ESCAPING BEAR AND SNAIL: HOW READY ARE ENGINEERING STUDENTS FOR PUZZLE-BASED LEARNING?

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Abstract
Critical thinking and problem-solving abilities are recognized as fundamental and crucial abilities in teaching science concept. The current study aims to explore undergraduate engineering students’ critical thinking and problem-solving skills. In addition, their problem solving, and puzzle-based learning abilities were examined. Data were collected from 139 freshman students enrolled in different engineering department including Mechatronic, Civil, Electrical and Electronics, Biomedical, Industrial, Computer and Metallurgical and Materials engineering during the Spring semester of 2013. In terms of gender, the majority of them (N= 94) were male and % 33 (N=46) were female. In conclusion, findings revealed that most of the students’ lack employing critical thinking and problem-solving skills and are not prepared for puzzle-based learning science activities.

Keywords: Critical thinking, problem-solving, puzzle-based learning, engineering education.

INTRODUCTION

What is missing in most curricula - from elementary school all the way through to university education - is coursework focused on the development of problem-solving skills. Most students never learn how to think about solving problems. Besides being a lot of fun, a puzzle-based learning approach also does a remarkable job of convincing students that (a) science is useful and interesting, (b) the basic courses they take are relevant, (c) mathematics is not that scary (no need to hate it!), and (d) it is worthwhile to stay in school, get a degree, and move into the real world which is loaded with interesting problems (problems perceived as real-world puzzles). Problem-solving ability is included in PISA competencies as one of the eight main elements.
In the history of education, several methods of instruction were proposed to develop students’ process skills such as observing, analyzing, synthesizing, experimenting, data selecting and eventually problem solving (Padilla, 1990; Clarke, 2010). The common purpose of such instructional approaches is to prepare students to excel such skills since they are needed when they face in their future endeavors in real life. Originally, the discovery-learning approach by Jerome Bruner (1915- ) made a major contribution in the development of teaching science concepts with the use of discovery learning. Beyond that, derivations, of this approach have been developed. Those included learning cycle, discussion, inquiry, problem solving and critical thinking (Yerrick, 2000). According to the mostly accepted constructivist learning theory, individuals actively configure the information, think critically and solve the problems from different angles (Kıngır el al., 2011). At the problem solving and critical thinking stage, argumentation is required (Akarsu, 2012; Kariper et al., 2014; Cho and Jonassen, 2002; Duschl and Osborne, 2002; Zohar and Nemet, 2002).

Argumentation has been examined extensively for decades in education. It is widely accepted as a fundamental pillar of teaching (Akarsu et al., 2013; Pontecorvo and Girardet, 1993; Yerrick, 2000; Duschl and Osborne, 2002; Zohar and Nemet, 2002; Osborne et al., 2004; Erduran and Jimenez, 2007; Sadler, 2006; Duschl, 2008; Bricker and Bell, 2008; Kuhn, 2009, 2010). These studies mainly pointed out the importance of argumentation and it has been described as follows, "Argumentation is a form of discourse that needs to be appropriated by students and explicitly taught through instruction, task structuring, and modeling". Moreover, early researchers (Stephen, 1958; Kuhn, 1991) described argumentation as the ability of informal reasoning to make claims and to ensure evidence in supporting these claims, in solving problems or in making decisions. Historically, Stephen (1958) proposed a layout containing six interrelated components for analyzing arguments: claim, data, warrant, backing, rebuttal, and qualifier. The above steps are known as Toulmin’s Argument Pattern (TAP) and are used for the analysis of arguments (Erduran et al., 2004; Pontecorvo and Girardet, 1993). This argumentation model which is primarily based on Toulmin’s theory helps learners to make an argument and to support this argument with data or evidence, then to connect these data or evidence with correct and relevant sources, and finally to assess the constraints of their solutions (Erduran, et al., 2004). Already, when applied to an educational environment, the argumentation model of Toulmin encourages both teachers and students to discuss their ideas thereby verbalizing their standpoint and deciding on different ideas because of the interactivity involved (Hewson and Ogguniyi, 2011).

