25 (1), 2024, 87-102
Jurnal Pendidikan MIPA
e-ISSN: 2685-5488 | p-ISSN: 1411-2531
http://jurnal.fkip.unila.ac.id/index.php/jpmipa/

Misconceptions of Physics Students On The Concept of Equilibrium of Rigid Bodies: A Case Study of Keku Culture

John Rafafy Batlolona[1*], Jamaludin[1], Ashari Bayu P. Dulhasyim[1] & Stevi Silahooy[2]
[1]Department of Physics Education, Pattimura University, Indonesia
[2]Petroleum Engineering Study Program, Pattimura University, Indonesia

Abstract: Physics scientists have paid serious attention to student misconceptions at various levels of education. The results show that learners have different ideas, which need to be more accurate about what is accepted in a scientific context. Student misconceptions in physics education have been assessed to date through various tests and found to be high. One less explored topic in physics teaching is the equilibrium of rigid bodies. Students consider this to be one of the most complicated topics. Therefore, this research used a test to measure students' misconceptions. This study aimed to determine the extent of student's misconceptions about the concept of equilibrium of rigid bodies in the case of Keku culture. This research is ethnographic research using a survey technique. One hundred prospective physics teachers participated in this study. Findings in the field showed that students experienced high misconceptions. It is because teachers at the lower level do not accustom students to learn from natural phenomena around them related to cultural concepts, and they are given scientific questions to search for and provide answers and solutions related to these natural phenomena. Teachers explore more conditions and physics problems in textbooks and less explore contextual things. Future researchers are advised that teacher teaching must be improved by developing physics teaching using appropriate strategies that can encourage students' understanding of concepts to reduce student misconceptions so that they impact students' academic performance.

Keywords: concept understanding, misconceptions, ethnophysics, object equilibrium, keku.

▪ INTRODUCTION

Research in physics education has published findings on student misconceptions covering almost every physics topic (Hull et al., 2021). Students need help solving physics problems to understand basic concepts, formulas, and principles (Balta & Asikainen, 2019). Today's fast-moving global world demands graduates who can think critically, solve real-world problems, communicate effectively, and work ethically and fairly in multidisciplinary collaboration (Seniuk Cicek et al., 2019). It is common knowledge that most countries experience unimpressive physics learning among students. The main common reason to explain this fact is that students usually find physics uninteresting and challenging, and as a result, they lose interest in it (Martín-Blas et al., 2010). Mathematics is considered the backbone of physics and is an essential element in the teaching of physics, as it provides a language for the concise expression and application of physical laws and relationships. The fusion of math and physics may be exciting for scientists, but the same cannot be said for most students. There often needs to be more clarity in the mathematical relationships used in physics. It is considered one of the most prominent factors that discourage students from choosing this subject for further study, as well as a barrier to teaching physics (Eriksson et al., 2022). Physics teachers are often surprised by their students' poor use of mathematics in class, even though they may have performed exceptionally well in math class (Meli et al., 2016). Higher education has been tasked with providing students with the educational

John Rafafy Batlolona
*Email: john.batlolona@lecturer.unpatti.ac.id
DOI: http://dx.doi.org/10.23960/jpmipa/v25i1.pp87-102
Received: 05 June 2024
Accepted: 02 July 2024
Published: 19 July 2024

opportunities to obtain the outcomes necessary to succeed in this challenging and fast-paced world. However, pedagogical practices have only sometimes been able to deliver. In recent years, higher education institutions have sought to equip students with both hard skills, which are cognitive and professional, and soft skills, such as problem-solving and teamwork (Vogler et al., 2018). However, the goals related to these skills are not easy to achieve because traditional learning still dominates the role where the teacher is the "dispenser of knowledge." At the same time, the students play the role of "receiver of information" (Rossi et al., 2021). The gap between learning outcomes and teaching practices is receiving increasing attention in higher education research (Guo et al., 2020). Higher education institutions have played a key role in developing a skillful academic environment to nurture the younger generation with advanced technology. Saudi Arabia and Malaysia are two examples among many other countries that have implemented modern technology systems in the education sector and rank very high among the list of most developed countries. Zimbabwe and Sri Lanka are two examples of countries that are far behind in terms of modernization in the education sector (Alharbi, 2023). This situation is similar to Indonesia, which still needs to catch up on the quality of education (Lumban Gaol, 2023).

