ACTA DIDACTICA NAPOCENSIA
Volume 17, Number 2, 2024 - DOI: 10.24193/adn.17.2.1

DIAGNOSING 8TH GRADE STUDENTS' MISCONCEPTIONS OF PRESSURE THROUGH CONCEPT CARTOONS

Atike SARI, Çiğdem ŞAHİN ÇAKIR

Abstract: This study employed a case study methodology to investigate students' misconceptions about solid, liquid, and atmospheric pressure. The research included 36 8th-grade students from various middle schools in Giresun, comprising 19 girls and 17 boys. Data collection involved a test consisting of 14 concept cartoon questions, and the concept cartoons themselves were created using the Storyboard That program. These concept cartoons covered solid, liquid and atmospheric pressure. The study revealed that students held a variety of misconceptions related to solid, liquid, and atmospheric pressures. Notably, the students exhibited low levels of understanding when it came to the relationship between liquid pressure and Pascal's Principle, as well as the factors influencing atmospheric pressure. Concept cartoons emerged as effective tools for identifying and diagnosing these misconceptions among students. In summary, this research aimed to uncover misconceptions regarding pressure among 8th-grade students. It underscored the significance of concept cartoons in pinpointing areas where students required additional clarification and education to rectify these misconceptions.

Key words: Atmospheric pressure; concept cartoon. liquid pressure; misconception; pressure; pressure exerted by solids.

1. Introduction

Given the intricate nature of science, learning it poses challenges and biases for students (Yağbasan & Gülçiçek, 2003). Students enter science lessons with prior knowledge acquired from previous lessons or personal observations (Bodner, 1990; Yağbasan & Gülçiçek, 2003). Eryılmaz and Tatlı (2000) referred to these pre-existing ideas as 'preconceptions,' Driver and Easley as 'alternative concepts,' Helm as 'misconceptions,' Sutton as 'children's scientific instincts,' Gilbert, Watts, and Osborne as 'children's science,' Halloun and Hestenes as 'general sense concepts,' and Pines and West as 'self-generated information' (as cited in Eryılmaz & Tatlı, 2000).

Misconceptions are beliefs based on personal experiences that contradict scientific facts and can impede meaningful learning (Demir, 2008). The root of many misconceptions lies in students' preconceived notions about the subject matter, hindering the development of meaningful learning (Aydoğan, Güneş & Gülçiçek, 2003).

Various factors contribute to misconceptions that hinder student learning (Yürük & Çakır, 2000). The reasons for misconceptions can be listed as follows:

• Lack of knowledge because students answer questions about concepts with their current knowledge.

• Not experimenting to concretize abstract topics.

• How teachers present topics to students.

• Experiences and opinions of students.

• The way textbooks present topics.

Students' incorrect associations between concepts cause misconceptions (Coştu, Ayas & Ünal, 2007). Misconceptions vary according to different education levels. For this reason, the causes of misconceptions may differ according to level and age (Coştu et al., 2007; Meşeci, Tekin & Karamustafaoğlu, 2013). Misconceptions can occur at any level of culture and students, and they are

Received November 2023.

Cite as: Sari, A. & Şahin Çakır, Ç. (2024). Diagnosing 8th grade students' misconceptions of pressure through concept cartoons. *Acta Didactica Napocensia*, 17(2), 1-28, https://doi.org/10.24193/adn.17.2.1

highly resistant to change (Meşeci et al., 2013). In order for science education to achieve its goal, first of all, it is necessary to reveal the preliminary concepts that students have related to the subject (Yağbasan & Gülçiçek, 2003). Previous research has revealed that students harbor numerous misconceptions about various scientific concepts. For example, photosynthesis and respiration (Tekkaya & Balcı, 2003; Yürük & Çakır, 2000), light (Andersson & Kärrqvist 1983; Stephenson & Warwick, 2002) and motion (Fadaei & Mora, 2015), DNA and genetic code (Kibuka-Sebitosi, 2007) are some of these. One of the topics that students have misconceptions about is pressure (Akdemir, 2005; Besson, 2004; Kariotoglou & Psillos, 1993; Şahin & Çepni, 2012; Yaman, 2016).

When the literature was examined, it was seen that different studies have been conducted on the concept of pressure. Some of these studies are related to gas pressure (Rollnick & Rutherford, 1990; Sere, 1982; Stavy, 1988; Şahin & Çepni, 2012; Tytler, 1998; Yaman, 2016), liquid pressure (Akdemir, 2005; Besson, 2004; Ipek-Akbulut, Şahin & Çepni, 2012; Kariotoglou & Psillos, 1993; Saputra, Setiawan & Rusdiana, 2019; Stavy & Stachel, 1985; Yaman, 2016) and pressure exerted by solids (Ammase, 2019; Şahin, Akbulut & Çepni, 2012; Yaman, 2016). In these studies, students' misconceptions were determined with two-tier data collection tools such as concept tests (Akdemir, 2005; Şahin & Çepni, 2011) and open-ended questions (Benli-Ozdemir, 2021; Yaman, 2016). Concept cartoons are also a very effective data collection tool in revealing students' misconceptions (Demir, 2008; Önal, 2023; Serttaş & Yenilmez Türkoğlu, 2020). It's noteworthy that concept cartoons weren't used in studies where students' misconceptions about solid, liquid, and atmospheric pressure were determined and tried to be eliminated. Pressure is a fundamental concept in physics that underpins many advanced topics, such as fluid dynamics, thermodynamics, and engineering principles. If students carry misconceptions into higher grades, they may struggle with more complex concepts, leading to gaps in understanding and difficulties in learning more advanced material. Identifying misconceptions early allows educators to address and correct them before they become deeply ingrained. Misconceptions that persist can hinder students' ability to grasp related concepts and apply their knowledge effectively in different contexts. Identifying common misconceptions can help educators refine their teaching methods. By understanding where students struggle, teachers can design more effective instructional strategies, create targeted interventions, and use appropriate analogies to clarify difficult concepts. Addressing misconceptions fosters conceptual change, where students replace incorrect ideas with scientifically accurate ones (Rohmi, 2024). This process helps students build a more coherent and integrated understanding of scientific principles, which is essential for their overall cognitive development. In inquiry-based learning environments, understanding students' misconceptions allows educators to guide students through the process of discovery and inquiry more effectively. By challenging and resolving misconceptions, students can engage in deeper learning and develop stronger problem-solving skills. The use of concept cartoons is highly effective in encouraging students to inquiry and critically evaluate concepts (Rohmi, 2024).

Identifying and addressing misconceptions about pressure at an early stage is therefore essential for fostering a solid foundation in science, promoting accurate understanding, and preparing students for future academic challenges. In this regard the aim of this study was to identify 8th-grade students' misconceptions about pressure concept using concept cartoons.

1.1. Concept Cartoon

Concept cartoons were initially introduced in 1992, and subsequent studies have confirmed their effectiveness in facilitating student understanding (Stephenson & Warwick, 2002; Keogh & Naylor, 1999). In concept cartoons, a connection is established between daily events and scientific subjects, and written text in the form of dialogue is integrated with visual stimuli and presented to students (Stephenson & Warwick, 2002; Keogh & Naylor, 1999). Concept cartoons enable students to discuss among themselves and encourage reluctant students to interact and focus on the lesson (Keogh & Naylor, 1999; Naylor & Keogh, 2013). While concept cartoons increase the educational success of students, they also allow discussions and increase in-class interaction (Kabapınar, 2005), can be used for different educational purposes, such as enabling students to gain logical thinking skills, grasp scientific concepts, and increase their motivation (Şengül & Üner, 2010), can serve various educational purposes, including learning-teaching strategies, teaching materials, assessments, and more (Ormancı & Şaşmaz Ören, 2011;

Şaşmaz Ören, 2009), andare an effective method for identifying misconceptions, as the cartoons contain visual elements, and the dialogues between the characters in the cartoon demonstrate that students' ideas are valuable (Demir, 2008; Önal, 2023).

When reviewing the literature regarding concept cartoons (Atasoy, 2020; Kabapınar, 2005; Keogh & Naylor, 2000; Ormancı & Şaşmaz Ören, 2011; Önal, 2023; Serttaş & Yenilmez Türkoğlu, 2020; Stephenson & Warwick, 2002; Şengül & Üner, 2010), various studies have been observed. For instance, Serttaş & Yenilmez Türkoğlu (2020) identified students' misconceptions about "Astronomy topics" in their study by using concept cartoons. Stephenson & Warwick (2002) employed concept cartoons to support students' learning about light in their study.

2. Method

In the study, case study methodology was employed to identify the misconceptions of 8th-grade students regarding pressure. Case studies are research methods that seek to provide a comprehensive understanding of a specific subject by exploring its depth, breadth, and its relationships with itself and its environment (Cohen & Manion, 1994).

2. 1. The Participant

The study's sample was selected using convenience sampling, chosen for its practicality and efficiency. Convenience sampling is a quick and cost-effective method that allows for easy access to participants. Appropriate sampling is generally a process that involves selecting samples that are suitable, representative, and reliable for the purpose of the research. Appropriate sampling aims to provide data sets that best address the researcher's questions and objectives (Oribhabor & Anyanwu, 2019). The sample of this study comprises a total of 36 8th-grade students (Ngirls=19; Nboys=17) who were enrolled in various middle schools in Giresun, Turkey. Data collection was conducted using the concept cartoon test, which was distributed to middle schools in Giresun via Google Forms during the spring term of the 2020-2021 academic year due to the COVID-19 pandemic. However, students from different schools participated in the concept cartoon questions through Google Forms. To maintain anonymity, students were assigned alphanumeric codes from S1 to S36 for identification.

2.2. Instrument and Procedures

A concept cartoon test comprising 14 concept cartoon questions was employed as the data collection tool. The following procedural steps were adhered to during the development of concept cartoons:

(1) Concept cartoons were designed using the Storyboard That program. Additionally, the researchers designed some concept cartoons using graphic design software. The diver images in Figure 6 were included with permission from the http://www.dnzhoca.com/ website.

(2) The eighth-grade science curriculum's content related to the "Pressure" unit was taken into consideration.

Within the science curriculum, the content encompassed the following key topics and concepts: Pressure, variables affecting pressure exerted by solids, variables affecting liquid pressure, and applications of pressure in daily life and technology. The specific curriculum objectives were as follows:

F.8.3.1.1: Students discover, through experimentation, the variables that influence pressure exerted by solids. The pressure unit of Pascal is introduced, but mathematical correlations are not included.

F.8.3.1.2: Students make estimates regarding the variables affecting liquid pressure and test their hypotheses.

a. It is noted that gases exert pressure similarly to liquids, with a sample of atmospheric pressure.

b. Mathematical correlations are not included.

c. Variables affecting gas pressure are not included.

F.8.3.1.3: Students provide examples of the practical applications of pressure properties in solids, liquids, and gases in everyday life and technology.

a. Examples of applications related to Pascal's Principle concerning liquid pressure are presented.

b. Principles and concepts are emphasized as a form of scientific knowledge (Ministry of National Education, 2018).

(3) Concept cartoons were designed based on misconceptions identified in the literature. Table 1 illustrates misconceptions gleaned from the literature related to the concept of pressure.

(4) A total of 5 concept cartoons related to pressure exerted by solids, 6 concept cartoons related to liquid pressure, and 3 concept cartoons related to atmospheric pressure were carefully prepared.

(5) In the concept cartoon questions, Figures 1, 2, 3, 5, 9, 10, and 11 featured 3 characters, while Figures 4, 6, 7, 8, and 12 included 4 characters. The correct answer was written in the speech bubble of one of the characters in each concept cartoon, and misconceptions identified from the literature were written in the speech bubbles of the other characters.

(6)

(7) To ensure the validity of the concept cartoon test, which considered alignment with curriculum goals, the researchers sought the expert opinions of two professionals in the field of science education. Subsequently, the concept cartoon test was refined to improve the clarity and comprehensibility of character explanations for students, as well as to make the visuals more realistic, based on the recommendations from these experts.