Recent articles explored different ways to enhance argumentation abilities or willingness to initiate an argument. Sampson and his friends (2010) aimed to increase students’ participation in scientific argumentation and the quality of the scientific arguments. The authors utilized a series of laboratory activities designed using an instructional model (Argument-Driven Inquiry (ADI)) and investigated its influences. Nineteen 10th grade students were selected for that purpose. The participants were engaged in 15 different laboratory experiments in groups. The results of their study revealed that the students had better engagement and produced better arguments after the intervention. In a similar study, researchers (Ryu and Sandoval, 2012) assessed whether an instructional model could improve children’s understandings and applications of epistemic criteria for argumentation. The study took place in a class with 3rd/4th-grade students. Students' ages ranged between 8 and 10. The researchers designed a "science time" corner during a regular academic year curriculum. In conclusion, students achieved an understanding of argumentation and the ability not only to construct but also to evaluate scientific arguments. The above-mentioned experimental studies focus on improving student’s argumentation skills or their ability to evaluate arguments. Some other studies in the literature aim to enhance such skills.

Because further information being available in the current century, education environment is experiencing the era of technology and information is subject to rapid change.
Goh (2008) states that according to educators, knowledge may become outdated more quickly than in the past. Due to this statement, the development of knowledge acquisition skills is required. This development equips a student with the opportunity to acquire knowledge that may not exist now and to solve problems they have not encountered before (Pithers and Soden, 2000). Dealing with sudden changes also requires students to engage in active critical thinking processes including higher-order thinking (Halpern, 1999).

Because the argumentation not only becomes the focal point of critical thinking (Ingram, 2008) but also the realization of critical thinking processes, it is of the utmost importance that primarily the concept of critical thinking should be understood fully. Since 1900, many definitions have been made of critical thinking in different disciplines. John Dewey defined the term critical thinking in 1910 as suspended judgment involving active, persistent and careful consideration of any belief or supposed form of knowledge in light of the evidence (German, 2008). Later, Dewey (1916) described the essence of critical thinking as suspended judgment to determine the nature of the problem before trying to solve it and suggested that analysis and synthesis of the problem were necessary components of critical thinking (Becker, 2007). According to Paul’s (1990) definition, critical thinking is disciplined, self-directed thinking appropriates to a particular mode or domain of thought. In the late 1990s, the Delphi Project, which was conducted as a two-year multi-faceted research project, devised a definition of critical thinking, which was intended for instruction and educational assessment (Burns, 2009). As cited in Derwin (2008), Facione (1990) suggested that the Delphi report lists six skills related to critical thinking, which are interpretation, analysis, evaluation, inference, explanation, and self-regulation (Derwin, 2008). In a Delphi study conducted by the American Philosophical Association (APA), critical thinking was described as the process of purposeful, self-regulatory judgment and an interactive, reflective reasoning process (Becker, 2007). Moreover, Halpern (1999) also described critical thinking as purposeful and logical and aimed at the use of cognitive skills and strategies. He stated that critical thinking is related to our thought processes of how good a decision is or how well a problem is solved (Halpern, 1999).

The consensus that emerges from this and similar definitions is that critical thinking is not only a contextual or subject related skill but also extends beyond a set of skills (Byrne and Johnstone, 1987; Ingram, 2008). In this process, thinking critically requires knowledge and an understanding of the content, skills, and processes of the subjects under consideration (Byrne and Johnstone, 1987). Also, in this connection, critical thinking involves going through certain processes, for example analyzing the issue, gathering, evaluating the data and synthesizing the information (Bailin, 2002). To sum up, as mentioned by Ingram (2008), critical thinking is a reflective process, from which the outcome may be more thinking, and involves the application of the above-mentioned skills in a logical and rational manner.

