**Momentum: Physics Education Journal**
**6 (2), 2022, 199-213**

Available at: ejournal.unikama.ac.id/index.php/momentum

# Assessing college students' factual, conceptual, and procedural knowledge of newton's laws of motion

**Zerihun Anibo Cashata [a] *, Desta Gebeyehu Suyeam [b], Shemelise Assefa Alemu [c]**

Addis Ababa University. NBH1, 4killo King George VI St, Addis Ababa, Ethiopia

[a] zerihun.anibo@aau.edu.et; [b] dgebeyeh68@gmail.com; [c] shi.assefa@gmail.com

*Corresponding Author

*Received: 24 February 2022; Revised: 2 June 2022; Accepted: 8 June 2022*

**Abstract**: The study aims to assess the difficulties in factual knowledge, conceptual understanding, and procedural knowledge of physics pre-service teachers in Newton's laws of motion. The study was conducted in four colleges of teacher education found in the southern regions of Ethiopia .This study employed descriptive survey methods. For data collection, 14- Factual-Knowledge Test, 19- Conceptual understanding test and 3-open ended questionaries' were used. Descriptive statics such as means, standard deviations, percentages, and frequencies, and Minnesota Assessment of problem solving Rubric are used for written solution, where 136 students were involved in the quantitative part .Whereas 136 participants were consulted in the qualitative part of this study. The findings revealed the existence of a lack of conceptual understanding (61 percent), and also procedural knowledge among pre-service physics teachers, evidenced-based on their low performance in the dimension of categories or indicators using ,determining and understanding problems (56 percent), in writing laws and principles (61%), and in determining the correct answer to problems (59 percent). A plausible recommendation was given to solve such problems so that pre-service physics teachers possess adequate conceptual and procedural knowledge.

**Keywords**: conceptual- understanding, procedural- knowledge, Newton's law of motion.

**How to Cite:** Cashata, Z. A., Seyoum, D. G., & Alemu, S. A. (2022). Assessing students' factual, conceptual, and procedural knowledge of Newton's Laws of motion. *Momentum: Physics Education Journal*, *6*(2), 199-213. https://doi.org/10.21067/mpej.v6i2.6664

## Introduction

Education is a lifelong process in which all experiences, knowledge, and wisdom of human beings are acquired at different stages, which can be formal, informal, or incidental (Gupta et al., 2014) .In this fast-changing world, knowledge and the application of science are ever-expanding and are important in everyday life. Science is the major component that contributes to the level of prosperity, welfare, and security of a nation, and it serves as the foundation of technology and a key factor in economic growth (Watson et al., 2003).Hence, studies on students' understanding of science concepts have been an area of discussion for the last four decades and have eventually become one of the major fields of research in science education(Daud et al., 2015).

Physics is generally known as the fundamental science, as it studies the natural phenomena of the world around us (Poljak & Jakić, 2017). However, physics has become a very difficult subject, and it is a common occurrence for students to have some alternative conceptions and difficulties regarding the subject matter. Learning Physics is typically one of the causal factors to Physics being seen as difficult to grasp, as students struggle to comprehend the obscurity of the concepts covered in Physics, regardless of whether they are at high school or university level. As a result, students have a wide gap in their understanding of important topics such as Newton's laws, electricity, magnetism, and thermodynamics, wave, and optics (McDermott & Redish, 1999; National Educational

Assessment and Examinations Agency, 2017). The way physics is presented to students or the pedagogy is one of the contributing factors to Physics being considered difficult to understand because students fail to understand the structure of the concepts contained in Physics (B. O. Ogunleye, 2019).

The pedagogy being used has also affected physics not being applied in everyday life (Nordin & Ling, 2011) .Concerning college physics, the key concepts of classical mechanics are displacement, velocity, acceleration, mass, force, and momentum. It is used as a prerequisite for other topics in physics such as work, kinetic and potential energy, linear and angular momentum, gravitation, electrostatics, electromagnetism, rotation, and oscillation (Awrejcewicz, 2012a; Mahajan, 2020) . Through the understanding of Newton's laws of motion, college students can gain a full understanding of college mechanics, which is governed by Newton's laws of motion (Saglam-Arslan & Devecioglu, 2010) To ensure compliance with the new curriculum content and materials, the Ministry of Education (Tefera, 2018) is assessing all national examinations in collaboration with the National Educational Assessment and Examinations Agency (Yibrah, 2017) reported that the percent of students who scored below 50% in physics for both grade 12 and 10 was 92.6 percent for grade 12 and 95.4 percent for grade 10. According to the report, students' achievement in physics were very low, and the national learning assessment result of the certificate of competence exam in physics was below the standard of Ministry of Education's Ethiopian (Woldetsadik, 2013). In this regard, the status of physics education in. The physics situation in Ethiopia and other developing countries is becoming a source of debate and is rapidly deteriorating (Castillo, 2017) .

The overall physics achievement of pupils in grades 10 and 12 was 31%, which is lower than the Ethiopian ministries of educations pass mark of 50(Yibrah, 2017). The achievement of the physics topic domain in a particular course fell short of the pass mark, particularly the student's achievement in mechanics ,for grade 10 and 12 29% and 32.24 respectively, which is below the standards of Minster of Education of Ethiopia (National Educational Assessment and Examinations Agency, 2017). Also students in grades 10 and 12 have more difficulty with mechanics, electricity and magnetism, temperature and heat in physics, On the other hand students' achievement in physics across cognitive domain demonstrated that when we progress from lower level (factual knowledge) to higher level (conceptual understanding, procedural knowledge) in grades 10 and 12 is 27% ,31.45% respectively , their performance drops (NLA, 2017; Yibrah, 2017) .

According to the report, student achievement in physics is very low, and the national learning assessment result of the professional exam in physics is below the Ethiopian Ministry of Education's standard(Woldetsadik, 2013). In this regard, the status of physics education in Ethiopia and other developing countries is becoming a source of debate(Castillo, 2017; WAEC, 2011).

