning phases respectively. This performance was even better than physics related problem (Task 2). In addition to these, students have shown lower performance in getting answer and the increasing trend of errors was found in answering to logical questions.
Overall, to improve differential equation problem solving, context familiarity and contextual based problem solving must be given attention. Teachers should be emphasized on students' practicing in getting the right answers.

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Appendix A: Differential equation tasks

1. In a research laboratory, a researcher studied the growth of bacteria culture. Normally, the bacteria population increases at the rate proportional to the size of bacteria present. The researcher found the number of bacteria increases six fold (times) in 10 hours. Initially number of bacteria is 10.

    a. Write differential equation that describes population increase for bacteria.
    b. Assuming normal growth, how long it would take for their population to double?

2. In a playground, a football player has to hit the ball vertically upward, or at certain angel to pass it to another player or hit the goal. During a match, a player hit the ball vertically upward with a velocity of 15 m/s.
    a. Write differential equation (model) that describes the velocity of the ball with respect to time (Neglecting air resistance).
    b. Find the equation for the distance (height) travelled by the ball in any time "t".
    c. Find the height of the ball after one second.

3. In Pakistan as well as in the world, banks provide incentives in the term of interest on the deposited money. Ayaan deposited an amount of 1000 Rupees in the bank Islami, which has an interest rate (dM/dt) of 5.0% per year. He did not draw any money and interest compounds continuously. How much amount he will have after 5 years? What you think, the amount of money increased, decreased or remained constant?