The recent literature suggests that critical thinking skills can be developed if educators facilitate processes requiring students’ experience and inquiry and test their ways of thinking (Erduran and Jimenez, 2007; Sadler, 2006; Osborne et al., 2004). In this process, though encouraging educators to utilize strategies promoting critical thinking skills is a rigid step, this issue needs to be considered more globally as well and, most importantly; critical thinking itself should be the mission of an educational institution (Van Erp, 2008). However, obstacles still exist in the teaching of critical thinking though standards mandate instruction in higher-order thinking (Thurman, 2009). Studies in the literature indicate that the lack of instruction for teachers in regard to critical thinking is a problem if they are expected to teach the skills with any degree of proficiency (Burns, 2009). In the same way, few introductory science courses provide students with learning environments where they engage in tasks, which encourage their critical thinking skills (McConnell 2005). As cited in Burns (2009), Moreno (1999) asserted that the other barriers facing teachers in regard to teaching, the lack of background and pedagogical knowledge can hinder the teaching of critical thinking skills.
and critical thinking; these include a lack of teacher training opportunities for both pre-service and practicing teachers. The other deficiency in this issue is the assessment of critical thinking skills. Many educators do not feel that written tests can appropriately measure the students' higher-order thinking skills (Burns, 2009). Consequently, in spite of these, this is an education reform movement should be initiated to eliminate the gap related to the development of critical thinking skills because critical thinking skills will not only prepare students for postsecondary education and close the gap in college preparedness but also equip them with a 21st century skill necessary to compete in our global society thinking (Thurman, 2009).

Puzzle-based learning is intrinsically related to problem-solving and more importantly argumentation and critical thinking skills. Several books were published to express the importance of this skill including university students – engineering, mathematics, computer science etc. – but secondary students also benefit from this approach (Michalewicz and Michalewicz, 2008; Amsbrus, 2008). The term "puzzle" is also used instead of "problem" in recent literature. Puzzle based learning approach help educators to investigate the problem-solving skills of students. Problem-solving is also included in many core standards for middle school students (KDE, 2012) as a skill that needs to be achieved. It emphasizes making sense of problems and persevering in solving them; modeling with Mathematics; looking for and making use of repeated reasoning. In addition, as Vygotsky (1978) suggested “zone of proximal development” proposed that students actively collaborating will be able to go beyond their development levels (Savery and Duffy, 1995). Studies (Falkner at el, 2010) drew attention to the business world as they prefer to recruit good puzzle-solver engineers.

Problem-solving is an important analytical and procedural approach to education (Hermann, 1995) since the scientific thinking process is dominantly based on it. Students like scientist are continuously challenged to solve scientific problems by using the scientific method. Problem-solving is also considered as a major ability student should possess since it is included in science and mathematics sections of PISA competencies (Navarra et al., 2008).

Recent studies have been conducted in several disciplines including medicine (Turan et al., 2012), electrical engineering (Yadav et al., 2011), civil engineering (Ahern, 2010; Angelides et al., 2000; Aparicio and Ruiz-Teran, 2007), biomedical engineering (Wallen and Pandit, 2009), structural engineering (Quinn and Albano, 2008) and telecommunications engineering (Macho-Stadler and Jesus, 2013) to investigate effectiveness and importance of problem-based learning and to explore possible ways to develop such ability. Hmelo-Silver (2004) expressed five goals of problem-based learning (PBL) and found out that PBL is an instructional approach to help the student develop a critical understanding and lifelong learning skills. Other studies (Gleason et al., 2010; Mosalam et al., 2012) concluded that hands-on experiences are the best approach to enhance problem-solving ability.

The above-mentioned studies on problem-solving and critical thinking skills generally investigated these two topics separately and experimentally. Few studies, however, focus on how students reflect their problem solving and critical thinking skills in discrepant science problems. In this paper, we report the preliminary findings on levels of elementary students’ problem-solving abilities in a proposed science activity.