Similar trends were observed when Regional Education Bureaus (REBs) REB (2019) conducted a similar assessment regionally. The South Nation Nationalities and People Region (SNNPR) educational bureau administered the certificate of competence (COC) examination to pre-service college students from 2015 to 2018, and the results of the examination were disseminated at the college level . The results of all college-level subjects are included in this official report document. The result shows that the number of students who took the COC exam in 2015 and 2016 was 170 and 39, respectively, with 63 percent of 170 and 83 percent of 39 failing the exam. Furthermore, the number of pre-service teachers who took and failed the exam in 2017 and 2018 was 226, 302, and 83 percent of 226, and 58 percent of 302, respectively. There are some irregularities in this official report of the COC examination results, but it appears that the (REB, 2019) physics achievement of college students from 2015 to 2018 was unsatisfactory. Furthermore, research shows that the majority of college students complete their Newton's Law of Motion course with poor problem-solving skills, misunderstanding of concepts, and knowledge (Liu & Fang, 2016) resulting in low achievement.

Despite numerous studies on physics achievement, a number of issues related to students' poor performance persist (Eguabor & Adeleke, 2017; Liu & Fang, 2016). Some of the factors influencing the academic achievement of pre-service physics teachers in Newton's laws of motion are lack of prior knowledge, (van Riesen et al., 2018), rote memorization (Ahmed & Ahmad, 2017), lack of conceptual understanding, (Erfan & Ratu, 2018), a lack of higher-order thinking skills (Yuliati & Lestari, 2018) and a deficiency in problem-solving skills (Morphew et al., 2020) .

Prior knowledge refers to the knowledge that pupils bring to the classroom. Prior knowledge is defined as multidimensional knowledge that comprises factual knowledge, conceptual understanding, and procedural know (Utari et al., 2021) Prior knowledge has long been thought to be the most influential element in student learning and achievement (Thompson & Zamboanga, 2003) .Prior knowledge is critical for learning processes. According to A. Ogunleye et al. (2014) activating preservice physics teachers' prior knowledge and linking them to the personal world by displaying their worth beyond their undergraduate educational concepts can improve their grasp of Newton's laws of motion. Knowledge of previous students is potentially useful instructional tools, as is current students' motivation to learn (Wu et al., 2019).

It is also used in the designing of instructional materials and to determine the most effective teaching method (Binder et al., 2019; Esanu & Hatu, 2015). It promotes self–study by connecting new concepts to the learner's prior knowledge(Esanu & Hatu, 2015). Therefore, assessing pre-service physics teachers' past knowledge in terms of factual knowledge, conceptual understanding, and procedural knowledge supports in identifying the issues they face (Binder et al., 2019).A lot of research findings are required in order to improve academic performance. The poor performance of pre-service teachers in physics arose from a variety of sources, including their background, an overburdened curriculum, teaching strategies, and assessment methods. Hence, this study assesses the difficulties of pre-service physics teachers in factual knowledge, conceptual understanding, and procedural knowledge of physics in general and Newton’s law of motion in particular.

Empirical evidence suggests that Learning outcomes in science are poor in developing countries (International Bank for Reconstruction and Development, 2021; Lewin, 1992). And also physics education in both developing and developed countries is in a state of crisis (Apple, 2009; International Bank for Reconstruction and Development, 2021) .Newton's laws of motion are the cornerstone of mechanics. Other fields of physics require knowledge of mechanics as prerequisite (Awrejcewicz, 2012b; Mualem & Eylon, 2007; Urone et al., 2012). The Ministry of Education and the Research and Evaluation Board have agreed that education quality in general, and physics instruction in particular, are a severe concern in Ethiopia at all levels. According to NLA data, the average physics grade 10 and 12 score was 31%, with a large percentage of students scoring below 50%. The findings of this study imply that low physics achievement in Ethiopian compulsory education Little & Rolleston (2014) continues to be a problem in teacher education

Despite failing tests at both levels and strong evidence of low commitment for the teaching profession, Ethiopia's government has chosen to allow individuals into teacher education and thereafter into teaching jobs using low entrance profile considerations, which appear to work against the change's effectiveness in achieving the anticipated learning results (Alemu et al., 2019a). Methods of instruction are one of the most important factors.PSPT has weak problem-solving abilities and low achievement as a result of the lecture technique, which is a dominant teaching approach at the college level (Alemu et al., 2019; Dejene, 2019; Marmah, 2014) .Furthermore, students find mechanics difficult in comparison to other branches of physics. Students' average mechanics achievement in grades 10 and 12 was 28.99 percent and 32.24 percent, respectively, according NLA (National Educational Assessment and Examinations Agency, 2017) data, which is less than half of the national average (50 percent ). And also the Regional Bureaus of Education (RBE), competence levels for regionally set and administered tests for licensing college students have been declining from 2015 to 2018.The low achievement of secondary school pupils was reflected in poor physics performance on the entrance exam for pre-service physics teachers NLA (National Educational Assessment and Examinations Agency, 2017) they also struggle with Newton's laws of motion (REB, 2019),

The aim of this article is to figure out why college students face difficulty with Newton's laws of motion concepts and with the acquisition of procedural knowledge, so that solutions can be designed and tested to address the issues. The issues with Newton's laws of motion, which are part of a mechanics topic, are discussed. Researchers are attempting to understand pre-service physics teachers difficult in application of facts, concepts, and procedural knowledge of Newton's laws of motion, under the following contents such as inertia, mass, velocity, acceleration, force, type of force, friction, and gravity. The difficulties identified using the following dimensions such as, determining and identifying the problem from a word problem, free body diagram–interpretation, graphical representation (Erfan & Ratu, 2018; Khan et al., 2017; Long et al., 2018; National & Pillars, 2014; Pysmenetska & Peleshenko, 2017; Yuliati & Lestari, 2018). The specific objectives that were considered while identifying why college students face difficulty with Newton low of motion were (1) To assess difficulties in the factual knowledge of pre-service teachers of Newton's law of motion at a college of teachers' education; (2) To examine the level of conceptual understanding of pre-service teachers on Newton's law of motion using concept inventory test at college of teachers' education; and (3) Examine difficulties in the procedural knowledge of pre-service teachers of Newton's law of motion at the college of teachers' education.

## Methods

Therefore, mixed-method design combines were employed by combining both quantitative and qualitative research approaches (Azorín & Cameron, 2010; Creswell & Clark, 2017; Razali et al., 2019). In this work, a quasi-experimental design with a non-equivalent pretest-posttest was used to compare three treatment groups with one comparison group.The reason for this was that it was difficult to regulate all variables in the classroom's natural setting and all groups were not chosen at random.