(8) The concept cartoon test was administered via Google Forms with parental consent (https://forms.gle/AqfhvTcJ8htAVwUy7). Students completed it during their online science class, guided by the teacher. The teacher asked the students to read each concept cartoon in the virtual classroom (the classroom created with the help of the Zoom application) and write their answers independently in the space below the relevant concept cartoon. The students were given approximately five minutes to write their answers about each concept cartoon.

Table 1. *Misconceptions identified in the literature regarding the topic of pressure.*

Topics	**Misconceptions**	**References**
Pressure exerted by solid	Difficulty in establishing a correlation between pressure exerted by solids and surface area.	Kaya, Bozdağ & Ok, 2018; Benli-Ozdemir, 2021; Şahin et al., 2012
	Associating pressure exerted by solids solely with weight. Difficulty in establishing a correlation between pressure, force, and surface area.	Akdemir, 2005; Kaya et al., 2018; Benli-Ozdemir, 2021 Baytok, 2007; Kaya et al., 2018; Şahin et al., 2012; Yaman, 2016
	Associating pressure exerted by solids solely with surface area or only with weight.	Akdemir, 2005; Baytok, 2007; Kaya et al., 2018; Yaman, 2016
	Making incorrect associations between surface area and pressure exerted by solids.	Akdemir, 2005; Kaya et al., 2018; Şahin et al., 2012,
	Thinking that pressure will decrease when both surface area and weight increase.	Benli-Ozdemir, 2021
Liquid pressure	Liquid pressure depends on the base area of the container.	Akdemir, 2005; Kaya et al., 2018; Benli-Ozdemir, 2021; Şahin & Çepni, 2011; Yaman, 2016
	Liquid pressure depends on the amount of liquid.	Akdemir, 2005; Besson, 2004; Kaya et al., 2018; Benli-Ozdemir, 2021; Şahin & Çepni, 2011; Psillos, 1999; Yaman, 2016
	Inability to correlate between liquid pressure and density.	Benli-Ozdemir, 2021
	Difficulty in understanding the relationship between Pascal's law and liquid pressure.	Baytok 2007

Atmospheric pressure	Believing that atmospheric pressure increases as one ascends.	Kaya et al., 2018; Benli-Ozdemir, 2021
	The variation of atmospheric pressure is influenced by changes in density and temperature as altitude increases.	Baytok, 2007; Yaman, 2016
	Windy air exerts atmospheric pressure	Benli-Ozdemir, 2021; Sere (1982); Şahin & Çepni, 2012

2.3. Data Analaysis

Data obtained from the concept cartoons were meticulously analyzed using the scoring rubric developed by Kusumaningrum, Ashadi, and Indriyanti (2018) through a descriptive approach. The analysis followed a predefined conceptual framework and thematic structure.

Table 2. *The Conceptual Understanding Categories (CUC) established by Kusumaningrum et al. (2018).*

Answer	Category
Correct Answer + Correct Explanation	Understanding
Correct Answer + Partially Correct Explanation	Partial understanding
Correct Answer + Wrong Explanation	Misconception
Wrong Answer + Correct explanation	Misconception
Wrong Answer + Wrong Explanation	Not understanding

It looks like you have provided some content related to coding student answers according to a categorization system called "CUC" (which stands for Correct, Partial, and Misconception categories). To improve the clarity and grammar of this passage, you can consider the following revisions: Table 2 illustrates the categorization of student responses based on the CUC system, which assesses the understanding of students regarding the selection of the correct answer and the quality of their scientific explanations. Students who choose the correct answer and provide a scientifically accurate explanation fall into the 'Understanding' category. Those who choose the right answer but are unable to provide a comprehensive scientific explanation fall into the 'Partial Understanding' category. If a student chooses the correct answer but gives an incorrect explanation or chooses the wrong answer but provides a correct explanation, they are categorized as 'Misconception.' Lastly, selecting the wrong answer without any explanation, providing no reasons, or presenting irrelevant and unscientific explanations places students in the 'Not Understanding' category.

The explanations themselves are further categorized as follows:

'Correct Explanation': This category encompasses explanations that cover all aspects of the scientific understanding of the concept in question.

'Partially Correct Explanation': This category includes explanations that address one or more aspects of the scientific understanding of the concept but do not cover all aspects.

'Wrong Explanation': These explanations, although addressing the concept, reflect misconceptions that do not align with scientific facts.

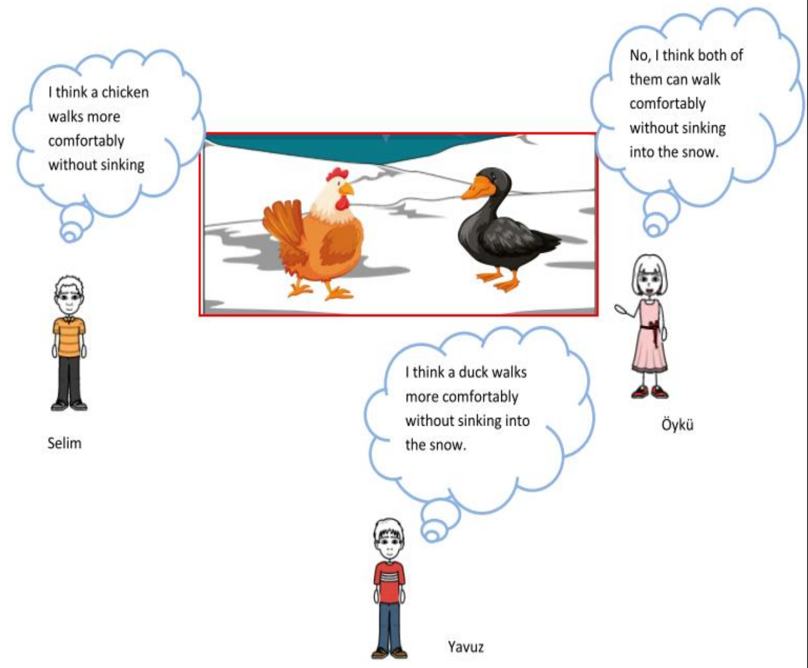
Table 3. *Examples of coding student answers according to the CUC*

Category of conceptual understanding	Excerpts from student statements
Correct Explanation	"Among objects with identical surface areas but different weights, the heavier one will exert greater pressure on the ground" (S20). "To facilitate cutting a watermelon with a knife, we should enhance pressure by reducing the contact surface" (S14).
Partial Correct Explanation	"When the surface area of the blade decreases, the pressure increases" (S24). "The surface area of one foot is smaller" (S31).
Wrong Explanation	"Due to the webbed feet, the body weight is distributed evenly" (S10). "It exerts more pressure when standing on two legs" (S8).

3.Results

3.1. Results from concept cartoons about pressure exerted by solids

In this section, the results related to concept cartoons about pressure exerted by solids in relation to surface area, pressure exerted by solids in relation to weight, and pressure exerted by solids in relation to force and surface area are presented sequentially.



The children in the visual are discussing the duck and the chicken's ability to walk comfortably on the snow without sinking. Who do you think like?

.... I think like. Because ....

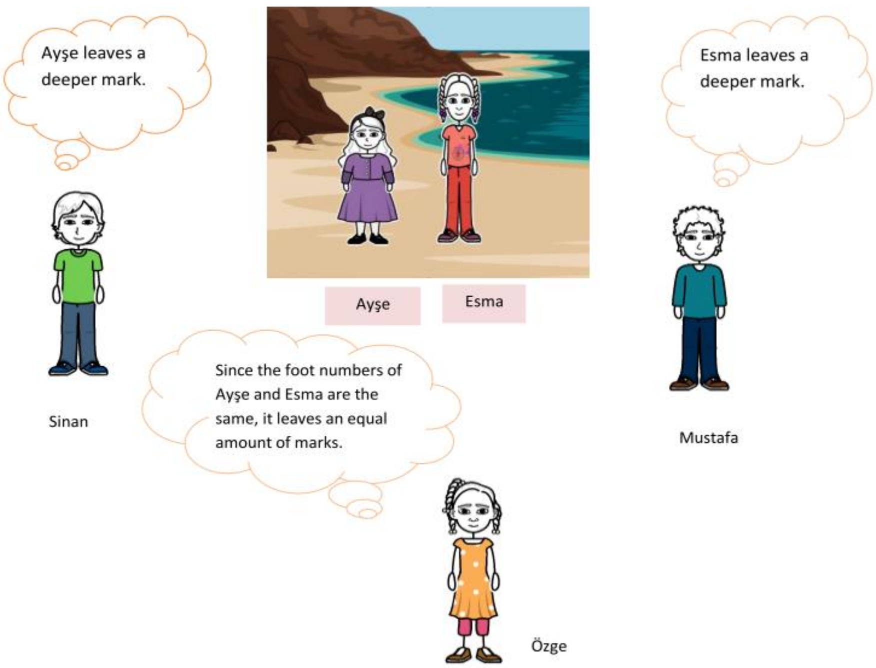
....

Figure 1. *The concept cartoon about the relation of pressure exerted by solids to surface area.*

Table 4. *Results on students' CUC related to the correlation between pressure exerted by solids and surface area*

Answer	f	%
Understanding (Correct Answer + Correct Explanation)	13	36,11
Partial understanding (Correct Answer + Partially Correct Explanation)	11	30,55
Misconception (Correct Answer + Wrong Explanation)	7	19,44
Misconception (Wrong Answer + Correct explanation)	0	0
Not understanding (Wrong Answer + Wrong Explanation)	5	13,88

When Table 4 was analyzed, it can be observed that 36.11% of the students selected the correct answer, affirming the inverse relationship between pressure exerted by solids and surface area when the weight is kept constant, and that pressure exerted by solids decreases as the surface area increases. One student, for example, stated, 'Since duck feet are webbed, the surface area increases, and as the surface area increases, the pressure decreases' (S15). In contrast, 30.55% of the students chose the correct answer but provided incomplete or brief explanations, failing to fully elaborate on the correlation between pressure exerted by solids and surface area. An example of such a response was, 'Since the duck has a larger surface area, it can walk without sinking' (S13). Furthermore, 13.88% of the students either provided an incorrect explanation in the concept cartoon or did not answer the question at all, failing to select any explanation. For instance, a student stated, 'The weights and feet of both are balanced' (S6).



The children in the visual are discussing the depth of the footprints that Ayşe and Esma will leave on the sand while standing on the beach. Since Ayşe and Esma have the same shoe size, who do you think like? Explain with your reasons.

.... I think like. Because ....

....

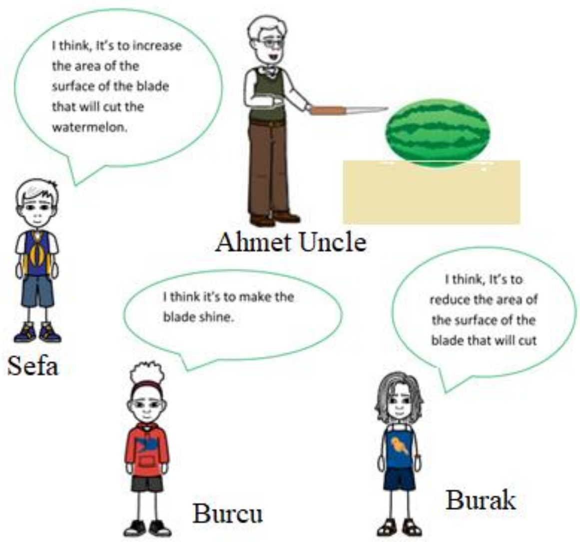
Figure 2. *The concept cartoon showing the correlation between pressure exerted by solids and weight*

Lastly, 19.44% of the students believed that the chicken would sink due to the shape of its feet. One student explained, 'The chicken's finger declaw is open, and the chicken can sink. A duck, on the other hand, is not expected to sink because the finger declaw is adjacent to each other' (S37)." However, these students failed to establish the correct relationship between pressure exerted by solid and surface area, leading to a misconception. By overlooking how the shape of the feet affects the surface area and, consequently, the pressure exerted, this view reflects a difficulty in grasping the fundamental physical principles related to this concept. The reason for this situation might be rooted in a fundamental misunderstanding or lack of knowledge about the relationship between pressure, force, and surface area. Students may not fully grasp that pressure is determined by the force applied per unit area, and as a result, they might overlook how different surface areas can alter the pressure exerted by an object. This could also be due to insufficient emphasis on the concept in previous lessons or a lack of practical examples that clearly illustrate this relationship.