Typical Problem-solving strategies are categorized into 3 forms: Algorithms, Heuristic method, trial, and error and insight methods (Mayer, 1992). Algorithm method is defined as a step-by-step process that always produces a correct solution. It contains a specific set of procedures or exact directions like a cookbook style lab experiment. Although this process results in incorrect answers it is time-consuming, so it is not practical for many situations. Heuristic method, on the other hand, is a rule of thumb by trial and error. It involves choice, hunch, creativity, and short cut solution. However, it doesn't guarantee a solution. It increases the probability of finding a solution. Unlike algorithm method heuristic method does not guarantee a correct result but it simplifies complex problems and reduces possible solutions and is practical. The history of the method goes back as early as Socrates in ancient Greece.
civilization. Trial and error method basically eliminates possible incorrect answers and is considered as a good option if there is a limited number of options. Lastly, insight approach is totally different from the above methods. It is believed to be connected to depth mind abilities of people. The solution appears immediately once a question is posed. It requires thinking experience and not practical for a beginner problem solver.

Given the aforementioned gap in current literature, this study examined two important aspects of ability that pertain to critical thinking and problem solving (Ketelaar, 1993). Engineers should possess analytical and imaginative mindsets in their professions. In this respect, we investigated and compared the individual and group responses of students. Problem-solving and critical thinking were also investigated. Secondly, the students also commented on the discrepant problem and discussed it from different perspectives. Finally, participants widely evaluated their responses, and therefore their thinking skills.

**METHODOLOGY**

The literature indicated that although critical thinking and problem-solving abilities have been investigated separately in most experimental studies, few studies attempted to focus on both concepts together. This study was therefore designed to address the following research questions:

1- What types of critical thinking and problem-solving reasonings do engineering students possess?
2- What types of operation and algebraic thinking do engineering students possess?
3- How do engineering students evaluate puzzle-based questions?

In order to assess students’ problem solving and critical thinking skills, they were asked to respond to two similar non-routine problems to engage them in critical thinking and problem solving and discuss potential logical explanations. It is focused that the solution attempt is more important than a conclusion. These problems, called *Bear and Snail Escape*, required students to first determine which explanation, of three plausible alternatives, was the most valid conclusion to explain the ir observations by using the available data. Students were allowed to spend 20 minutes on each problem.

Once the participants had determined which explanation best explained the phenomena, they were guided to solve it algebraically in they didn't already do so by providing some hints. They included “Let us suppose that x is the number of days the polar bear needs to escape. Write down an algebraic equation which x should satisfy to be the solution to the problem”.

After bear problem, they were instructed to solve the second problem similar to the first question but more difficult on the task with the same approach. The last question was asked to them was how they evaluate two puzzle-based questions on the task. Students’ responses were collected for three questions and analyzed.

<table>
<thead>
<tr>
<th>The content of the Problems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Escaping Bear Problem</strong></td>
</tr>
<tr>
<td>A polar bear trapped in a 20 m. ice well climbs up to escape. Every day, he climbs 5 m but slides down 4 m. How many days should pass until he escapes the well?</td>
</tr>
<tr>
<td><em>(a) 16 (b) 17 (c) 18 (d) 19 (e) 20</em></td>
</tr>
</tbody>
</table>
A. Select your answer.
B. Show how did you get your answer

*Correct answer

2. Escaping Snail Problem
A snail is in 10 meters deep well. It climbs 3 m during the day and slips back 2 m. during night. How many days and nights does it need to get to the top of the well?

*(a) 8 days and 7 nights (b) 9 days and 9 nights
(c) 9 days and 8 nights (d) 10 days and 10 nights (e) 10 days and 9 nights

A. Select your answer.
B. Show how did you get your answer

*Correct answer

Hint: Let us suppose that x is the number of days the polar bear needs to escape. Write down an algebraic equation which x should satisfy to be the solution of the problem.

Following above problems, the students were asked to discuss and compare the difficulty of the problems. For the reason, below item is added to the form:

Choose one statement which expresses best your experience with algebraic solutions of polar bear and snail problems.

a) Both problems are equally EASY to be solved algebraically
b) Both problems are equally DIFFICULT to be solved algebraically
c) Bear problem is EASIER than snail problem to be solved algebraically.
d) Bear problem is MORE DIFFICULT than snail problem to be solved algebraically.