**Table 1.** Quantitative research design

| | | | | |
|---|---|---|---|---|
| Treatment group 1 | N | $O_1$ | $X_1$ | $O_2$ |
| Treatment group 2 | N | $O_1$ | $X_2$ | $O_2$ |
| Treatment group 3 | N | $O_1$ | $X_3$ | $O_2$ |
| Comparison group | N | $O_1$ | | $O_2$ |

N represents the non-randomization of subjects to groups. $O_1$ represents the pretest; $O_2$ represents the posttest; $X_1$ represents the problem solving strategy with the lecture instructional approach; $X_2$ represents a jigsaw IV instructional approach; $X_3$ represents jigsaw –IV problem-solving strategy instructional approach

A descriptive survey research design was employed to examine the academic level of pre-service teachers' factual knowledge, procedural and conceptual understanding. A case study design was employed for the qualitative part. There are five colleges of teacher education in the SNNP region. The target group of this study was second-year physics pre-service teachers.

Three kinds of instruments were used for data collection. Such factual knowledge test, conceptual understanding test, and procedural knowledge test. Factual knowledge test, 14 multiple-choice items adapted from Force Concept Inventory Test (FCIT) (Hestenes et al., 1992) based on the objective of the lesson used to measure the factual knowledge of preservice physics teachers in Newton's laws of motion. Conceptual understanding test, 19 two-tier tests in which the first tier is used to measure the concepts about the Newtons laws of motion, second-tier explore the reason behind the concepts adapted from FCIT based on the objective of the lesson used to measure the conceptual understanding of preservice physics teachers in Newtons laws of motion. Procedural knowledge test ,three open ended problems has been adapted from FCIT based on the objective of the lesson of Newtons laws of motion.

A variable is defined as a characteristic of the participants or situation for a given study that has different values. A variable must be able to vary or have different values or levels. In quantitative research, variables are defined operationally and are commonly divided into independent variables, dependent variables, and extraneous variables. Accordingly, the independent variables in this study are factual knowledge, conceptual understanding, and procedural knowledge. Whereas the dependent variable considered in this study was academic achievement in Newton's laws of motion concept.

Reliability and validity are the two most important and fundamental features in the evaluation of any measurement instrument or tool for good research(Taherdoost, 2016). Validity concerns what an instrument measures and how well it does so. Reliability concerns the faith that one can have in the data obtained from the use of an instrument; that is, the degree to which any measuring tool controls for random error. The reliability of this research regarding the factual knowledge and conceptual knowledge was calculated by using Kuder Richardison-20 (KR-20) were 0.723 and 0.719. This showed that the internal consistencies of the questions are reliable. An attempt has been made here to address the reliability and validity concerns.

The quantitative data was analyzed using descriptive statistics such as means, standard deviations, percentages, and frequencies. For the qualitative data collection, the raw data obtained from written open-ended problem-solving solutions were rated using the Minnesota Assessment of Problem Solving Rubric based on dimensional categories set by them (Docktor et al., 2016) .The information was organized into various categories and turned into useful information for the reader.

### Consideration of ethical issues

Permission to conduct the study at the college was required beforehand from the education bureau of SNNPR and the dean of each college before data collection. At the commencement of the study, its essence and potential benefits, including its objectives, the roles of learners, and the teachers, were carefully explained to the participating students and teachers, respectively. Participating teachers and learners were assured of the anonymity and extent of confidentiality of the study results. To this end, codes were used for recording data from all the participants. An effort was made to lessen the possibility of the researcher's bias while marking and processing the data by showing it to colleagues during these activities.

## Results and Discussion

This section of the study was explained in three sections. First, factual knowledge diagnostic test results were explained. In the second part, the conceptual understanding diagnostic two-tier test results were explained and in the third part, procedural knowledge test results were presented in a table.

### First section: The results of factual knowledge diagnostic test

The average scores of preservice physics teachers (Table 2) were allowed to sit for the Factual Knowledge Diagnostic Test, which was administered to identify areas of preservice physics students' "factual knowledge of preservice physics teachers" related to Newton's laws of motion. An average score of 7.71 was obtained. The maximum score archived by preservice physics teachers was 12 and the minimum was 2. The average results of preservice physics teachers in factual knowledge are greater than the standard score of the Minster of Education of Ethiopia. But the mean score of the conceptual understanding test related to Newton’s laws of motion was 14.3, the maximum score was 23, and the minimum score was 6. The mean of conceptual understanding was below the standards of the minister of education of Ethiopia (National Educational Assessment and Examinations Agency, 2017; Tefera, 2018),

**Table 2.** Descriptive Statistics

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| F k .frequency | 136 | 2.00 | 12.00 | 7.7132 | 2.22080 |
| CU. Frequency | 136 | 6.00 | 23.00 | 14.2721 | 3.47790 |
| Valid N | 136 | | | | |

Table 3 showed the factual knowledge of the physics pre-service teachers in four colleges of teacher education about Newton's laws of motion. The data revealed that most of the questions regarding the factual knowledge of the pre-service teachers of Newton's laws of motion scored more than 55%.This supported by the research done by Bøe et al. (2018)

**Table 3.** Results on the factual knowledge of Newton's laws of motion

| Items | Incorrect | | Correct | |
|---|---|---|---|---|
| | Frequency | Percent | Frequency | Percent |
| Q1 | 40 | 29.4 | 96 | 70.4 |
| Q2 | 23 | 16.9 | 113 | 83.1 |
| Q3 | 61 | 44.9 | 75 | 55.1 |
| Q4 | 97 | 71.3 | 39 | 28.7 |
| Q5 | 106 | 77.9 | 30 | 22.1 |
| Q6 | 80 | 58.8 | 56 | 41.2 |
| Q7 | 37 | 27.2 | 99 | 72.8 |
| Q8 | 75 | 55.1 | 61 | 44.9 |
| Q9 | 14 | 10.3 | 122 | 89.7 |
| Q10 | 46 | 37.8 | 90 | 66.2 |
| Q11 | 70 | 51.5 | 66 | 48.5 |
| Q12 | 49 | 36.0 | 87 | 64.0 |
| Q13 | 131 | 96.3 | 5 | 3.7 |
| Q14 | 26 | 19.1 | 110 | 80.9 |
| Average | 61.07 | 45.18 | 74.93 | 55.09 |

The following questions

Q1. When you push someone and you both fall back, this law of motion illustrated by

A. Newton’s second law
B. Newton’s first law
C. Newton’s third law
D. none

Q3. Which of the following is not contact force?