Table 5. *Results on students' CUC related to the correlation between pressure exerted by solids and weight*

Answer	**f**	**%**
Understanding (Correct Answer + Correct Explanation)	6	16,66
Partial understanding (Correct Answer + Partially Correct Explanation)	13	36,11
Misconception (Correct Answer + Wrong Explanation)	13	36,11
Misconception (Wrong Answer + Correct explanation)	1	2,77
Not understanding (Wrong Answer + Wrong Explanation)	3	8,33

When Table 5 was examined, it was evident that 16.66% of the students selected the correct answer, affirming a direct proportionality between pressure exerted by solid and weight when the surface area was kept constant. They noted that pressure exerted by solid increases as weight increases. For example, a student explained, 'Objects with the same surface area but different weights will exert more pressure on the ground, given their increased weight' (S20). On the other hand, 36.11% of the students chose the correct answer, but their explanations were often incomplete or brief, failing to provide a comprehensive explanation for the relationship between pressure exerted by solids and weight. It is understood from these explanations of the students that they focus on a single concept when explaining the pressure exerted by solids, and that they only take into account the dependent (pressure exerted by solids) and independent variables (weight) without considering the variables that need to be controlled (surface area). This situation may be due to the fact that the students have not had enough experience of designing experiments by taking into account the dependent, independent and controlled variables. It may also be due to the fact that the students are not aware of the variables that need to be controlled when explaining scientific information. An example of such a response is, 'The one with more weight has more pressure' (S18). Furthermore, 8.33% of the students selected a wrong explanation in the concept cartoon or did not provide any explanation at all. An example of such an explanation is, 'Esma puts more pressure where she is' (S6). Lastly, 38.88% of the students believed that pressure was solely related to weight, leading to a misconception. They incorrectly thought that heavy objects would always sink. A student explained, 'Ayşe sinks because she has more weight' (S28). S28, who made this statement, did not take into account the possibility that by increasing the surface area of heavy objects, lighter objects would leave a trace at a lesser depth. He made the mistake of overgeneralization.



The children in the image are discussing the reason why Ahmet Uncle sharpens edge of the blade before cutting the watermelon. Who do you think like? Explain with your reasons.

.... I think like. Because ....

....

Figure 3. *Concept cartoon associated with pressure exerted by solids and surface area.*

Table 6. *Results on students' CUC related to the correlation between pressure exerted by solids and surface area.*

Answer	f	%
Understanding (Correct Answer + Correct Explanation)	10	27,77
Partial understanding (Correct Answer + Partially Correct Explanation)	8	22,22
Misconception (Correct Answer + Wrong Explanation)	9	25
Misconception (Wrong Answer + Correct explanation)	0	0
Not understanding (Wrong Answer + Wrong Explanation)	9	25

When examining Table 6, it becomes evident that 27.77% of the students selected the correct answer, highlighting an inverse proportionality between pressure and the surface area in solid objects. They correctly pointed out that pressure increases when the surface area of the object is reduced. For instance, a student explained, 'I'm thinking like Burak. Uncle Ahmet will be able to cut the watermelon more easily with less force by reducing the surface area of the edge of the blade to cut' (S9). On the other hand, 25% of the students selected a wrong explanation in the concept cartoon, offering explanations that did not align with the correct answer or not providing any explanation at all. An example of such an explanation is, 'I'm thinking like Omer. Since increasing the surface area of the blade makes it easier to cut the watermelon' (S13). Furthermore, another 25% of the students displayed misconceptions. They either chose the correct answer but provided a wrong explanation or chose the wrong answer but offered a correct explanation. An example is, 'I'm thinking like Burak. As the blade is sharpened, the pressure increases' (S18). S18 explained the high pressure simply by the sharpness of the edge of the blade, without taking into account the magnitude of the force applied to the blade.

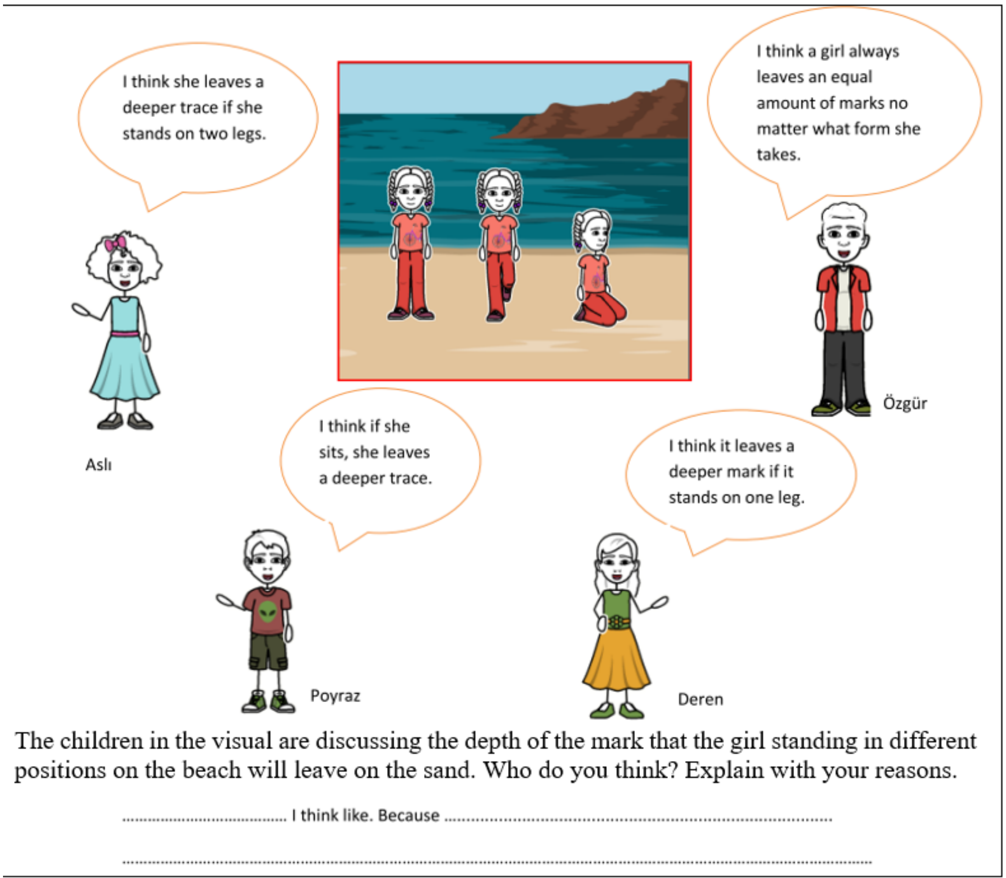


Figure 4. Concept cartoon associated with pressure exerted by solids and surface area

Table 7. *Results on students' CUC related to the correlation between pressure exerted by solids and surface area.*

Answer	f	%
Understanding **(**Correct Answer + Correct Explanation**)**	16	44
Partial understanding **(**Correct Answer + Partially Correct Explanation**)**	9	25
Misconception **(**Correct Answer + Wrong Explanation**)**	2	5,55
Misconception **(**Wrong Answer + Correct explanation**)**	0	0
Not understanding **(**Wrong Answer + Wrong Explanation**)**	9	25

When examining Table 7, it was evident that 44.44% of the students selected the correct answer and provided accurate explanations. They made a correct connection between the force, surface area and pressure exerted by the solid. They stated that if the weight, that is, the force, is the same, decreasing the surface area of the object will increase the pressure exerted by solid the object. For instance, a student explained, 'I'm thinking like Ozgür because if the surface area is small in pressure exerted by solids, the pressure will be greater, leaving deeper traces in the sand' (S19). Similarly, 25% of the students selected the correct answer but often provided incomplete or brief explanations. An example of such an explanation is, 'I'm thinking like Özgür because of the smallness of the surface area' (S35). Conversely, 25% of the students chose a wrong explanation in the concept cartoon, offering explanations that did not align with the correct answer or not providing any explanation at all. An example of such an explanation is, 'I'm thinking like Ozgür, but I don't know how to explain it' (S37). Additionally, 5.55% of the students demonstrated misconceptions. They either chose the correct answer but provided a wrong explanation or chose the wrong answer but offered a correct explanation. An example is, 'I'm thinking like Ozgür. Since if the surface area decreases, the pressure decreases, so it leaves more traces on one foot' (S3)

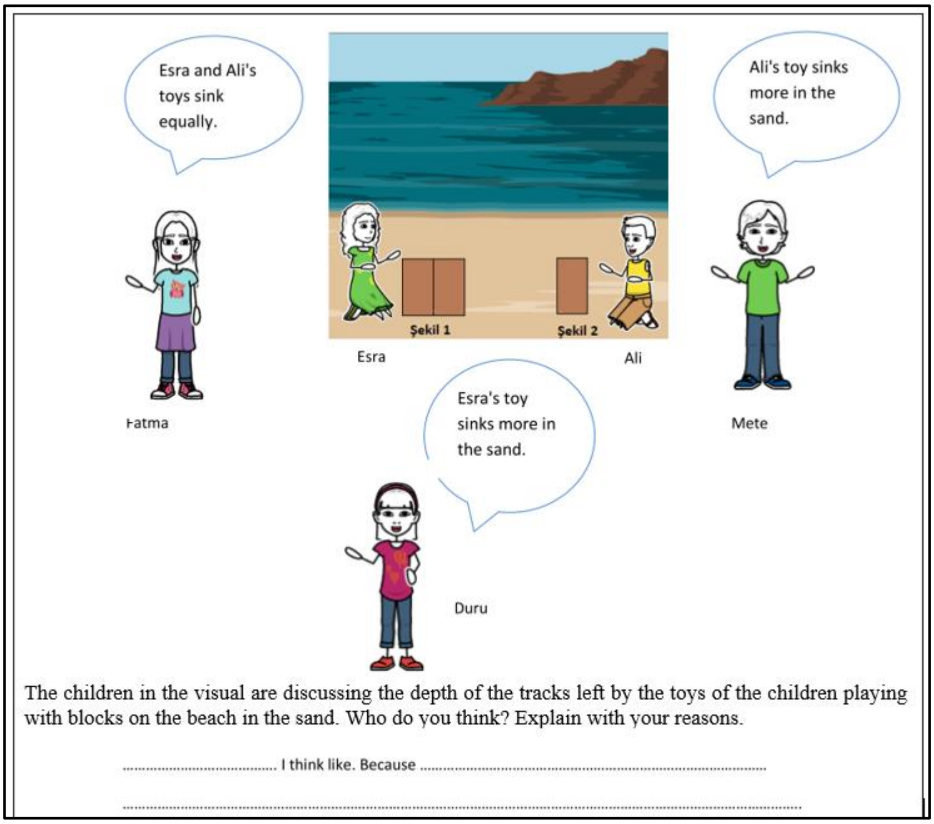


Figure 5. *Concept cartoon related to the ratio between solid pressure force and surface area.*

Table 8. *Results on students' CUC related to the ratio between solid pressure force and surface area*

Answer	f	%
Understanding (Correct Answer + Correct Explanation)	12	33,33
Partial understanding (Correct Answer + Partially Correct Explanation)	1	2,77
Misconception (Correct Answer + Wrong Explanation)	3	8,33
Misconception (Wrong Answer + Correct explanation)	8	22,22
Not understanding (Wrong Answer + Wrong Explanation)	12	33,33

When examining Table 8, it was evident that 33.33% of the students selected the correct answer and provided accurate explanations. They correctly noted that if the weight-to-surface area ratio in a solid material remains unchanged, the pressure will also remain constant. For example, a student explained, 'Fatma says that since the weight-to-surface area ratios are equal, it sinks evenly' (S12). A small percentage, 2.77% of the students, selected the correct answer but often provided incomplete or brief explanations. An example of such an explanation is, 'I'm thinking like Fatma. Since they are identical blocks, they sink evenly' (S9). On the other hand, 33.33% of the students chose incorrect explanations in the concept cartoon, offering responses that did not align with the correct answer or not providing any explanation at all. An example of such an explanation is, 'I'm thinking like Mete. Because of putting pressure on one place in the second figure' (S6). Furthermore, 30.55% of the students demonstrated misconceptions. They either chose the correct answer but provided a wrong explanation or chose the wrong answer but offered a correct explanation. An example is, 'I'm thinking like Mete. Since the surface area is small, the pressure increases' (S24).