Content analysis was utilized to achieve patterns from data. Descriptive and inferential statistical analyses were also utilized to provide rich analysis and findings. The participants were randomly assigned to this study. Their department included mechatronic (ME), civil (CE), electrical (EE), biological (BE), industrial (IE), and computer (CENG), and metallurgy (MME). The question was posed to 474 students enrolled in the different engineering department and a total of 139 them responded to the questions in the task. A number of responses were believed to indicate patterns among all of the engineering students' problem-solving skills. Figure 1 illustrates the number of participants in each department. Mechatronic, Civil and Biomechanical engineering students constitute 67 % of the whole participants.

<table>
<thead>
<tr>
<th>Dept.</th>
<th>Number of Students</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ME</td>
<td>43</td>
<td>29</td>
</tr>
<tr>
<td>CE</td>
<td>31</td>
<td>24</td>
</tr>
<tr>
<td>EE</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>BE</td>
<td>20</td>
<td>11</td>
</tr>
<tr>
<td>IE</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>CENG</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>MME</td>
<td>16</td>
<td>7</td>
</tr>
<tr>
<td>TOTAL</td>
<td>139</td>
<td>85</td>
</tr>
</tbody>
</table>

Research data were collected during the last week of the semester. Therefore, students are expected to show their full potential. They were asked to put their responses and support
their choices with paper and pencil method. The researchers did not guide the students to further explain the problem beyond necessary information.

RESULTS

The presentation of the results is divided into three subsections by the research question. Each subsection includes a brief overview of the analysis, the result of the analysis and a discussion of the findings. Initially, we posed the students a puzzle-based bear question to collect data regarding their problem solving and critical thinking skills. Their responses to the question are illustrated in figure 1.

![Figure 1. Students’ Responses to The First Question (Polar Bear)](image)

As indicated in figure 1, approximately 54 % of the students (N=75) answered the question correctly. The second top selected choice was E chosen by 43 students (%31). Therefore, choice E was a top distractor for this problem. Few students (%15; N= 21) selected other choices. The students who selected choice E expressed their argument as "Polar bear goes up 5 meters and slides down 4 meters daily and it needs to climb 20 meters. Therefore, it must be 20 days". Some of them used mathematical expressions to back up their responses such as “5x-4x=20” or “(5 m. up – 4 m. down) = 20”. They also used mathematical equations as argument as follows: “20 = (x-1)*5 – (x-1)*4+5” or “5x-4y=20” or “(5x-4x)+4=20” or “5x-4(x-1)” or “20=(5-4) x”.

![Figure 2. Students’ Responses for Problem 2 (Snail Problem)](image)

Above figure shows that distribution of the students’ responses to the second problem. Contrary to the Bear problem, more students (%65; N = 90) correctly answered the first question about this problem. A top distractor for this problem was choice E. A total of 20
students chose choice C or D. The student who got the correct answer for the first problem expressed some textual explanations and mathematical expressions for their arguments. They used similar explanations such as "The bear climbs 1 meter per day and at the end of the 15\textsuperscript{th} day he climbs 15 meters and last day he is out of the well". The most (N=32) constructed a mathematical equation by the students was "3x-2y=10 with x: day and y: night". 20 students selected this choice. Other mathematical expressions include “10x+9y=12; (3-1)(x-1)+3=10; 3(x-1)-2y+3=10". Students sample responses for problems were as stated:

**Problem 1:**

*Student 1*: “If Bear climbs 5m and slides down 4m everyday, he will climb up 15 meters in 15 days. When he climbs 5 meter in 16\textsuperscript{th} day, he is out of the well. (Daily argument?)”

*Student 2*: “In 20 days he climbs up for 100 m and slides down for 80m which makes a total of 20 meters gain. (Multiplication argument?)”

*Student 3*: “Bear gains 1m every 9m. At the end of 16\textsuperscript{th} day he gains 16 meters. At the end of 17\textsuperscript{th} day, 16+5=21 m and he is out. (Algebraic argument?)”