A. Gravitational force
B. magnetic force
C. Frictional force
D. A and B

Q7. Which Newton’s laws state “If an object at rest, it remains at rest, if an object is moving with a constant velocity, it continues with constant velocity, unless a balanced force acts on it”?

A. Newton’s second law
B. Newton’s first law
C. Newton’s third law
D. None

Q9. What kind of a force that can keep the movement of something in a circle?

A. Gravitational force
B. Centripetal force
C. Magnetic force
D. None of the above

Q14. The SI unit of coefficient of friction is__

A. Newton
B. Watt
C. Meter
D. it has no unit

Table 3 showed the results of preservice physics teacher factual knowledge test. They above multiple choices are easily understandable by pre-service. Among these questions, Q9, and Q14, the correct response rates are 89.7%, and 80.9% respectively. This implies that pre-service easily understand the force moving in the circle, and the SI unit of friction. Furthermore, Q1, Q3, and Q7, are averagely understandable by pre-service physics teachers in the four colleges of teachers' education. These questions included the types of Newton's laws (70.4%), contact force (55.1%), definitions of Newton's laws of motion (72.8) respectively. This implies that factual knowledge of the above facts can be understandable if students are engaged in the learning teaching process.it align with the research done by Yılmaz and Yalçın (2012) revealed that the declarative or factual knowledge of learner in Newtons laws of motion is good.

Q4. The amount of force applied to a car‘s brakes makes it stop, which illustration of Newton’s law of motion is this?

A. Newton’s 3rd law
B. Newton’s 1st low
C. Low of inertia
D. Newton’s second law

Q5. Which of the following objects has more inertia?

A. Car
B. Truck
C. Cotton
D. Train

Q13. The resultant of Newton’s third law of motion is----

A. Double of applied force
B. Zero
C. We cannot add
D. None of the above

There was difficulty in identifying the factual knowledge with the pre-service teachers. Among these questions, Q13 was the most difficult fact (3.7%) that could not be easily understood by pre-service teachers at the college level. This implies that pre-service teachers have difficulty of understanding the resultant of Newton's third law of motion. The second and third most difficult facts were Q5 (22.1%) and Q4 (28.7%). This showed that pre-service didn't understand how to identify which given objects had more inertia and were unable to relate Newton's law of motion with real-world examples. Therefore, there was a problem with teaching or assessing these topics in pre-service teachers in all four colleges of teachers' education.it similar with the study done by Murti et al.,(2019) concluded that there was low student understanding and still many misconceptions on Newton's law of motion. Generally, the factual knowledge of physics pre-service teachers in the teachers' college of teachers' education in the South nation nationalities of the people regional states were good but needed some modification regarding the teaching approach and assessment strategies (Watson et al., 2003).

### Second section: conceptual understanding diagnostic two-tier test

136 preservice physics teacher (the categories and percentage of respective categories were summarized in Table 4 were allowed to sit for conceptual understanding diagnostic two-tier test, which was administered to identify area of preservice physics teachers level of conceptual understanding based on students responses, and those misconceptions commonly appeared in the literature, the results of open ended test were interpreted and grouped in to categories. In doing so, students‟ answers and answers of similar implications were grouped together and common central categories were formed. In such cases, categories Marked as Full understanding, Misconception and No-Understanding. Are explained in Table 4.

**Table 4.** Preservice physics teachers level of understanding of Newton’s laws motion

| Tier-one | Tier -two | Level of understanding | Code |
|---|---|---|---|
| Right | Right | Full understanding | 2 |
| Right | Wrong | Misconception | 1 |
| Wrong | Right | Misconception | 1 |
| Wrong | Wrong | No understanding | 0 |

**Table 5.** Result obtained from the conceptual understanding diagnostic two tier test of Newton's law of Motion

| Items | Level of understanding | | |
|---|---|---|---|
| | No understanding | Misconception | Full understanding |
| Q1 | 14(10.3)[1] | 15(11.0) | 107(78.7) |
| Q2 | 35(25.7) | 65(47.8) | 36(26.5) |
| Q3 | 31(22.8) | 49(36.0) | 56(41.2) |
| Q4 | 25(18.4) | 33(24.3) | 78(57.4) |
| Q5 | 44(32.4) | 44(32.4) | 48(35.3) |
| Q6 | 30(22.1) | 63(46.3) | 43(31.6) |
| Q7 | 28(20.6) | 29(21.3) | 79(58.1) |
| Q8 | 38(27.9) | 57(41.9) | 41(30.1) |
| Q9 | 26(19.1) | 68(50.0) | 42(30.9) |
| Q10 | 49(36.0) | 32(23.5) | 55(40.4) |
| Q11 | 45(33.1) | 42(30.9) | 49(36.0) |
| Q12 | 40(29.4) | 65(47.8) | 31(22.8) |
| Q13 | 34(25.0) | 35(25.7) | 67(49.3) |
| Q14 | 36(26,5) | 70(51.5) | 30(22.1) |
| Q15 | 34(25.0) | 46(33.8) | 56(41.2) |
| Q16 | 33(24.3) | 74(54.4) | 29(21.3) |
| Q17 | 44(32.4) | 36(26.5) | 56(41.2) |
| Q18 | 38(27.9) | 55(40.4) | 43(31.6) |
| Q19 | 32(23.5) | 60(44.1) | 44(32.4) |
| Av (%) | 25.4 | 36.3 | 38.3 |

[1] Percentages in parenthesis

The discussion of the results in Table 4 shows the number of students (with percentages in parenthesis) making right or wrong responses to the two tiers of multiple-choice items on Newton's laws of motion. Table 4 reveals that more than 61% of the pre-service teachers in this study were able to provide no understanding and have misconceptions in both tiers. This implies that pre-service physics teachers have less conceptual knowledge and ability to understand concepts related to questions about Newton's law of motion. This result was supported by the research done by Murti et al. (2019) confirmed that the students had low understanding and still many misconceptions on Newton's law 38.3% of the pre-service teachers have a full conceptual understanding of Newton's law of motion. This implies that pre-service physics teachers have problems with the conceptual understanding of questions that focus on Newton's law of motion. From the concepts of Newton's law of motion, physics pre-service teachers scored lower academic. This finding align with Saprudin et al. (2017) reveal that concept mastery of preservice physics teacher is very low.