The existence of physics education in higher education is one clear and direct way that the discipline of physics can impact the teaching and learning of physics. It can be seen that physicists in Sweden who are serious about teaching physics to trainee teachers talk about physics teacher education (Larsson et al., 2021). Physics education produces professional prospective teachers and trains prospective physics teachers who are strong in physics concepts correctly. It is related to the severe problem of students' low understanding of physics concepts. In the current Swedish physics curriculum, physics teaching should provide students with opportunities to develop their knowledge of physics, how physics is used to solve problems, its significance for individuals and society, and the ability to use physics to communicate and evaluate information. Therefore, the content focus of school physics is different from the focus of university physics courses, and there is an argument that this is one of the reasons that the transition from university physics to school physics is (Kokkonen et al., 2022) only sometimes straightforward (Kokkonen et al., 2022). A review of well-functioning physics teacher programs in the US found two critical success factors: local support for physics teacher education programs and commitment to physics teacher education from physics departments. It was also suggested that physics departments must be responsible for recruiting more highly skilled students to become professional future teachers.

One of the hallmarks of improving education and learning is a focus on the learner. It includes uncovering how students think at a deeper, more detailed level, how their thinking evolves, and comparing it with experts (Newcomer & Steif, 2008; Wartono, Hudha, et al., 2018). They do not get high exam scores despite trying their best. Misconceptions and lack of understanding of the basic concepts of Physics cause this phenomenon. Such misconceptions are too strong to overcome and can hinder the learning process. Teachers should identify students' misconceptions before conducting formal teaching so that their misconceptions can be changed into scientific concepts after the teaching and learning process (Halim et al., 2014; Wartono et al., 2018). However, the role of qualified physics teachers has been realized, as in many countries, for example, Pakistan, Australia, New Zealand, the United States, the United Kingdom, and even

Malaysia, face the problem of lack of trained science teachers, especially in teaching physics, chemistry, and mathematics. As a result, teachers who need to be trained to teach science subjects play an essential role in teaching science (Osman et al., 2006). The results of a study in Thailand indicated that of the five subjects students studied, they obtained low results in physics. The fundamental reason is that this subject is taught without excitement and is difficult to understand. As a result, students' interest in science needs to be improved, resulting in students' failure to understand scientific concepts. The hands-on model is very effective, suitable for learning, and helps improve students' understanding of concepts (Kitrungloadjanaporn et al., 2018). The same information from a Thai study on the concepts of force and motion showed misconceptions occurred in (1) resultant force, (2) Newton's first law of motion, (3) Newton's second law of motion, (4) Newton's third law of motion, (5) friction force, and (6) gravitational force. The concept of force and the laws of motion are critical for learning mechanics and understanding other complex concepts in physics. If students have misconceptions about these concepts, learning mechanics will be meaningless, which can lead to failure in learning physics (Wancham et al., 2023). Study results at the University of Ioannina, Greece, on graduate students majoring in physics, showed that many students needed in-depth knowledge of various basic concepts (Stylos & Kotsis, 2023). The study in Ghana showed that most students had the misconception that gravity is selective and, therefore, acts more on heavier objects than lighter objects. Therefore, they argued that a larger object should hit the ground first when a light object dropped from the same height, which is scientifically inaccurate (Dognia & Dah, 2023).

These difficulties can lead to misunderstandings; if they occur continuously, they can result in better understanding. Misconceptions are understandings of concepts that differ from the scientific community's knowledge (Jusniar et al., 2021). Many studies on physics education reveal that students need help in physics and have many misconceptions about various physics subjects. Suppose a student needs clarification about one or more concepts that he will use to explain a physical event. In that case, he will need clarification when explaining the concept of the event or the relationship between concepts. A teacher who teaches physics with traditional teaching methods must actively educate students to associate the concepts they have just compiled with everyday events (Bozkurt, 2022). Students' misconceptions about some science concepts, including physics, may be caused by their misunderstanding of fundamental issues. It may illustrate the lack of skills embodied in science literacy, usually influenced by several socio-demographic factors, cognitive factors, and motivation (Stylos et al., 2021). At the individual socio-demographic level, gender is considered an alternative factor affecting student achievement in science (Acar, 2019). Some studies have found that male students have fewer misconceptions than their female counterparts in secondary school (Fratiwi et al., 2020) and university level (Bates et al., 2013). In contrast, other studies show no difference between male and female college students when students of different genders experience misconceptions. (AL-RSA ’ I et al., 2020). This deviation could be due to the existing stereotype that boys should be more successful in science than girls, resulting in boys trying harder to succeed and, therefore, experiencing an increase in their achievement (Else-Quest et al., 2013). The misconceptions experienced by students are usually caused by the teacher's provision of incomplete initial concepts or facts, so students need clarification or clarification when receiving ideas. It can also occur because of the students themselves (Aligo et al., 2021). One form of misconception identification is by giving diagnostic tests to students. This diagnostic test is a solution to find students' misconceptions (Maison et al., 2022). Therefore, this study aimed to determine the extent of student's misconceptions about the concept of equilibrium of rigid bodies in the case of Keku culture.