Table 9. *Results from students' misconceptions about pressure exerted by solids*

Concept	Misconception	Student	Frequency of explanation
The correlation between pressure exerted by solids and surface area	The pressure exerted by solids depends only on the surface area, the larger the surface area, the less it sinks.	S5, S8, S10, S22, S24, S30, S37	7
	If the surface area increases, the pressure increases.	S10, S15, S18, S30, S31, S35, S36, S37	8
	If the surface area decreases, the pressure decreases.	S3	1
	Failure to establish the ratio between solid pressure force and surface area	S3, S8, S10, S12, S18, S19, S23, S24, S30, S35, S37	11
Pressure exerted by solids-weight correlation	Pressure exerted by solids depends only on weight, pressure always increases as weight increases.	S3, S10, S12, S22, S24, S25, S26, S27, S28, S30, S31, S35, S36, S37, S8	14

When Table 9 was examined, it was observed that 7 students, represented by N=7, believed that solid pressure is solely dependent on surface area. They thought that pressure would increase when surface area decreased, without considering the impact of weight. Similarly, 8 students (N=8) held the belief that pressure would increase whenever surface area increased, regardless of weight. Conversely, 1 student (N=1) thought that pressure would decrease if the surface area decreased. Additionally, 11 students (N=11) displayed misconceptions regarding the relationship between force and surface area. They incorrectly believed that pressure would remain constant when both force and surface area increased or decreased at the same rate. Furthermore, 14 students (N=14) did not take the surface area into account and thought that pressure would increase whenever weight increased.

3.2. Results obtained from liquid pressure concept cartoons

In this section, the results related to the concept cartoons concerning the relationship between liquid pressure and depth, as well as liquid pressure and density, are presented below.

Table 10. *Results on students' CUC related to the correlation between liquid pressure and depth*

Answer	F	%
Understanding (Correct Answer + Correct Explanation)	17	47,22
Partial understanding (Correct Answer + Partially Correct Explanation)	7	19,44
Misconception (Correct Answer + Wrong Explanation)	5	13,88
Misconception (Wrong Answer + Correct explanation)	0	0
Not understanding (Wrong Answer + Wrong Explanation)	7	19,44

When Table 10 was examined, it was found that 47.22% of the students chose the right answer and explained it correctly. They stated that there was a direct proportionality between liquid pressure and the depth, and the liquid pressure will increase as the depth increases. For example, a student explained, 'I'm thinking like Yavuz. Since if the depth increases, the pressure of liquids also increases' (S17). Although 19.44% of the students chose the correct answer, they made incomplete or short explanations. 'I'm thinking like Yavuz. As you go down to the bottom of the water, the pressure increases' (S18). These students explained the pressure of the liquid as increasing with the depth of the liquid, without considering all the factors affecting the pressure of the liquid (density of the liquid, acceleration due to gravity, and depth of the liquid). This situation is considered as a result of students' inability to think in multiple ways. In addition, 19.44% of the students chose the wrong explanation in the concept cartoon or made a wrong explanation or did not explain. 'Yavuz, because the pressure is higher at point z' (S30). These students also explained the reason for the high liquid pressure at point z with their intuitive thoughts, without expressing the reason. On the other hand, 13.88% of them used misconceptions by choosing the right answer and making a wrong explanation, or by choosing the wrong answer and making a correct explanation. 'I'm thinking like Yavuz. Since there is more water on the deeper divers' (S32). These students also explained the high liquid pressure at point z by the high amount of water, without expressing the relationship between liquid pressure and depth. In other words, they explained the liquid pressure by relating it to volume, not depth.

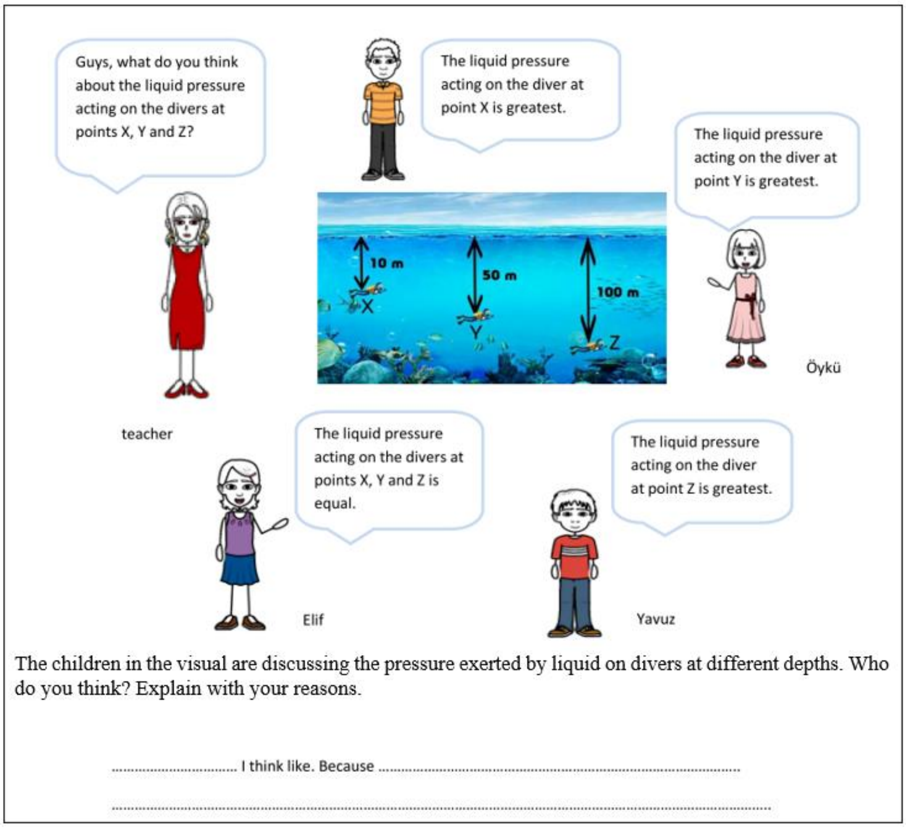


Figure 6. *Concept cartoon associated with liquid pressure and depth*

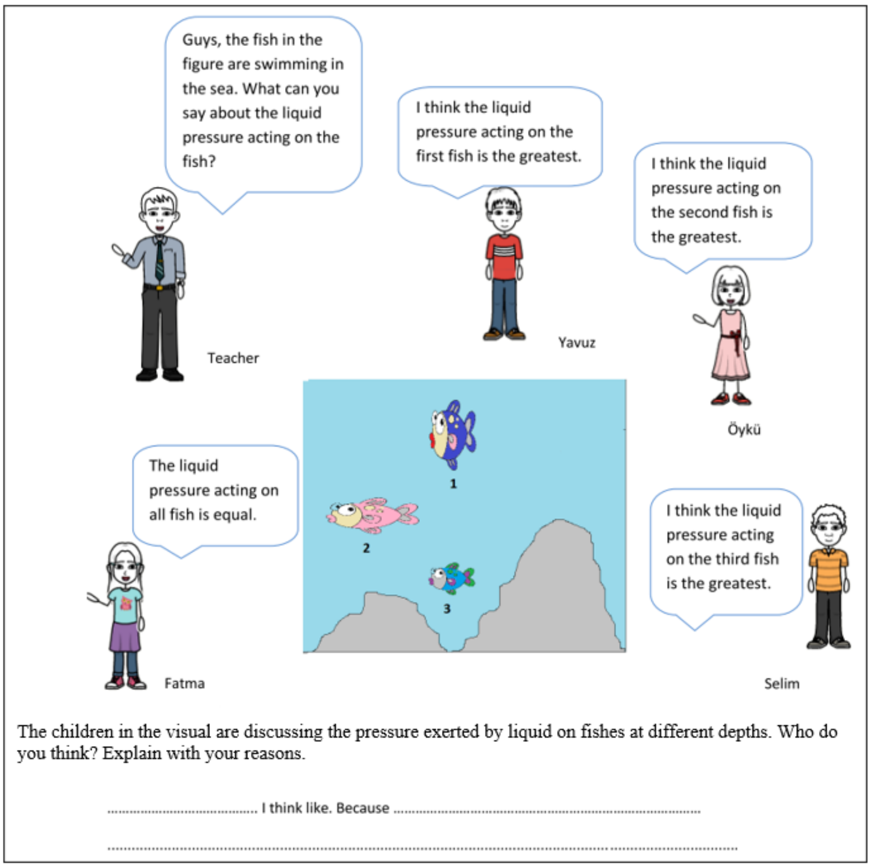


Figure 7. *Concept cartoon about liquid pressure and depth*

Table 11. *Results on students' CUC related to liquid pressure and depth*

Answer	**F**	**%**
Understanding **(**Correct Answer + Correct Explanation**)**	19	52,77
Partial understanding **(**Correct Answer + Partially Correct Explanation**)**	5	13,88
Misconception **(**Correct Answer + Wrong Explanation**)**	6	16,66
Misconception **(**Wrong Answer + Correct explanation**)**	0	0
Not understanding **(**Wrong Answer + Wrong Explanation**)**	6	16,66

When Table 11 was examined, it was evident that 52.77% of the students selected the correct answer and provided accurate explanations. They correctly recognized a linear relationship between liquid pressure and depth, explaining that as the depth increases, liquid pressure also increases. For example, a student explained, “I'm thinking like Selim because the third fish is in the deepest part, and liquid pressure is directly proportional to depth” (S12). Additionally, 13.88% of the students chose the correct answer, but their explanations were often incomplete or brief. An example of such an explanation is, 'I'm thinking like Selim. Since liquid pressure is higher at depth' (S25). On the other hand, 16.66% of the students selected wrong explanations in the concept cartoon, offering responses that did not align with the correct answer or not providing any explanation. An example of such an explanation is, “I'm thinking like Selim because he is right” (S21). Furthermore, 16.66% of the students displayed misconceptions. These students also did not explain in depth why the liquid pressure acting on fish number 3 was the greatest. For example, S18 explained, "I think like Selim. Because fish number 3 is the smallest fish, so it gets squeezed the most in the water (S18)." S18 explained why the liquid pressure acts the most on fish number 3 by relating it to the volume of the fish. Additionally, 16.6% of the students both marked the wrong answer and gave the wrong explanation. . These students could not mark the correct answer because they did not know the factors affecting liquid pressure and they wrote the wrong explanation. For example, “I think like Fatma. Because fish are affected by the same pressure since they are in the same liquid. (S13)”. S13 does not know how the liquid pressure changes depending on the depth variable. He thinks that the same pressure acts everywhere in the liquid because it is the same liquid. Some students think like Yavuz. The reason why these students think this way is because they cannot distinguish the concepts of depth and height. They interpret the pressure force acting on the first fish as the distance from the bottom of the sea to the surface. This situation may be due to the fact that the students are not aware of the pressure force that causes liquid pressure and that they structure the information in their minds without making sense of it. For example: “I think like Yavuz. Because the first fish is the highest. (S8)”.