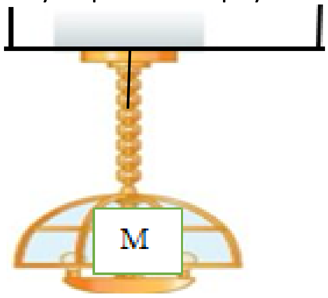


**Figure 1.** A body of lamp suspended by the cord

Q1. A cord from the ceiling, as shown above in Figure 1, suspended M = 10.5-kg lamp. The force exerted on the lamp by the cord is most nearly_ (g=10m/s)

A. Zero
B. 105N
C. 50N
D. 100N
Reason out, why you choice the answer_______________________________________

Q4. Let a ball be placed on an infinitely leveled and frictionless surface. In the meantime, the ball is received a momentary horizontal kick, which made it move along the arrow's direction as in Figure 2. Which of the following is true about the situation? F= force, V = velocity

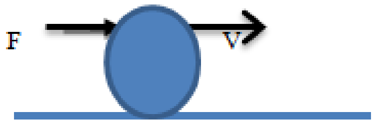


**Figure 2.** A rolling ball on a frictionless surface

A. The ball comes into rest in the specific condition
B. The force imparted to the ball during the kick
C. It change the state of the ball made it move
D. Both C and B
Reason out, why you choice the answer_____________________________

Q7 Taking two identical boxes, one placed on the surface of the earth and the other is on the moon. The force required to lift the box in either place is------
A. Less on the surface of the earth,
B. Less on the surface of the moon,
C. The same in both place,
D. Large on the surface of the moon
Reason out, why you choice the answer____________________________________

The medium achievements of the pre-service teachers in Q1, Q4, and Q7 were due to the pictorial representation of Q1 and Q4 about the force exerted on the block and the rolling of the ball on the frictionless surface, whereas, for Q7, the use of easier distractors in the choice of the concept of exerting force. Even though the academic achievement of students in Newton's laws of motion is at a satisfactory level, it still needs improvement in the conceptual understanding of physics pre-service teachers in the colleges of teachers' education. This is supported by a number of studies showing that many students usually experience difficulty when conceptualizing abstract concepts Newtons laws of motion (Galili & Hazan, 2000; Horn et al., 2002; Suprapto et al., 2016). And also regarding the lower academic performances of the physics pre-service teachers on the conceptual understanding of Newton's laws of motion needs the best way of teaching strategies, assessment strategies, and relating the concepts to the real lives of the learners (Bøe et al., 2018).

Q12. Zapaw lifts a brick, which weights 'A' with constant velocity to a certain height. The force exerted on the brick is
A. Constant, but equal to zero
B. Constant, but equal to 'A'
C. Constant, but less than 'A'
D. Constant, but greater than 'A'
Reason out, why you choice the answer_______________

Q14. The block is shown moves with constant velocity on a horizontal surface. Two forces act on it as shown in Figure 3. A frictional force exerted by the surface is the only other horizontal force on the block. The frictional force is:

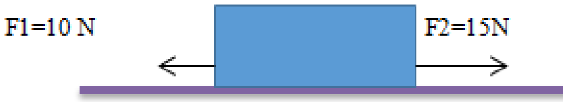


**Figure 3.** Two forces act in opposite direction

A. 5 N, leftward
B. 5 N, rightward
C. Slightly more than 5 N, leftward
D. Slightly less than 5 N, leftward
Reason out, why you choice the answer ______________________________

Q16. Different masses of objects rest on a level frictionless surface. The force required to set in motion --
A. Increases as the mass increases
B. is the same for all objects
C. Increases as the mass decreases
D. is equal to the respective weight of the object.
Reason out, why you choice the answer__________

The conceptual understanding of preservice physics teachers regarding questions related to Q12 (22.8%), Q14 (22.1%), and Q16 (21.3%) were the most difficult concepts that were not easily understandable for the learners. This revealed that the relationship between exerted force and (weight, constant velocity, and height), was unable to relate to frictional force and applied force and the masses of different objects to the applied forces respectively. Generally, there were problems with the conceptual understanding of physics pre-service teachers about the concepts of Newton's laws of motion regarding the questions prepared for this study. The college and the instructors found immediate solutions to this investigated low academic performance in the concepts of Newton's law of motion by proposing the best instructional strategies and assessment strategies as well. The result of this study was in agreement with the study done by Akcanca and Özsevgeç (2020) and Lillian et al (McDermott & Redish, 1999) which explained the learning methods employed have a direct correlation to the difficulties pupils have in grasping ideas. Students' conceptual challenges seem to be beyond the reach of traditional learning approaches. Through the utilization of challenges in diverse situations, this basic issue must be addressed specifically.

### The third section, Results obtained from procedural knowledge test of open ended questions of Newton's laws of motion

The third set of procedural knowledge questions tested students' science process skills. This section also measured how students conducted activities to solve the problems. From the analysis of questions, the procedural knowledge level of students was determined by taking into account the average percentage of students who responded correctly to the questions based on rubric or dimension of categories See Table 5 and Table 6.

Q1. Two boxes of the same shape are placed on a frictionless leveled surface as depicted in fig 4 below where. But mass 'B' = 40kg and mass 'A'=25kg .A man applied force of 500N is applied to move them with constant velocity.

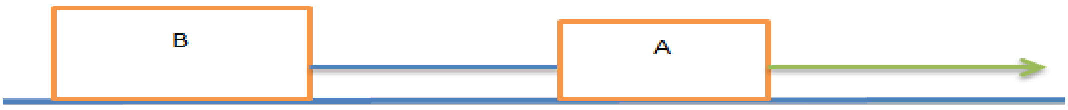


**Figure 4.** Two boxes are moving with constant velocity.

Depending on the Figure 4 answer the following question respectively. Is there any force acting on block "A" and "B" ? If your answer is "a" is yes, Calculate the force's exerted on each block, the direction, and the magnitude of acceleration.

**Table 5.** Is showing the Results obtained from procedural knowledge test open ended question of Newton's laws of motion Q 1

| Item | Dimension of category | Criteria for evaluation of Procedural knowledge | | | |
|---|---|---|---|---|---|
| | | N | Poor (Av) | Acceptable(Av) | Well done (AV) |
| Q1, | Determining and understanding of the problem | 136 | 56% | 13% | 31% |
| | Writing important laws and principles | 136 | 61% | 6.7% | 32.3% |
| | Correctness of the solution | 136 | 59% | 21% | 20% |

Q2. The system of two blocks of masses of M1=4kg and M2= 5 kg are connected by an ideal massless string on a massless pulley as shown in Figure 5. If the coefficient of friction between the table and mass one (M1) IS 0.6. Find the tension and acceleration of the system.