**Problem 2:**

Student 1: “Everyday Snail climbs up 1 meter so 20 days he is out of the hole”

Student 2: “Every day and night, Snail climbs up with net gain 1 m. At the end of 7 days, he is out. (Correct approach but weak argument) X=3 y=2, 7/x+y=1; 7x+7y=7; X=3 so 8x+7y=10”

When responses of students for both problems are combined, figure 3 could be structured that shows to what degree they successfully solved both problems. It is expressed that a number of students who got the second problem with a higher percentage than the first one was among four groups (Mechatronics, Industrial, EE, and Biomedical). Unusually, EE group was much more successful at the increase rate. Other engineering students either solve both problems with equal success or better on the first problem. Overall, more students solve correctly the second question (N=93) than the first (N = 76). An overall number of students who answered both questions correctly was 66 (%71). That value was very close to the number of students (N = 59) who thought both questions are easy to solve them algebraically.

**Table 2. Percentages of Correct Responses for Each Discipline on Problems**

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Problem 1</th>
<th></th>
<th>Problem 2</th>
<th></th>
<th>Mean UEE Score (Max. 500)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (%)</td>
<td>N (%)</td>
<td>N (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ME</td>
<td>25 58</td>
<td>33 79</td>
<td>340</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MME</td>
<td>3 6</td>
<td>3 6</td>
<td>209</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IE</td>
<td>3 43</td>
<td>4 57</td>
<td>320</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CE</td>
<td>25 83</td>
<td>24 80</td>
<td>358</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE</td>
<td>4 40</td>
<td>10 100</td>
<td>355</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BE</td>
<td>10 50</td>
<td>13 65</td>
<td>380</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CENG</td>
<td>8 62</td>
<td>7 54</td>
<td>329</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Finally, table 2 illustrates how successfully students’ construction of algebraic equations for both problems. It reveals that only 32 students (%23) successfully constructed correct algebraic statements for both questions. However, 60 students (%43) were not able to construct any useful algebraic equation. They couldn't respond algebraic parts of both questions. In addition, remaining 47 students (%34) correctly provided the necessary algebraic equation for either problem. Three students did try to solve both problems by using a table that includes step-by-step calculation. They basically constructed a two-row table with a number of day and amount of climbing in meter and showed how many mates the bear or the snail climbs. Only one of the students who used table method got the correct answers for both questions.

![Figure 3](image_url)  
*Figure 3. Number of correct answers on both problems*

Students’ opinions about two problems were shown in figure 3. It reveals that about 59 (42%) students believed that both questions were easy to solve. 29 students (20%) believed that bear question is easier than snail problem. Only 24 students (17%) evaluated both problems as difficult. Overall, 100 (%72) thought that at least one question is easy to solve. Overall, 76 (55%) of the students picked the correct response for Bear problem and 93 (67%) for the Snail problem, respectively.

![Figure 4](image_url)  
*Figure 4. Students’ opinions about the problems*

In terms of the algebraic skills in solving the research problems, only 60 students (43%) were able to construct the correct algebraic equations for either of the questions. Few of them (N=33, 24%) created algebraic parts of both questions. Sample responses for algebraic equations for both questions are shown in below table.
Table 3. Students’ algebraic responses to the problems

<table>
<thead>
<tr>
<th>Bear Problem</th>
<th>Snail Problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>20=(x-1).5-(x-1).4+5</td>
<td>3x-2y=10 (N=31, %57)</td>
</tr>
<tr>
<td>20=(x-1). (5-4) +4</td>
<td>8x+7y=10 (N=5)</td>
</tr>
<tr>
<td>5 (x-1) -4 (x-1) +5 =20</td>
<td>3x+2y=10 (N =3)</td>
</tr>
<tr>
<td>5x- 4 (x-1) = 0</td>
<td>10x+9y=12 (N=2)</td>
</tr>
<tr>
<td>(x-1) .5 -(x-1) .4+5=20</td>
<td>10=(x-1).3-y.2+3</td>
</tr>
<tr>
<td>(x-1).(5-4) =15</td>
<td>3(x-1) -2y +3=10</td>
</tr>
<tr>
<td>1(x-1)+5=20</td>
<td></td>
</tr>
<tr>
<td>(5-4) (x-1) +5=20</td>
<td></td>
</tr>
</tbody>
</table>