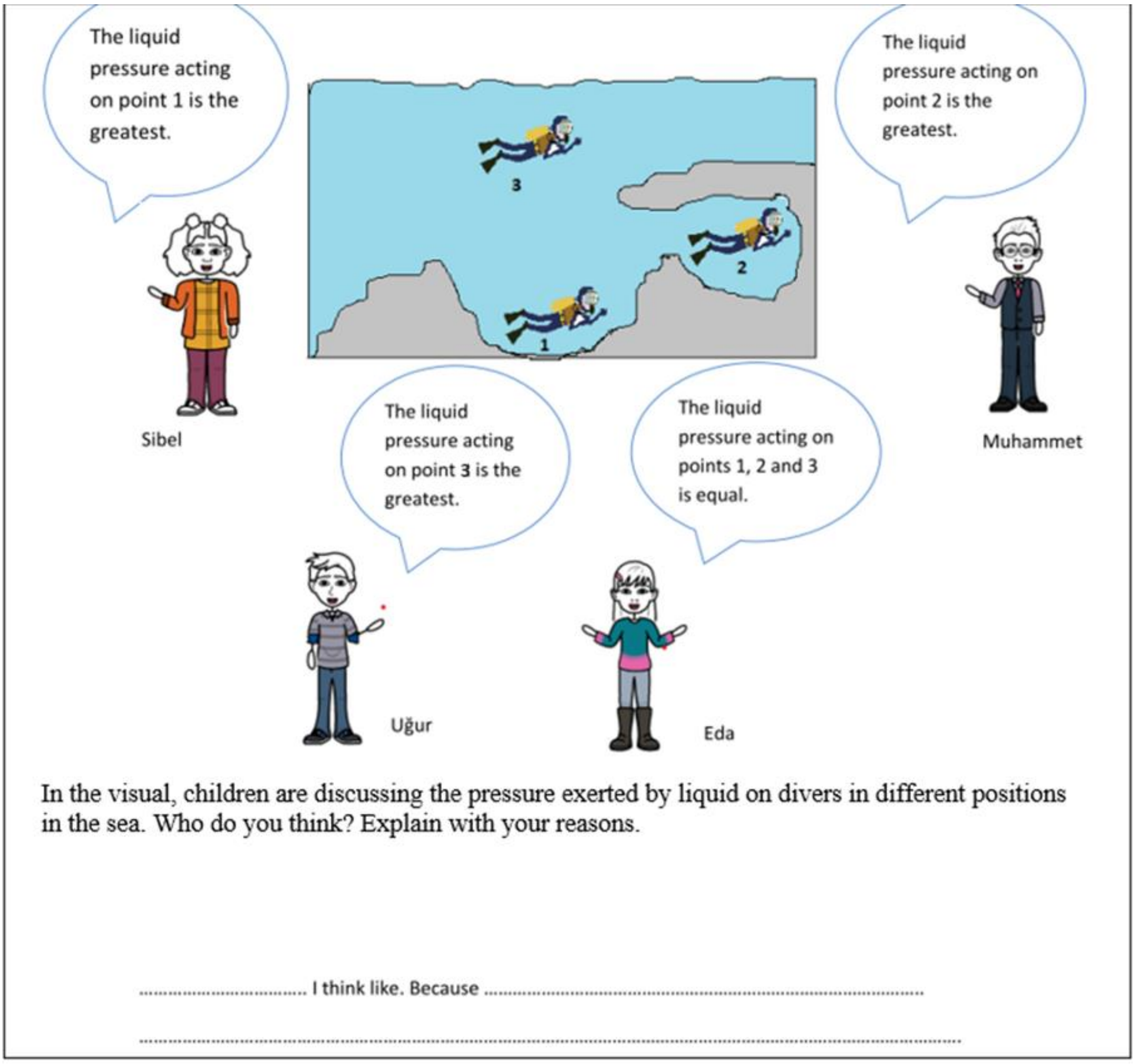
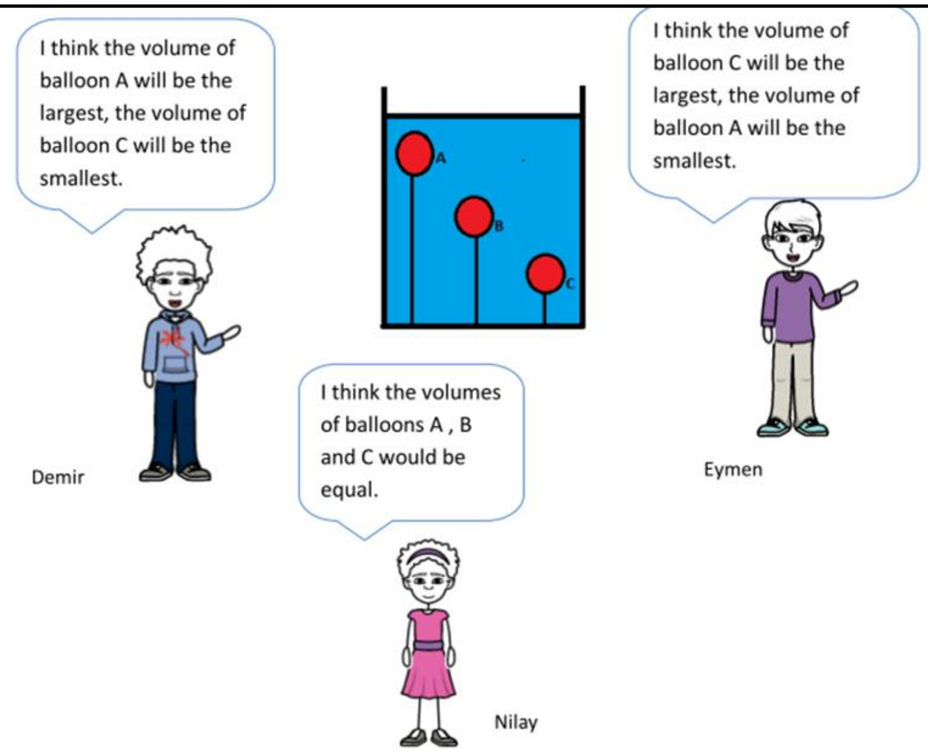


Figure 8. *Concept cartoon about liquid pressure and depth*

Table 12. *Results for students' CUC related to liquid pressure and depth*

Answer	**F**	**%**
Understanding **(**Correct Answer + Correct Explanation**)**	19	52,77
Partial understanding **(**Correct Answer + Partially Correct Explanation**)**	0	0
Misconception **(**Correct Answer + Wrong Explanation**)**	5	13,88
Misconception **(**Wrong Answer + Correct explanation**)**	1	2,77
Not understanding **(**Wrong Answer + Wrong Explanation**)**	11	30,55

When analyzing Table 12, it becomes evident that 52.77% of the students selected the correct answer and provided correct explanations. They recognized a direct proportionality between liquid pressure and depth, explaining that as the depth increases, the liquid pressure also increases. For example, a student explained, “I'm thinking like Sibel, because as the depth increases, the pressure increases” (S36). Additionally, 30.55% of the students chose wrong answer in and explained it wrongly. An example of such an explanation is, “I'm thinking like Sibel because the pressure is too high” (S10). Moreover, 16.65% of the students displayed misconceptions. They either chose the correct answer but provided a wrong explanation or chose the wrong answer but offered a correct explanation. For instance, 'Sibel says that when the density is high, the pressure increases' (S29). Although this student marked the correct answer, he explained it incorrectly. Because he stated that the liquid pressure acting on the diver at point 1 is due to the highest density of the liquid at point 1. From this, it is understood that the student thought that the density of the liquid would be different in different parts of the liquid. Another student also expressed that he thought like Muhammet. He presented as a reason that more pressure would be applied to the diver at point 2 because he would be more compressed in a small area. Another student also stated that more pressure would be applied to the diver at point 2 because there would be pressure on the side of the cave in the sea. This situation may be due to the students not being able to associate the sea image with a cave in the concept cartoon with the set of connected tubes of different shapes liquid pressure or not actively conducting an experiment related to the set of connected tubes of different shapes liquid pressure. Some students also stated that they thought like Uğur. They explained their reasoning for thinking like Uğur by saying that there was much more water in the area where the diver was at point number 3 in the sea. From this explanation, it is understood that the students again could not establish the relationship between liquid pressure and liquid depth. For example: “I think like Uğur. Because, there is a lot more water where the diver at point number 3 is.” (S15). This situation may also be due to the students' inability to visualize microscopically the pressure force that causes pressure on an object/person in liquid.



The children in the visual are discussing what will happen to the volumes of the balloons when they are connected to points A, B and C in a container filled with water, inflated plastic children's balloons of the same volume. Who do you think? Explain with your reasons.

……………………I think like. Because……………………………………………………………
……………………………………………………………………………………………………

Figure 9. *Concept cartoon about the correlation between liquid pressure and depth*

Table 13. *Results on students' CUC related to liquid pressure and depth*

Answer	**F**	**%**
Understanding **(**Correct Answer + Correct Explanation**)**	5	13,88
Partial understanding **(**Correct Answer + Partially Correct Explanation**)**	6	16,66
Misconception **(**Correct Answer + Wrong Explanation**)**	7	19,44
Misconception **(**Wrong Answer + Correct Explanation**)**	1	2,77
Not understanding **(**Wrong Answer + Wrong Explanation**)**	17	47,22

When analyzing Table 13, it became evident that 13.88% of the students selected the correct answer and provided correct explanations. They correctly recognized a direct correlation between liquid pressure and depth, explaining that as liquid pressure increases with depth, the gas pressure in the balloon decreases. For example, a student explained, 'I'm thinking like Demir. Since the liquid pressure acting on balloon C is the highest, the volume decrease will be the greatest in this balloon' (S33). Moreover, 16.66% of the students chose the correct answer, but their explanations were often incomplete or brief. An example of such an explanation is, 'I'm thinking like Demir. Since C is at the deepest point, its volume will be the smallest' (S25). On the other hand, 47.22% of the students selected incorrect explanations in the concept cartoon, offering responses that did not align with the correct answer or failing to provide any explanation. An example of such an explanation is, 'I'm thinking like Eymen because he is right' (S21). Additionally, 22.21% of the students displayed misconceptions. They either chose the correct answer but provided a wrong explanation or chose the wrong answer but offered a correct explanation. For instance, 'Eymen says that the volume is less at the top and more at the bottom' (S25). This situation is also evaluated as a result of the students not being able to establish the relationship between liquid pressure and depth and the fact that the volume of the plastic balloon will be compressed with the effect of liquid pressure.