▪ METHOD

Research Design and Procedures

This ethnographic research uses survey techniques. Ethnographic research is defined as a research methodology based on explicit and systematic sustained observation and paraphrasing of social situations relating to naturally occurring events (Cappellaro, 2017). Before the test was conducted on students, the research team conducted a study in Negeri Ema, Ambon City. The aim was to interview the King of Negeri Ema, the Village Staff, the Saniri Negeri, and the women who sell in the market with Keku activities. This data collection is to obtain valid results from trusted informant sources. I also confirmed and asked permission to take pictures to be included in the writing. All data was collected and then reviewed as needed to make test questions using pictures or standardized language so that when the questions were given, they could be understood by students who come from outside Maluku. It can be seen from each answer choice and the students' scientific reasoning for the question. The question of possible student answers follows the scoring rubric of Kamcharean & Wattanakasiwich (2016) (Kamcharean & Wattanakasiwich, 2016). The data of students' answers were then corrected using the scoring rubric of Tables 1 and 2. Then, the data were tabulated, and students were mapped according to the answers given.

Table 1. Analysis of student answer assessment

Type	Assessment Criteria
3	correct content level and correct reasoning level
2	content level is correct, but the reasoning level is incorrect
1	correct content level but correct reasoning level
0	incorrect content level and incorrect reasoning level

Participants

The subjects of this study amounted to 100 physics education students, Faculty of Teacher Training and Education, Pattimura University, who had studied the concept of equilibrium of rigid bodies in introductory physics courses. The participants were male (40) and female (60). The sampling technique used was purposive sampling due to the limited number of classes and students.

Instruments

The test instrument was related to the equilibrium of rigid bodies, namely Keku culture, which consisted of 5 description questions. Before this instrument was developed, the researcher conducted a validation test on 3 experts: physics, physics education, and history experts. The goal was to examine each test question given to students. After answering the questions provided, this test was given so the lecturer could find out the students' knowledge. Lecturers will analyze information or answers from each student according to filing. Errors or incorrect answers indicate the occurrence of misconceptions in students. The category of student misconceptions according to the assessment rubric of Minarni et al. (2018) (Minarni et al., 2018) can be seen in Table 2.

Table 2. Category of misconception

Misconception Interval	Category
0-30	Low
30-70	Medium
70-100	High

From the above categories, the percentage of 0-30 is included in the category of misconceptions experienced by low students, 30-70 moderate misconceptions, and 70-100 high misconceptions experienced by students. Data were collected in this study by giving misconception test questions in description format to be filled in by students, after which the answers from each student were collected and analyzed according to the researcher's needs.

Data Analysis Technique

The data obtained through the student misconception test were then analyzed. The percentage of student answers obtained was then described according to the instructions in Table 2.

▪ RESULT AND DISSCUSSION

Student Misconceptions about the Concept of Equilibrium of Objects in the Case of Keku Culture

Misconceptions hinder learning progress in the physics classroom and students' academics. Misconception is a learner's wrong opinion that is based on wrong thinking. The problem of student misconceptions about physics is a significant problem that afflicts the education sector. The lack of understanding of physics concepts results in student misconceptions that can occur. Physics misconceptions do not look at both low and high levels of education. It can be seen in Figure 1 that the misconceptions of prospective physics teacher students on the equilibrium of rigid bodies are reflected in the case study on Keku culture in Negeri Ema.

Data Figure 1 shows that of the 5 questions of the concept understanding test, students experience relatively high misconceptions, namely the average of the questions given both the first question there is a misconception of 75, question 2 is 75, question 3 is 72, question 4 is 77 and question 5 is 85. It shows that even though students have learned physics in essential Physics 1 and 2 courses and mechanics, some still have quite high misconceptions. It can be analyzed that students with basic physics knowledge from the high school level need to be stronger. It can be shown by the students' difficulty in answering contextual questions. The average questions given so far by teachers come from textbooks, so students need to familiarize themselves with conceptual questions based on higher-order thinking. On average, physics learning in schools and universities is still mathematically oriented, so when given simple or complex conceptual problems, students experience difficulties. This situation aligns with the research results for physics students in the UK, who also had high misconceptions (King, 2010). It should be remembered that understanding Newtonian mechanics's basic concepts and principles is a challenge for students, even those who have studied for several years. Several studies have documented student misconceptions about the concepts and principles of basic mechanics, which is a concrete branch of physics. Students face one of the most abstract and complex physics concepts, the concept of force. The result of an acting force is visible, and students have experienced force in their daily lives by feeling the force acting on their bodies or observing the result of a force acting on an object. However, we cannot directly observe or experience 'force' (Stavrum, 2020).