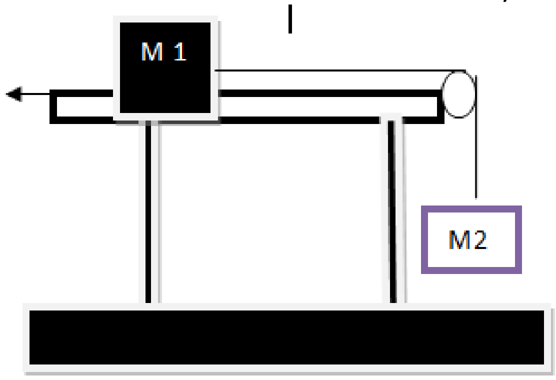


**Figure 5.** Two blocks are connected by an ideal massless string on the table.

**Table 6.** Results obtained from procedural knowledge test open ended question of Newton's laws of motion (Q2)

| Item | Dimension of category (indicator of procedural knowledge ) | Criteria for evaluation of Procedural knowledge | | | |
|---|---|---|---|---|---|
| | | N | Poor (Av) | Acceptable(Av) | Well done (AV) |
| Q2, | Determining and understanding of the problem | 136 | 60% | 13% | 27% |
| | Writing important laws and principles | 136 | 70 % | 6.7% | 23.3% |
| | Correctness of the solution | 136 | 55% | 22% | 23% |

The discussion on results obtained from procedural knowledge test open ended question of Newton's laws of motion Q1 in Table 5 showed that the procedural knowledge of physics pre-service teachers characterized based on the standard rubrics and rated by percentage of average of two raters Q1 based on dimension of categories.

This revealed that physics pre-service teachers in the college of teachers' education leveled as poor performance in the dimensions of categories unable to determine and understand the given problems (56%), unable to write important laws and principles (61%), and correctness of the solution for the problem (59%). This indicated that physics pre-service on the course of Newton's laws of motion had a lack of procedural knowledge. As we compared the poor achievement of the pre-service teachers with the accepted and well-done achievement it was a large difference. 44% of the pre-service teachers labeled as acceptable and well done determining the concepts of Newton's laws of motion by identifying the given problems and 39% of the pre-service are good in writing important laws and principles and 41% of them were accepted and well done. This was in line with the study done by Saglam-arslan and Devecioglu (2021) have significant weaknesses in understanding of procedural knowledge of Newton's Laws of Motion.

From this, the researcher concluded that there were problems of students in learning Newton's laws of motion which may emerge from teaching strategies, backgrounds of the learners, the bulkiness of the curriculum material and assessment strategies, etc.. Thus, to overcome these problems in learning Newton's laws of motion the vital responsibility was on the shoulders of teachers, curriculum designers, and the college administrative bodies. To come to the target issues on the poor performance of pre-service teachers revising the instructional approaches and visualizing the concepts were mandatory and make pre-service teachers engaged in the teaching learning process. This was in line with the study done by Schiller (2002) and Sornkhatha & Srisawasdi (2013) that states visual learning is one way of training students' knowledge of physics ideas in the material of Newton's law (Yılmaz & Yalçın, 2012).As a result, it has become increasingly necessary for students to acquire physics information in a visual format. The following conclusions were made from the results and discussions obtained from this research.

## Conclusion

Pre-service physics instructors were adept at acquiring factual knowledge of physics issues pertaining to Newton's law of motion. This indicated that the mean score of factual knowledge was 55.1 percent, which was higher than the Ethiopian standard cutoff limit. Even if the factual knowledge score was higher than the passing threshold, there was a need to design teaching strategies to improve students' understanding of Newton's law of motion concepts. In terms of physics pre-service teachers' conceptual understanding of Newton's law of motion, just 38.3 percent had a full conceptual understanding. However, 25.4 percent of physics pre-service teachers had misconceptions, and 36 percent had no conceptual understanding of Newton's rule of motion. This found that around 61 percent of physics pre-service teachers lack conceptual understanding of Newton's law of motion. Learning about Newton's law was difficult in procedural knowledge for pre-service teachers, as evidenced based on their low performance in dimension of categories or indicator using determining and understanding problems (56 percent), in writing laws and principles (61%), and in determining the correct answer to problems (59 percent). Students' procedural understanding of Newton's law of motion was found to be lacking. Researchers found that pre-service teachers were extremely had poor performance in studying Newton's law of motion, possibly due to a lack of learning strategies and an inability to connect physics concepts with real-world situations.

### Recommendations and further implications

To enhance the learning of Newton's law of motion, physics teachers should use interactive teaching techniques, including problem-based learning, problem-solving strategies, and jigsaw-4 teaching strategies. Teachers' overburdening themselves with physics subjects and a lack of adequate teaching techniques led to difficulties with conceptual understanding and procedural knowledge. Therefore, curriculum specialists should have designed concepts based on the learning standards of the learner at the college of teacher education to address these deficiencies. Instructors should plan based on prior knowledge of pre-service physics teachers to understand Newton's law of motion, as well as link these concepts to learners' everyday lives using active learning method.

## References

Ahmed, A., & Ahmad, N. (2017). Comparative Analysis of Rote Learning on High and Low Achievers in Graduate and Undergraduate Programs. *Journal of Education and Educational Development, 4*(1), 111-129. http://jmsnew.iobmresearch.com/index.php/joeed/article/view/189

Akcanca, N., & Cerrah Özsevgeç, L. (2020). Effect on academic achievement and misconceptions of pre-service teachers through combining different teaching methods in a preschool science course. *Journal of Science Learning*, *4*(1), 41–49. https://doi.org/10.17509/jsl.v4i1.24672

Alemu, M., Tadesse, M., Michael, K., & Atnafu, M. (2019). Pre-service physics teachers' physics understanding and upper primary teacher education in Ethiopia. *Bulgarian Journal of Science & Education Policy*, *13*(2), 204–224. http://bjsep.org/getfile.php?id=294

Apple, M. W. (2009). *Global crises, social justice, and education*. Routledge.

Awrejcewicz, J. (2012a). *Classical mechanics: kinematics and statics*. Springer.