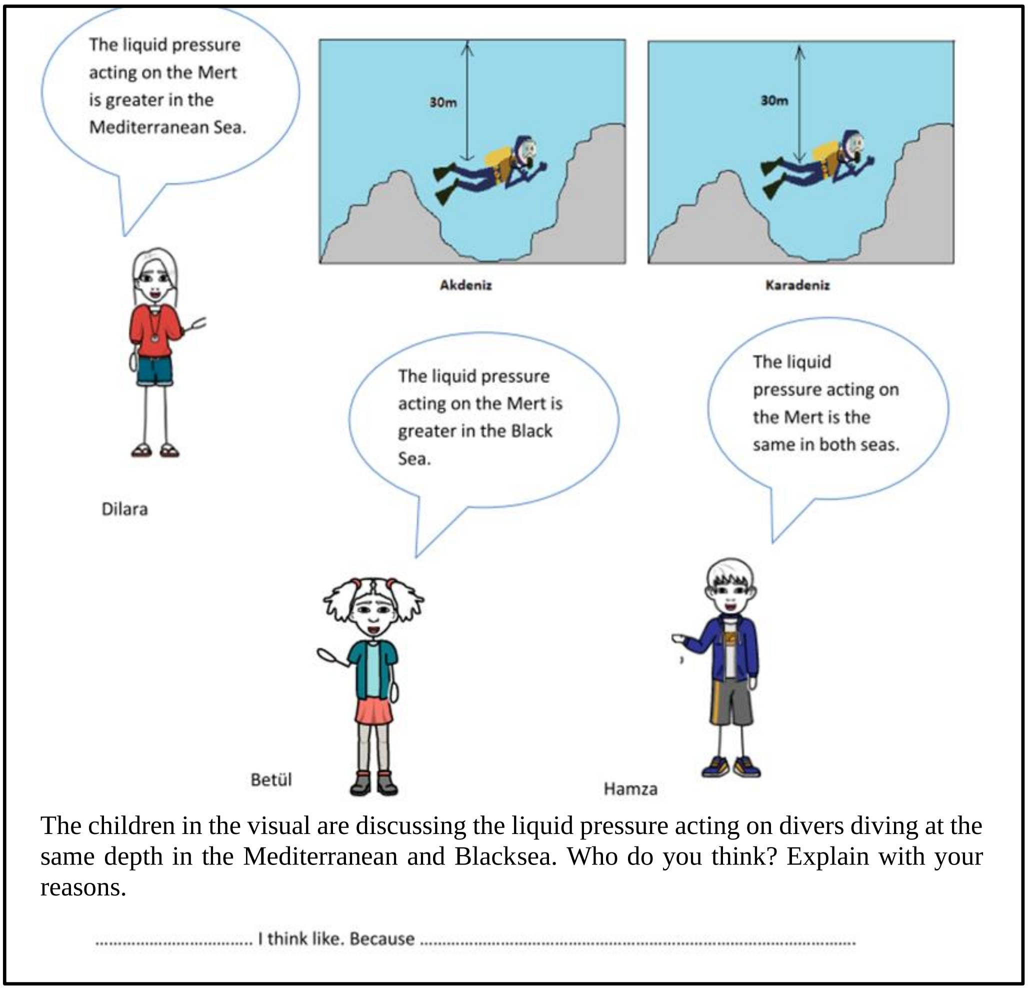
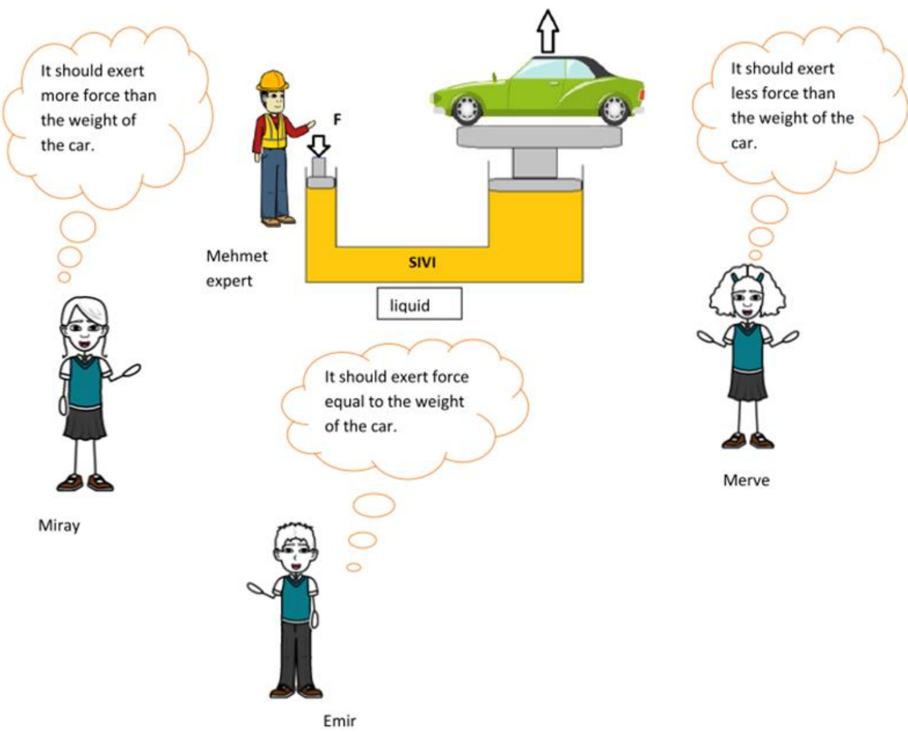


Figure 10. *Concept cartoon about the correlation between liquid pressure and density*

Table 14. *Results on students' CUC related to the correlation between liquid pressure and density*

Answer	F	%
Understanding **(**Correct Answer + Correct Explanation**)**	19	52,77
Partial understanding **(**Correct Answer + Partially Correct Explanation**)**	2	5,55
Misconception **(**Correct Answer + Wrong Explanation**)**	1	2,77
Misconception **(**Wrong Answer + Correct explanation**)**	0	0
Not understanding **(**Wrong Answer + Wrong Explanation**)**	14	38,88

When analyzing Table 14, it became evident that 52.77% of the students selected the correct answer and provided accurate explanations. They correctly identified a direct correlation between liquid pressure and density, explaining that as the density of the liquid increases, so does the liquid pressure. For example, a student explained, 'I'm thinking like Dilara. As the density increases, the liquid pressure increases' (S14). Moreover, 5.55% of the students chose the correct answer, although their explanations were often incomplete or brief. An example of such an explanation is, 'I'm thinking like Dilara. Density affects pressure' (S23). Conversely, 38.88% of the students selected incorrect explanations in the concept cartoon, offering responses that did not align with the correct answer or failing to provide any explanation. An example of such an explanation is, 'I'm thinking like Hamza because the depth levels (h) are the same in both seas' (S19). Additionally, 2.77% of the students displayed misconceptions. They either chose the correct answer but provided a wrong explanation or chose the wrong answer but offered a correct explanation. For instance, 'I'm thinking like Dilara. Since the density is the same as the pressure' (S25).



In the car repair shop, they are discussing how much force Mehmet Expert should apply in the hydraulic lift service to lift a car up. Who do you think like? Explain with your reasons.

.... I think like. Because ....

Figure 11. *Concept cartoon about the implementation of Pascal's Principle in daily life*

Table 15. Results on students' CUC related to the implementation of Pascal's Principle

Answer	F	%
Understanding **(**Correct Answer + Correct Explanation**)**	0	0
Partial understanding **(**Correct Answer + Partially Correct Explanation**)**	5	13,88
Misconception **(**Correct Answer + Wrong Explanation**)**	8	22,22
Misconception **(**Wrong Answer + Correct explanation**)**	0	0
Not understanding **(**Wrong Answer + Wrong Explanation**)**	23	63,88

When analyzing Table 15, it became apparent that none of the students, represented as 0%, provided correct explanations while choosing the right answer. They struggled to accurately describe how a liquid transmits pressure in closed containers. In contrast, 13.88% of the students selected the correct answer, although their explanations were often incomplete or brief. An example of such an explanation is, 'It must exert less force than the weight of the car. In such systems, objects can be balanced with a small force' (S34). Conversely, 63.88% of the students chose incorrect explanations in the concept cartoon, offering responses that did not align with the correct answer or failing to provide any explanation. An example of such an explanation is, 'I'm thinking like Miray. Since a greater force is required for the car to lift up' (S23). Additionally, 22.22% of the students displayed misconceptions. They either chose the correct answer but provided a wrong explanation or chose the wrong answer but offered a correct explanation. For example, 'I'm thinking like Miray. Since what she said makes sense, we have to apply a greater force than her to lift an object' (S32). This situation may be due to the students' inability to establish relationships between concepts and to accommodate the concepts in their minds.

Table 16. *Results related to the liquid pressure*

Concept	Misconception	Student	Frequency of explanation
Liquid pressure-depth correlation	The liquid pressure depends on the amount of liquid.	S32, S24, S30	3
	The liquid pressure increases as the surface area increases.	S10, S28	2
	The liquid pressure increases as the surface area decreases.	S11	1
	As the depth of the liquid increases, so does its density, resulting in increased pressure."	S6, S18, S24, S28, S29,	5
	"The volume of the bubble within the liquid is influenced by atmospheric pressure."	S19, S8, S9, S23, S25	5
Liquid pressure-density correlation	The liquid pressure depends on the density of the object.	S8	1
	"As the number of liquid particles increases, the density also increases, resulting in higher liquid pressure."	S18	1
Pascal's Principle	"According to Pascal's Principle, if a force greater than the object's weight is not applied, it cannot be lifted."	S6, S8, S13, S23	4
	Pascal's Principle states that when the density and height are equal, the pressure is also equal."	S17	1

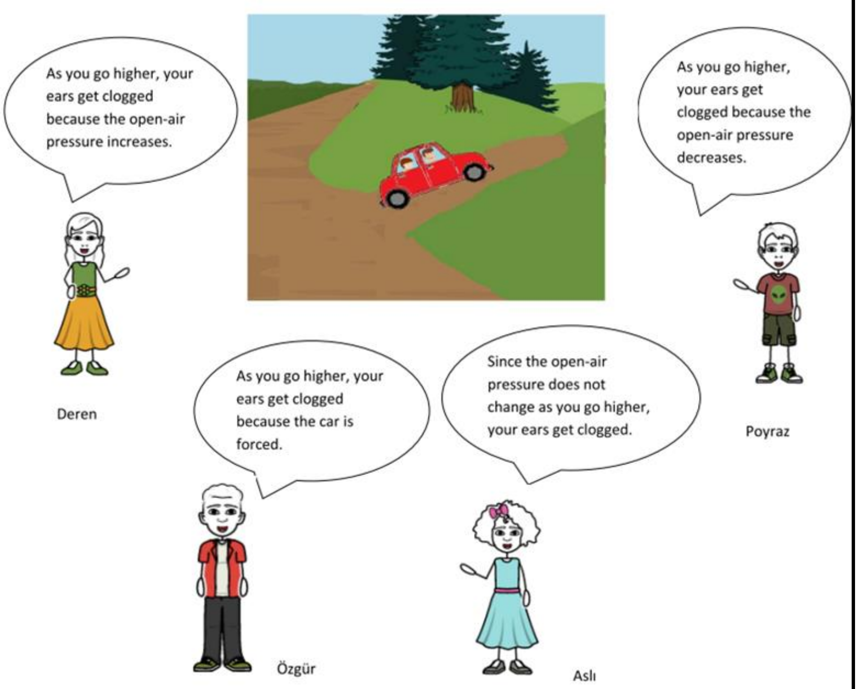
When analyzing Table 16, several misconceptions were identified among the students:

Three students believed that liquid pressure is contingent on the volume of the liquid. Three students erroneously thought that liquid pressure is akin to pressure exerted by solids and is determined by surface area. Five students incorrectly assumed a connection between liquid depth and density in determining liquid pressure. Another five students mistakenly asserted that the pressure of a balloon submerged in a liquid is linked to atmospheric pressure. These students also held misconceptions related to these concepts. In relation to the connection between liquid pressure and density, one student erroneously believed that liquid pressure depends on the density of the object. Additionally, another student held misconceptions regarding the correlation between the quantity of liquid and the density of the liquid. In addition, when evaluating the findings related to the relationship between liquid pressure and the Pascal Principle, it was observed that five students had misconceptions about the functioning of the Pascal Principle. These students incorrectly understood how the Pascal Principle operates. According to Pascal's Principle, if pressure is applied to a fluid in a closed container at any point, this pressure is transmitted equally and unchanged throughout the fluid. This occurs due to the fluid's ability to transmit pressure uniformly in all directions. Example: In a hydraulic system, the force applied to a small piston is transmitted through the fluid to a larger piston, resulting in a greater force. This principle is employed in various applications, such as car brakes, hydraulic presses, and many industrial machines. Understanding this principle is crucial for comprehending how fluids transmit pressure. In the concept cartoon, Mehmet Expert applies a small force to a small piston, creating pressure. This pressure is transmitted unchanged through the closed container to the larger piston. The car, due to its weight, causes a smaller pressure on the piston with a larger surface area. Therefore, by applying a small force to the piston with a smaller surface area, Mehmet Expert generates greater pressure.

The reason why students may struggle to conceptualize Pascal's Principle could be due to the lack of detailed explanation or demonstration of pressure transmission in closed containers. It may also stem from the principle being taught only superficially, with examples of its applications in daily life rather than in-depth exploration. Additionally, the group from which this data was collected consists of students who were educated during the COVID-19 pandemic, and these students might not have had the opportunity to actively engage in experiments that would help them fully grasp Pascal's Principle in remote learning environments.

3.3. Results obtained from atmospheric pressure concept cartoons

In this section, the results from the concept cartoons related to atmospheric pressure in relation to height, as well as atmospheric pressure in relation to air movements, are presented sequentially.



The children in the visual are discussing the situation of people in a car going to the plateau experiencing ear congestion as they climb higher. Who do you think like? Explain with your reasons.

.... I think like. Because ....

....