Another interesting result of the study lies in the correlation between the participants’ University Entrance Exam (UEE) scores and percentage of their correct responses to the problems directed at them. The correlation of the minimum exam scores with the Bear and Snail problems was found as 0.75 (figure 5a) and 0.85 (figure 5b) and such results indicated that there existed a high correlation between their UEE results and response rates for the problems. Therefore, content of UEE strongly measures problem-solving skills. The higher their exam scores the better they will be able to succeed in solving such problems.

![Figure 5a](image1)

![Figure 5b](image2)

**Figure 5.** The correlation between University Entrance Exam Minimum Score for the Participants Majors and Percentages of Correct responses to the Bear Problem and the Snail Problem

**Argumentation Schemes of the Problems**

The participants indicated several unstated premises when they were responding to the assigned problems. In this case, these premises constructed a complex set of arguments and eventually an enthymeme, a chain of argumentation based on various argumentations that are linked in the chain. Two types of argument premises could be constructed in this research: textual and algebraic premises. Textual argument premises are basically defined as scripts used by the students to support their conclusions. On the other hand, algebraic arguments are stated in terms of mathematical expressions and logical axioms. The chain of textual arguments for the first problem can be constructed based on students’ responses as follows:
Table 4. Chain of Textual Arguments for The Problems Set

<table>
<thead>
<tr>
<th></th>
<th>The Bear Problem</th>
<th>The Snail Problem</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strong</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Correct Response</td>
<td></td>
<td></td>
</tr>
<tr>
<td>– For the first 15 days, it is 15 meters and 16th day; it is 20 meters</td>
<td>– The snail climbs 3 m in each attempt but slides 2 m down each day. He climbs 1 m net daily. It takes 8 days and 7 nights.</td>
<td></td>
</tr>
<tr>
<td>– Every day, the Bear climbs 1 meter</td>
<td>– If the Bear climbs up for 5m and slides than 4m and repeats this process every day, he cannot get out with help.</td>
<td>– Snail climbs up with net gain 1 m. every day and night, At the end of 7 days, he is out.</td>
</tr>
<tr>
<td>– Every day, he climbs 5 m up and 4 m down so climbs up 1 m. in total</td>
<td>– If started in the morning it is 10 days.</td>
<td></td>
</tr>
<tr>
<td>– He goes up 1 m every 9 m.</td>
<td>– He climbs up for 100 m and slides down for 20 m.</td>
<td>– The snail climbs 1 m. So, 20 days he is out of the hole.</td>
</tr>
<tr>
<td>– He needs 20 days to climb 20 m</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Weak</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incorrect Response</td>
<td></td>
<td></td>
</tr>
<tr>
<td>– 16th day 16 m and next day he is out.</td>
<td>– Polar bear lives in the North Pole.</td>
<td>– If started in the morning it is 10 days.</td>
</tr>
<tr>
<td></td>
<td>– He climbs up for 100 m and slides down for 20 m.</td>
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</tbody>
</table>

Although the above chain of argument shows that most students correctly answer the problems, only a limited number of them were able to come up with the correct premises to support their argument. On the other hand, few of them who used strong arguments were not be able to come up with the correct responses.

For example, student 7 stated, “Similar to the Bear problem the snail climbs up for 1-meter net every day so travels 7 m. in 7 days/nights. On the 8th day, it would be 10 meters, so it doesn’t need another night. The answer is 8 days.” (Snail Problem) Similarly, student 23 said “Polar bears live in the Earth Poles. If we looked at the topic it escaped and went to another region” (Bear problem) and If started in the morning it would take 10 days. I don’t know how long he will live” (Snail problem). He pointed out important information about the problem because in the questions exact starting time was not indicated. Information is believed to be an important asset to the argumentation process.