Awrejcewicz, J. (2012b). Fundamental principles of mechanics. In *Classical mechanics. Advances in mechanics and mathematics* (Vol. 28, pp. 1–22). Springer. https://doi.org/10.1007/978-1-4614-3791-8_1

Azorín, J. M., & Cameron, R. (2010). The application of mixed methods in organisational research: A literature review. *Electronic Journal of Business Research Methods*, *8*(2), 95–105.

Binder, T., Sandmann, A., Sures, B., Friege, G., Theyssen, H., & Schmiemann, P. (2019). Assessing prior knowledge types as predictors of academic achievement in the introductory phase of biology and physics study programmes using logistic regression. *International Journal of STEM Education*, *6*(1), 33. https://doi.org/10.1186/s40594-019-0189-9

Bøe, M. V., Henriksen, E. K., & Angell, C. (2018). Actual versus implied physics students: How students from traditional physics classrooms related to an innovative approach to quantum physics. *Science Education*, *102*(4), 649–667. https://doi.org/10.1002/sce.21339

Castillo, J. (2017). *Submission of dissertation/thesis for examination*.

Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research*. Sage Publications.

Daud, N. S. N., Karim, M. M. A., Hassan, S. W. N. W., & Rahman, N. A. (2015). Misconception and difficulties in introductory physics among high school and university students : an overview in mechanics. *EDUCATUM Journal Of Science, Mathematics And Technology (EJSMT)*, *2*(1), 0. https://ejournal.upsi.edu.my/index.php/EJSMT/article/view/26

Dejene, W. (2019). The practice of modularized curriculum in higher education institution: Active learning and continuous assessment in focus. *Cogent Education*, *6*(1), Research Articl. https://doi.org/10.1080/2331186X.2019.1611052

Docktor, J. L., Dornfeld, J., Frodermann, E., Heller, K., Hsu, L., Jackson, K. A., Mason, A., Ryan, Q. X., & Yang, J. (2016). Assessing student written problem solutions: A problem-solving rubric with application to introductory physics. *Physical Review Physics Education Research*, *12*(1), 010130. https://doi.org/10.1103/PhysRevPhysEducRes.12.010130

Eguabor, B., & Adeleke, A. M. (2017). Investigating differential learning outcomes of students in physics using animation and textual information teaching strategies in ondo state secondary school. *European Journal of Sustainable Development Research*, *1*(2), 1–7. https://doi.org/10.20897/ejosdr.201710

Erfan, M., & Ratu, T. (2018). Analysis of student difficulties in understanding the concept of newton's law of motion. *JIPF (Jurnal Ilmu Pendidikan Fisika)*, *3*(1), 1. https://doi.org/10.26737/jipf.v3i1.161

Esanu, A., & Hatu, C. (2015). The significance of prior knowledge in physics learning. *The International Scientific Conference ELearning and Software for Education*, *3*, 477. https://doi.org/10.12753/2066-026X-15-00

Galili, I., & Hazan, A. (2000). Learners' knowledge in optics: interpretation, structure and analysis. *International Journal of Science Education*, *22*(1), 57–88. https://doi.org/10.1080/095006900290000

Gupta, N. K., Banerjee, K., Uppal, S., Ganguly, M. J. G., & Srivastava, S. (2014). *Basics in education, National council of educational research and training.* Sri Aurobindo Marg.

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The Physics Teacher*, *30*(3), 141–158. https://doi.org/10.1119/1.2343497

Horn, M. E., Leisner, A., & Mikelskis, H. F. (2002). German Physical Society Difficulties of model construction in optics (probleme der modellbildung in der optik) Conference Leipzig 2002. *German Physical Society*. https://doi.org/10.48550/arXiv.physics/0402080

International Bank for Reconstruction and Development. (2021). *The state of the global education crisis: A path to recovery*. The International Bank for Reconstruction and Development / The World Bank, UNESCO and UNICEF.

Khan, A., Ahmad, F. H., & Malik, M. M. (2017). Use of digital game based learning and gamification in secondary school science: The effect on student engagement, learning and gender difference. *Education and Information Technologies*, *22*(6), 2767–2804. https://doi.org/10.1007/s10639-017-9622-1

Lewin, K. M. (1992). *Science education in developing countries : issues and perspectives for planners The development of human resources: the provision of science education in secondary schools International Institute for Educational Planning*. International Institute for Educational Planning. https://unesdoc.unesco.org/ark:/48223/pf0000092308/PDF/92308eng.pdf.multi

Little, A. W., & Rolleston, C. (2014). School quality counts: Evidence from developing countries. Editorial. *Oxford Review of Education*, *40*(1), 1–9. https://doi.org/10.1080/03054985.2013.874799

Liu, G., & Fang, N. (2016). Student misconceptions about force and acceleration in physics and engineering mechanics education. *International Journal of Engineering Education*, *32*(1), 19–29. https://dialnet.unirioja.es/servlet/articulo?codigo=6902012

Long, D. N., Hobbs, L., & Devenish, S. (2018). Rote learning: the ugly duckling of student paramedic education? *Irish Journal of Paramedicine*, *3*(2), 3–5. https://doi.org/10.32378/ijp.v3i2.97

Mahajan, S. (2020). *A student's guide to Newton's Laws of motion*. Cambridge University Press.

Marmah, A. A. (2014). Students' perception about the lecture as a method of teaching in tertiary institutions. Views of students from college of technology eduction, kumasi (Coltek). *International Journal of Education and Research*, *2*(6), 601–612. http://www.ijern.com/journal/June-2014/50.pdf

McDermott, L. C., & Redish, E. F. (1999). Resource letter: PER-1: Physics education research. *American Journal of Physics*, *67*(9), 755–767. https://doi.org/10.1119/1.19122

Morphew, J. W., Gladding, G. E., & Mestre, J. P. (2020). Effect of presentation style and problem-solving attempts on metacognition and learning from solution videos. *Phys. Rev. Phys. Educ. Res.*, *16*(1), 10104. https://doi.org/10.1103/PhysRevPhysEducRes.16.010104

Mualem, R., & Eylon, B.-S. (2007). "Physics with a smile"—Explaining phenomena with a qualitative problem-solving strategy. *The Physics Teacher*, *45*(3), 158–163. https://doi.org/10.1119/1.2709674

Murti, P. R., Aminah, N. S., & Harjana. (2019). The identification of high school students' knowledge of newton's law of science literacy using a test based on nature of science (NOS). *Journal of Physics: Conference Series*, *1153*(1), 012122. https://doi.org/10.1088/1742-6596/1153/1/012122

National Educational Assessment and Examinations Agency. (2017). *Second national learning assessment on grades 10 and 12 students*. National Educational Assessment and Examinations Agency Educational Assessment Directorate.