Figure 12. *Concept cartoon about the correlation between atmospheric pressure and height*

Table 17. Results on students' conceptual understanding category about the correlation between atmospheric pressure and height

Answer	F	%
Understanding **(**Correct Answer + Correct Explanation**)**	1	2,77
Partial understanding **(**Correct Answer + Partially Correct Explanation**)**	16	44,44
Misconception **(**Correct Answer + Wrong Explanation**)**	1	2,77
Misconception **(**Wrong Answer + Correct explanation**)**	1	2,77
Not understanding **(**Wrong Answer + Wrong Explanation**)**	17	47,22

When Table 17 was examined, it became apparent that 2.77% of the students chose the correct answer and provided accurate explanations. They correctly noted that as one ascends, atmospheric pressure decreases, causing ears to become clogged due to the difference between internal and external pressures. For example, a student explained, 'I'm thinking like Poyraz. As the pressure decreases, the balance between internal and external pressure deteriorates' (S7). With this statement, S7 indicated the pressure difference between the air inside the ear and the external atmospheric pressure. Moreover, 44.44% of the students selected the correct answer, but their explanations were often incomplete or partially correct. An example of such an explanation is, 'I'm thinking like Poyraz because his ears get clogged due to the decrease in atmospheric pressure' (S6). With this statement, S6 shows that he knows that atmospheric pressure decreases as we go up higher. However, this explanation is insufficient for the cause of ear congestion. He cannot answer the question of what causes the decrease in pressure as we go up higher and ear congestion occurs. Conversely, 47.22% of the students chose incorrect explanations in the concept cartoon, offering responses that did not align with the correct answer or failing to provide any explanation. An example of such an explanation is, 'I'm thinking like Deren. Since the pressure increases, its is at higher altitude' (S10). S10 thinks that atmospheric pressure increases in direct proportion to altitude. Additionally, 5.54% of the students displayed misconceptions. They both chose the wrong answer and provided a wrong explanation. For instance, 'I'm thinking like Özgür. Since the pressure decreases at higher altitudes, I'm thinking like him' (S4)."

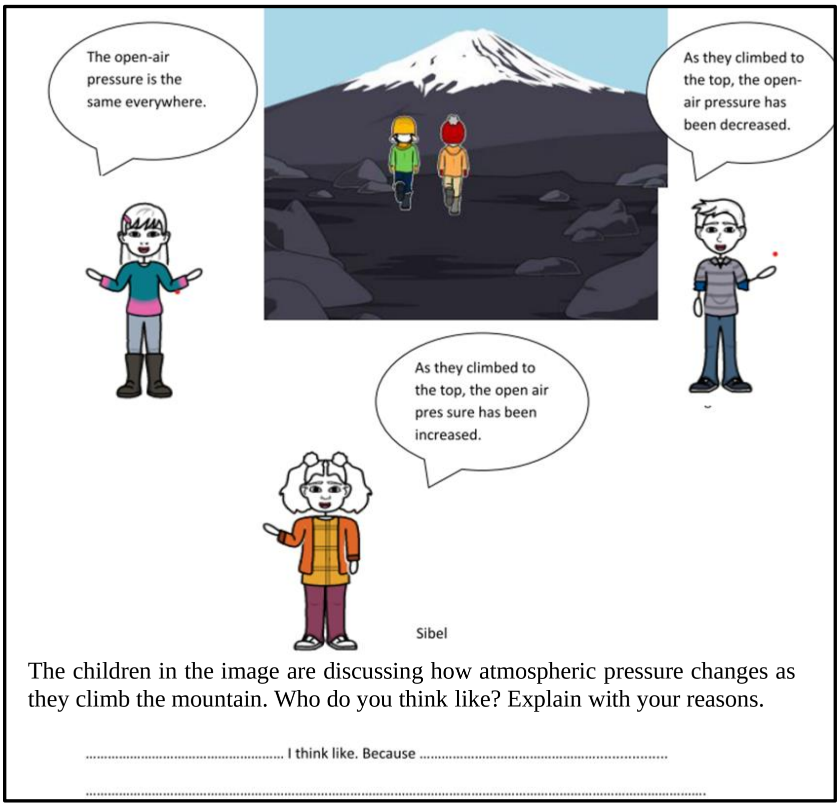
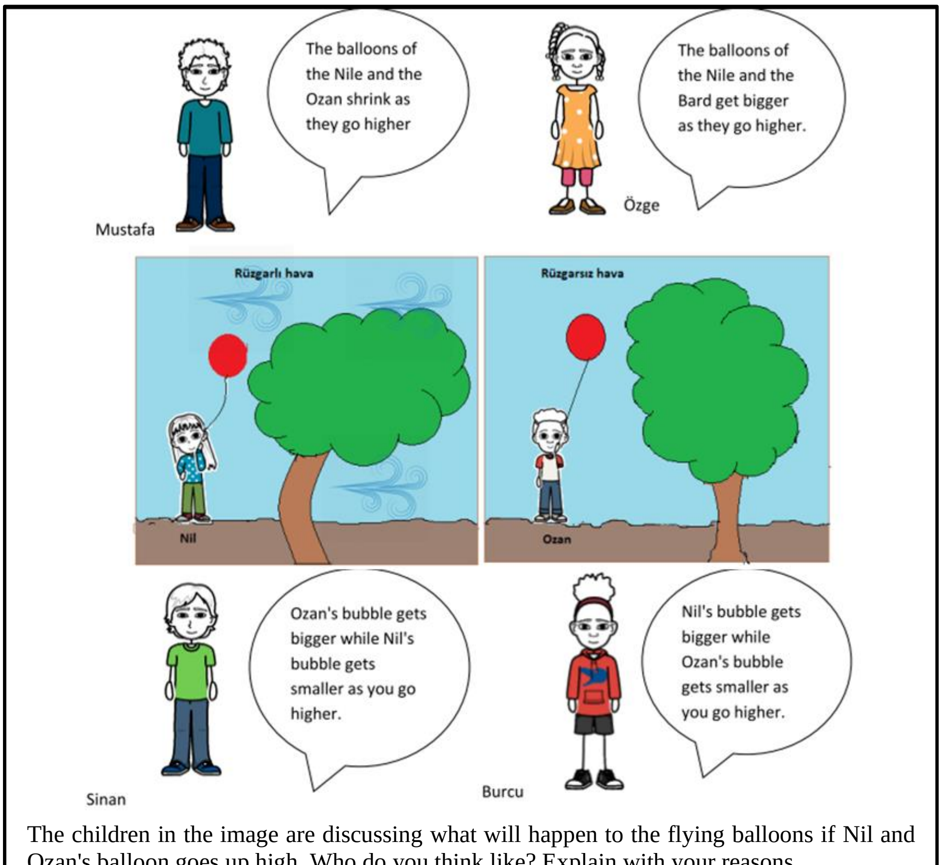


Figure 13. *Concept cartoon about the correlation between atmospheric pressure and height*

Table 18. Results on students' conceptual understanding category about the correlation between atmospheric pressure and height

Answer	F	%
Understanding **(**Correct Answer + Correct Explanation**)**	4	11,11
Partial understanding **(**Correct Answer + Partially Correct Explanation**)**	14	38,88
Misconception **(**Correct Answer + Wrong Explanation**)**	3	8,33
Misconception **(**Wrong Answer + Correct explanation**)**	0	0
Not understanding **(**Wrong Answer + Wrong Explanation**)**	15	41,66

When Table 18 was examined, it was observed that 11.11% of the students selected the correct answer and provided accurate explanations. They correctly recognized that as one ascends, atmospheric pressure decreases, leading to nosebleeds due to the difference between internal and external pressures. For example, a student explained, "I'm thinking like Uğur. Since if the atmospheric pressure decreases, the force that balances the blood pressure in the veins also decreases, similar to what occurs when not wearing a space suit in space" (S33). Additionally, 38.88% of the students chose the correct answer, although their explanations were often incomplete or brief. An example of such an explanation is, "I'm thinking like Uğur, as you go up, the atmospheric pressure decreases" (S15). On the other hand, 41.66% of the students selected incorrect explanations in the concept cartoon, offering responses that did not align with the correct answer or failing to provide any explanation. An example of such an explanation is, "I'm thinking like Uğur because we've been working on this issue for months in the class" (S21). Furthermore, 8.33% of the students displayed misconceptions. They either chose the correct answer but provided a wrong explanation or chose the wrong answer but offered a correct explanation. For instance, "I'm thinking like Uğur. Since the pressure increases as you go up from sea level, this causes the nosebleeds" (S32).



The children in the image are discussing what will happen to the flying balloons if Nil and Ozan's balloon goes up high. Who do you think like? Explain with your reasons.

.... I think like. Because ....

Figure 14. *Concept cartoon about the effect of windy weather on atmospheric pressure*

Table 19. *Results on students' CUC related to the correlation between atmospheric pressure and wind*

Answer	**F**	**%**
Understanding **(**Correct Answer + Correct Explanation**)**	5	13,88
Partial understanding **(**Correct Answer + Partially Correct Explanation**)**	2	5,55
Misconception **(**Correct Answer + Wrong Explanation**)**	0	0
Misconception **(**Wrong Answer + Correct explanation**)**	7	19,44
Not understanding **(**Wrong Answer + Wrong Explanation**)**	22	61,11

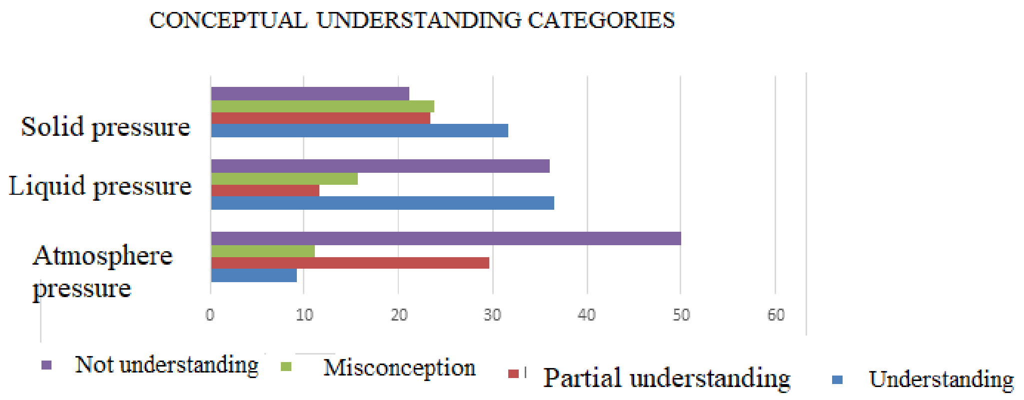
When Table 19 was examined, it was evident that 13.88% of the students selected the correct answer and provided accurate explanations. They correctly recognized that as one ascends, atmospheric pressure decreases, and there is no effect of the wind. For example, a student explained, “I'm thinking like Özge. As you go higher, the atmospheric pressure decreases, causing the volume of the balloons to increase. I don't believe windy weather will make any difference” (S33). Furthermore, 5.55% of the students chose the correct answer, although their explanations were often incomplete or brief. An example of such an explanation is, “I'm thinking like Özge. As you go higher, the atmospheric pressure decreases” (S14). Conversely, 61.11% of the students selected incorrect explanations in the concept cartoon, offering responses that did not align with the correct answer or failing to provide any explanation. An example of such an explanation is, “I'm thinking like Sinan. Since the place where the wind blows is hot, the pressure is higher at higher altitudes. Since the air is cold where the wind does not blow, the pressure is higher on the ground” (S11). Moreover, 19.44% of the students displayed misconceptions. They either chose the correct answer but provided a wrong explanation or chose the wrong answer but offered a correct explanation. For instance, “I'm thinking like Burcu. The pressure decreases at high altitudes” (S4)."