**DISCUSSION**

The results of the study revealed that although most of the college students participated in this study came up with the correct choice for both Bear and Snail problems when it comes to critically analyzing or create arguments, they lack such abilities. This result might have two meanings: 1) Students are good at answering multiple-choice (MC) question, which doesn't require any input from examinees; 2) Students cannot easily construct arguments to back up their responses. Since students had seen and intensively prepared for MC questions during their education, this result is not surprising. However, this only shows their knowledge is at remembering or understanding levels according to Bloom cognitive taxonomy. When questions are asked that require higher-order knowledge, it revealed that students do not possess critical thinking and problem-solving abilities.
Findings showed that most of the students (%54) correctly answered the Bear questions. The student with the correct answer for the first problem expressed some textual explanations and mathematical expressions for their arguments such as “The bear climbs 1 meter per day and at the end of 15th day he climbs 15 meters and last day he is out of the well” for explanations and “\(20 = (x-1) \times 5 - (x-1) \times 4 + 5\)” or “\(20 = (5-4) x\)” for mathematical equations. On the other hand, 31% of the students incorrectly picked the wrong choice E. The students who picked the choice E supported their answers with typical arguments that involve textual explanations or mathematical expressions. This result alone indicates that students do not hold enough level of critical thinking considered as one of the dimensions of argumentation (Habermas, 1981; Wertsch, 1991). It was surprising that although some students in both groups wrote down same mathematical expression \(20=(5-4) x\) some of them didn't get the correct answer. This means that either they don't know how to express their thinking, or they don't know how to apply mathematical expressions in real life situations.

More students answered the Snail problem correctly than the Bear problem. Although it was considered as a more difficult problem since it includes two unknowns (day and night) and expected to be correctly answered by less students. Maybe the students got familiar with the type of such similar question when they solved the bear problem. Another interesting result was most of the students (N=32) who answered the second question correctly used the same mathematical expression "\(10=3x-2y\)". This might be due to their experience on the first problem or they took this problem more seriously because it looked more complex. More students considered the first problem easier than the second one. Finally, about half of the students (N=17) who answered the first problem correctly constructed this expression and also answered the second question correctly.

Based on their responses on both problems, the students used "Heuristic Method" to solve the problem. They utilized common sense and rule of thumb approaches to acquire the correct response. However, their approaches led them to the incorrect answer. This result might have been due to a short period of time for solving the problem or rushing to solve it because they looked very easy or even silly. As they considered it’s a piece of cake, they didn't pay enough attention to solve it. This is actually one of the common mistakes a regular person does when encountering a problem even in real life. Another important finding was the most successful students were that enrolled in Mechatronic, Civil or Biomedical engineering departments. This is not so much surprised when the university entrance exam they took is taken into account. Above three departments accept their students with higher exam scores than other department examined in this study. Considering students performed better on Snail problem but expressed that Bear problem easier, they underestimated the Snail problem.

Based on the findings of this study, we suggest students to follow above steps for problem solving process. Our results revealed that college students do not possess adequate levels of ability of critical thinking and problem solving so they are not ready for puzzle-

![Figure 7. Content-Exercise-problem cycle](image-url)
based learning. This study revealed just the tip of an iceberg so more detailed and qualitative study should be conducted to examine the reasons behind it.

Final findings corresponding to third research questions, college students think of such problems easy. This is very typical thinking because when they first see them, they see different content and way of asking, they immediately think it is an easy question. This illustrates two main properties of puzzles: simplicity and Eureka factor (Michalewicz and Michalewicz, 2008). Puzzles must have elementary mathematical operations and simple solutions that are not obvious. High school and College textbooks around the World are mostly traditional. They have content-exercises-chapter end problems structure that leads to their readers to go into a phase of one-way strategy without alternative approaches. More unordinary and research-based (e.g. Based on inquiry, STEM and modern pedagogical approaches) should be employed.

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