National, G., & Pillars, H. (2014). *No 主観的健康感を中心とした在宅高齢者における健康関連指標に関する共分散構造分析Title* (pp. 1–90).

Nordin, A., & Ling, L. H. (2011). Hubungan sikap terhadap mata pelajaran sains dengan penguasaan konsep asas sains pelajar tingkatan dua. *Journal of Science & Mathematics Educational*, *2*(June), 89–101.

Ogunleye, A., Awofala, A. O. A., & Adekoya, E. A. (2014). Effect of students' background knowledge of mathematics on senior secondary school students' achievement in physics. *Chemistry: Bulgarian Journal of Science Education*, *23*(6), 863–880.

Ogunleye, B. O. (2019). Effects of concrete-representational-abstract instructional strategy on chemistry performance of students with mathematics learning difficulties in Ogun State …. *Kampala International University Journal of Education*, *14*(2), 135–151.

Poljak, D., & Jakić, M. (2017). A note on the character of physical models representing natural phenomena. *International Journal of Design & Nature and Ecodynamics*, *12*(2), 254–263. https://doi.org/10.2495/DNE-V12-N2-254-263

Pysmenetska, I., & Peleshenko, G. (2017). When meaningful and rote learning butt heads or an old threat of "test tyranny" in a new reality of Ukrainian medical education-. In *Book of abstracts of conference "New horizons in Biochemistry & Molecular biology education"* (pp. 20–30). Weizmann Institute of science.

Razali, F. M., Aziz, N. A. A., Rasli, R. M., Zulkefly, N. F., & Salim, S. A. (2019). Using convergent parallel design mixed method to assess the usage of multi-touch hand gestures towards fine motor skills among pre-school children. *International Journal of Academic Research in Business and Social Sciences*, *9*(14), 153–166. https://doi.org/10.6007/IJARBSS/v9-i14/7023

REB. (2019). *Report of regional education beaur*.

Saglam-arslan, A., & Devecioglu, Y. (2021). *Student teachers ' levels of understanding and model of understanding about Newton ' s laws of motion*. *June 2014*, 20–21.

Saglam-Arslan, A., & Devecioglu, Y. (2010). Student teachers' levels of understanding and model of understanding about Newton's laws of motion. *Asia-Pacific Forum Sci. Learn. Teach.*, *11*(1), 1–20.

Saprudin, S., Liliasari, L., & Prihatmanto, A. S. (2017). Pre-service physics teachers' concept mastery and the challenges of game development on physics learning. *Journal of Physics: Conference Series*, *895*(1), 012109. https://doi.org/10.1088/1742-6596/895/1/012109

Schiller, S. Z. (2002). Practicing learner-centered teaching: pedagogical design and assessment of a second life project. *Journal of Information Systems Education*, *20*(3), 369–382.

Sornkhatha, P., & Srisawasdi, N. (2013). Supporting conceptual development in newton's laws of motion using an interactive computer-simulated laboratory environment. *Procedia - Social and Behavioral Sciences*, *93*, 2010–2014. https://doi.org/10.1016/j.sbspro.2013.10.157

Suprapto, N., Syahrul, D. A., Agustihana, S., Pertiwi, C. A., & Ku, C. H. (2016). College students' conceptions of Newtonian mechanics: A case of Surabaya State University Indonesia. *Chemistry (Easton).*, *25*(5), 718–731.

Taherdoost, H. (2016). Validity and reliability of the research instrument; How to test the validation of a questionnaire/survey in a research. *International Journal of Academic Research in Management (IJARM)*, *5*(3), 28–36.

Tefera, B. (2018). Early Childhood Care and Education (ECCE) in Ethiopia: Developments, research, and implications. *Eastern Africa Social Science Research Review*, *34*(1), 171–206. https://doi.org/10.1353/eas.2018.0005

Thompson, R. A., & Zamboanga, B. L. (2003). Prior knowledge and its relevance to student achievement in introduction to psychology. *Teaching of Psychology*, *30*(2), 96–101. https://doi.org/10.1207/S15328023TOP3002_02

Urone, P. P., Hinrichs, R., & Dirks, K. (2012). *College physics*. OpenStax.

Utari, K., Mulyaningsih, N. N., Astuti, I. A. D., Bhakti, Y. B., & Zulherman, Z. (2021). Physics calculator application with matlab as a learning media to thermodynamics concept. *Momentum: Physics Education Journal*, 101–110. https://doi.org/10.21067/mpej.v5i2.5133

van Riesen, S. A. N., Gijlers, H., Anjewierden, A., & de Jong, T. (2018). The influence of prior knowledge on experiment design guidance in a science inquiry context. *International Journal of Science Education*, *40*(11), 1327–1344. https://doi.org/10.1080/09500693.2018.1477263

WAEC. (2011). *. Chief Examiners Reports of West African Examination Council on the Performance of Candidates in Science and Mathematics*.

Watson, R., Crawford, M., & Farley, S. (2003). *Strategic approaches to science and technology in development*. https://ssrn.com/abstract=636388

Woldetsadik, G. (2013). *National learning assessment in Ethiopia: Sharing experiences and lessons*. HD Learning Week. AFTEE, The World Bank.

Wu, Y.-C. J., Wu, T., & Li, Y. (2019). Impact of using classroom response systems on students' entrepreneurship learning experience. *Computers in Human Behavior*, *92*, 634–645. https://doi.org/10.1016/j.chb.2017.08.013

Yibrah, M. (2017). Assessing content validity of the EGSEC English examinations. *International Journal of Innovations in TESOL and Applied Linguistics*, *3*(1).

Yılmaz, İ., & Yalçın, N. (2012). The relationship of procedural and declarative knowledge of science teacher candidates in Newton's laws of motion to understanding. *American International Journal of Contemporary Research*, *2*(3), 50–56.

Yuliati, S. R., & Lestari, I. (2018). Higher-order thinking skills (HOTS) analysis of students in solving hots question in higher education. *Perspektif Ilmu Pendidikan*, *32*(2), 181–188. https://doi.org/10.21009/PIP.322.10