Table 20. *Results from students' misconceptions about atmospheric pressure*

Concept	**Misconception**	**Student**	**Frequency of explanation**
Atmospheric Pressure Height Correlation	Atmospheric pressure increases as you go high.	S9, S32, S6, S17, S20, S27, S4, S6	8
Correlation between atmospheric pressure and air movement	Wind increases the atmospheric pressure.	S37	1

It's important to note that atmospheric pressure generally decreases as altitude (height above sea level) increases. The primary reason atmospheric pressure decreases as altitude increases is that the weight and density of the atmosphere decrease with height. The layer of air closest to the Earth's surface supports the weight of the air layers above it. At sea level, there is a large amount of air above us, and this air mass is pulled downward by gravity, creating high pressure at sea level. As you ascend, the amount of air above you decrease, and consequently, the density of the air also decreases. Less dense air results in lower pressure. Thus, as altitude increases, the density of the atmosphere decreases, leading to a drop in atmospheric pressure. Gases in the atmosphere are more concentrated near the Earth's surface due to gravity. At higher altitudes, gas molecules spread out over a larger area, causing the density to decrease. With fewer molecules, there are fewer collisions, and thus, lower pressure. On the top of a mountain, the air is thinner and less dense, so atmospheric pressure is much lower than at sea level. This is one reason why mountaineers use oxygen tanks at high altitudes, as the decreasing pressure also reduces the amount of oxygen in the air.

However, it appears that some students had misconceptions about this concept. One common misconception was the belief that atmospheric pressure would increase as they ascended higher, which is not the case. This situation can be interpreted by students expressing this information intuitively, without understanding what effect the increase in altitude has on the air layer that causes atmospheric pressure. Another student had a misconception related to the correlation between atmospheric pressure and air movement, mistakenly thinking that the wind would increase atmospheric pressure, which is also not accurate. Some students think that windy air will exert pressure. These students may have thought that wind moves some objects as an effect of air pressure. At this point, it is important to ensure that students realize that still, windless air also exerts pressure. These findings highlight the need for further clarification and education on the topic of atmospheric pressure and its relationship with altitude and air movement. Students may have thought that the mobility of objects/living things is an indicator of the existence of atmospheric pressure. In order to explain to students that still air also exerts pressure, the pressure of the still air can be measured with a barometer and the students can observe it.



Graphic 1. *Students' CUC on the concepts of pressure exerted by solids, liquid pressure and atmospheric pressure*

4. Discussion

In this section, we meticulously analyze and discuss the research findings within the context of existing literature.

4..1. Discussion and conclusion of the results obtained from the pressure exerted by solids concept cartoons

When we analyze the results from the three concept cartoons related to pressure exerted by solids and surface area (refer to Tables 4, 6, and 7), it's evident that students exhibited fewer misconceptions, with a higher percentage falling into the 'understanding' categories. This could be attributed to the administration of concept cartoons after the students received instruction on the topic of pressure, indicating a better understanding of the relationship between pressure exerted by solids and surface area. This observation aligns with Baytok's findings, where students were presented with a similar scenario involving a chicken and a duck of the same weight sinking in the snow. The majority of students favored the duck due to its larger foot surface area.

Looking closer at misconceptions related to the correlation between pressure exerted by solids and surface area, it's clear that students commonly held certain misconceptions. These misconceptions included beliefs that 'pressure exerted by solids depends solely on surface area, a larger surface area leads to less sinking, pressure increases with surface area enlargement, and pressure decreases with surface area reduction.' These misconceptions highlight the challenges students face when trying to grasp and establish the relationship between pressure exerted by solids and surface area. These findings are consistent with previous research in the existing literature, where similar misconceptions have been documented (Benli-Ozdemir, 2021; Kaya et al., 2018; Şahin et al., 2012). For example, Benli-Ozdemir (2021) noted that students frequently hold the mistaken belief that the surface area of solid objects directly determines pressure. Akdemir (2005) also reported that students tend to associate pressure exerted by solids exclusively with surface area, revealing a gap in their understanding of the concept of pressure. Similarly, when examining misconceptions related to the correlation between pressure exerted by solids and weight, it's evident that students harbored misconceptions, including beliefs such as "pressure exerted by solids depends solely on weight, and pressure always increases as weight increases." These misconceptions shed light on the difficulties students face in comprehending and establishing the relationship between pressure exerted by solids and weight. Notably, these findings align with previous studies in the existing literature, including works by Benli-Ozdemir (2021), Kaya et al. (2018), and Şahin et al. (2012). For instance, Benli-Ozdemir (2021) observed that students frequently held misconceptions, such as the notion that pressure exerted by solids invariably increases with weight and that it is exclusively tied to weight. Moreover, when delving into misconceptions surrounding the relationship between solid pressure, force, and surface area, it's noticeable that the rates of student misconceptions and understanding categories are in close proximity, but the understanding rate is higher. This favorable outcome can be attributed to the utilization of concept cartoons after the students had received instruction on the topic of pressure, leading to an enhanced grasp of the connection between pressure exerted by solids, force, and surface area. In the context of these misconceptions, they encompassed students' difficulties in establishing the ratio between pressure exerted by solids, force, and surface area. These misconceptions underscore the challenges students faced in comprehending how pressure exerted by solids impacts the interplay between force and surface area and in making sense of this relationship. Similar misconceptions have been identified in previous studies, including those conducted by Baytok (2007), Kaya et al. (2018), Şahin et al. (2012), and Yaman (2016). Notably, Yaman (2016) revealed that students struggled to provide correct responses to questions related to pressure, force, and surface area. In order to eliminate these misconceptions, animations or analogies can be used to enable students to visualize the events taking place in the inner workings of experiments they observe with the naked eye at a microscopic level. Şahin et al., (2012) used animations and analogies to explain the pressure exerted by solids in his study.

4.2. Discussion and conclusion of the results obtained from the liquid pressure concept cartoons

When assessing the outcomes derived from the four concept cartoons related to the association between liquid pressure and depth (as shown in Tables 10, 11, 12, and 13), it's evident that students exhibited fewer misconceptions regarding this correlation, and the understanding category rate was remarkably high. This positive outcome may be credited to the implementation of concept cartoons following the students' instruction on pressure-related topics, suggesting an enhanced competence among students in comprehending the connection between liquid pressure and depth. Notably, prior research conducted by Baytok (2007) and Yaman (2016) similarly demonstrated students' success in correlating liquid pressure and depth in their respective studies on this subject. However, it was observed that some students confused the concepts of depth and height in questions about the relationship between liquid pressure and depth, and considered the distance of the object from the bottom of the liquid to the surface as depth.

Upon closer examination of misconceptions related to the correlation between liquid pressure and depth, it becomes evident that students held various misconceptions. These included beliefs such as 'liquid pressure depends on the amount of liquid, liquid pressure increases with an increase in surface area, liquid pressure increases with a decrease in surface area, and the change in the volume of a balloon submerged in a liquid is caused by atmospheric pressure.' These misconceptions indicate that students encountered challenges when trying to establish a connection between liquid pressure and depth, and they struggled to make sense of this relationship. Notably, similar misconceptions have been identified in previous research studies conducted by Akdemir (2005), Benli-Ozdemir (2021), Besson (2004), Kaya et al. (2018), Kariotoglou & Psillos (1999), Şahin et al. (2012), and Yaman (2016). For example, Akdemir (2005) found that students frequently associate liquid pressure with the quantity of liquid and mistakenly believe that pressure increases as the base area decreases, which is akin to the concept of pressure exerted by solids.

Analyzing the outcomes presented in Table 14, concerning the concept cartoon illustrating the relationship between liquid pressure and density, it's evident that students exhibited fewer misconceptions related to the liquid pressure-density correlation, with a higher rate of understanding. This favorable outcome can be attributed to the implementation of concept cartoons following the students' instruction on pressure-related subjects, suggesting that students developed a more proficient grasp of the connection between liquid pressure and density. However, in questions about liquid pressure and density, some students explained the liquid pressure with the depth of the liquid without paying attention to the density of the liquid.

Nevertheless, upon scrutinizing the misconceptions associated with the correlation between liquid pressure and Pascal's Principle (as presented in Table 15), it became evident that a significantly higher proportion of students fell into the misconception category compared to those in the understanding category. This suggests that students encountered challenges in comprehending the relationship between

Pascal's Principle and liquid pressure, even though they had received instruction on Pascal's Principle. Misconceptions related to the correlation between liquid pressure and Pascal's Principle encompassed beliefs such as 'In Pascal's Principle, if a force greater than the weight of the object is not applied, the object cannot be lifted,' and 'pressure is equal because density and height are equal in Pascal's Principle.' These misconceptions indicate that students struggled to establish an accurate connection between liquid pressure and Pascal's Principle, and they encountered difficulties in comprehending this relationship. Baytok (2007) also reported similar results, noting that students could define Pascal's Principle as a system that can lift heavy weights with a small force but had difficulty recalling the details of how the system functions.

To summarize, students demonstrated a better grasp of the correlation between liquid pressure and density. However, they encountered significant challenges when it came to connecting liquid pressure with Pascal's Principle, even after receiving instruction on the topic. These outcomes underscore the importance of implementing additional educational interventions to rectify these misconceptions and enhance students' understanding of these concepts.

4.3. Discussion and conclusion of the results obtained from the atmospheric pressure concept cartoons

When delving into the misconceptions related to the relationship between liquid pressure and depth, it becomes evident that students held misconceptions such as 'liquid pressure depends on the amount of liquid, liquid pressure increases with an increase in surface area, liquid pressure increases with a decrease in surface area, and the change in the volume of a balloon submerged in a liquid is caused by atmospheric pressure.' These misconceptions indicate that students faced challenges in establishing a connection between liquid pressure and depth and struggled to comprehend this relationship. Similar misconceptions have been identified in previous research studies (Akdemir, 2005; Benli-Ozdemir, 2021; Besson, 2004; Kaya et al., 2018; Kariotoglou & Psillos, 1999; Şahin et al., 2012; Yaman, 2016). For example, Akdemir (2005) discovered that students often link liquid pressure with the amount of liquid and hold the misconception that pressure increases as the base area decreases, which is similar to the concept of pressure exerted by solids.

Upon analyzing the results obtained from the concept cartoon related to the correlation between liquid pressure and density (refer to Table 14), it is evident that students had fewer misconceptions concerning the liquid pressure-density relationship, and the rate of understanding was notably higher. This could be attributed to the implementation of concept cartoons after students had received instruction on the topic of pressure. Additionally, it may indicate that students demonstrated a better grasp of the connection between liquid pressure and density. In the existing literature, Baytok (2007) and Yaman (2016) also reported that students were proficient in effectively correlating liquid pressure and density in their respective research studies on this subject. Nevertheless, when investigating the misconceptions related to the correlation between liquid pressure and Pascal's Principle (refer to Table 15), it became apparent that the percentage of students categorized under misconceptions was significantly higher compared to those falling into the understanding category. This suggests that students encountered challenges in comprehending the relationship between Pascal's Principle and liquid pressure, even though they had received instruction on Pascal's Principle. Misconceptions related to the correlation between liquid pressure and Pascal's Principle encompassed beliefs such as 'In Pascal's Principle, if a force greater than the weight of the object is not applied, the object cannot be lifted,' and 'pressure is equal because density and height are equal in Pascal's Principle.' These misconceptions indicate that students struggled to establish a correct connection between liquid pressure and Pascal's Principle and faced difficulties in grasping this relationship. Similar observations were made by Baytok (2007), who noted that students were able to define Pascal's Principle as a system that can lift heavy weights with a small force, but they struggled to remember how the system works.

In summary, students displayed a better understanding of the correlation between liquid pressure and density, but they encountered substantial challenges when it came to connecting liquid pressure with Pascal's Principle, even after receiving instruction on the topic. These findings underscore the necessity for additional educational interventions to rectify these misconceptions and enhance students' comprehension of these concepts.

This research is a situation determination where students' misconceptions about the subject of pressure are determined by concept cartoons. In another study, these concept cartoons can be used in the teaching process and students can be provided with learning by discussing, researching and questioning. Thus, the effect of concept cartoons in eliminating misconceptions about the subject of pressure can be revealed.

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Authors

Çiğdem ŞAHİN ÇAKIR, Giresun University, Giresun (Turkey). E-mail: cigdem.sahin@giresun.edu.tr

Atike SARI, Giresun University, Giresun (Turkey). E-mail: atikesari28@gmail.com

Acknowledgement

We would like to thank Kafkas University Dede Korkut Faculty of Education faculty member Assoc. Prof. Dr. Arzu Kirman Bilgin for her valuable contributions in the development of concept cartoons.