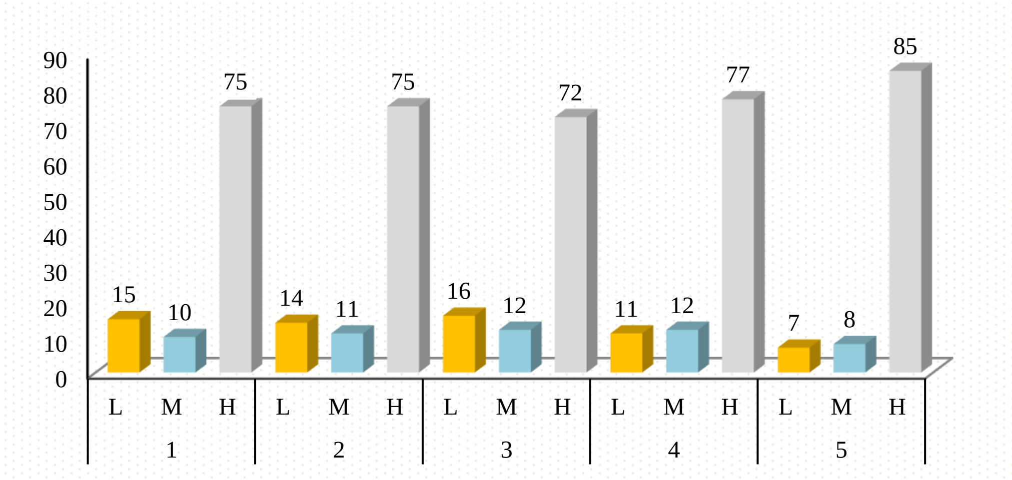

Figure 1. Presentation of students' misconceptions of the equilibrium of rigid bodies in the case of *Keku's* culture in Negeri Ema.

The presence of misconceptions heavily influences student learning. These misconceptions are deeply embedded and transferable between courses, thus impacting students long-term and across disciplines. Many studies identify student misconceptions and investigate how they are formed and ways to remediate them. Student misconceptions should be addressed in a way that does not discredit students' initial conceptions but reshapes them to promote conceptual change and meaningful learning (Chen et al., 2020). Many physics concepts and misconceptions originate from everyday language and experiences (Kulgemeyer & Wittwer, 2023). During these situations of confusion, learners get stuck because they need to learn how to proceed and when to try to complete the task. In addition, learners' confusion often manifests in the form of errors resulting from misconceptions. An error is a deviation from the correct solution. In other words, errors are inaccuracies resulting from lapses in concentration or misunderstanding of concepts. Errors stemming from lapses in concentration are slips or mistakes that the learner can intentionally correct (Ndemo et al., 2022). Slips are random deviations in declarative knowledge that do not indicate systematic misunderstanding. An error occurs when a student believes an incorrect concept is correct (Msomi, 2022).

Misconceptions about the Equilibrium of Rigid Bodies Among the Participants of the Keku Competition

The following shows a culture in Maluku, namely in Negeri Ema, namely the Keku Kelapa culture, as shown in Figure 2. This Keku culture is usually carried out for competitions in commemorating big days such as the Independence Day of the Indonesian Republic, the birthday of Ambon City, and the birthday of the Maluku Protestant Church.

Each participant in this race must wear ambon clothes and on the head is given 5 coconuts arranged neatly and walk on their respective trajectories within 20m. If, on the way, there is a coconut that falls, the participant is defeated, and the participant who enters faster with a head position that does not fall becomes the champion.

Figure 2. Coconut *keku* competition in negeri ema, ambon city

The process of the coconut keku competition is a Maluku culture-based event that fulfills the concept of equilibrium of a rigid body because the requirement for victory in the race is that the coconut that is keku by the race participants must not fall from the keku. The participants must reach the finish line quickly. It means that as long as the participants race, the coconut must be in a state of equilibrium of a rigid body. If the coconut is in the moment of equilibrium, either at rest or moving at a constant speed, then the coconut is experiencing a change in momentum valued at zero. The coconut is also said to be in a state of equilibrium if the coconut does not experience translational or rotational motion and is at rest or moving at a constant speed. According to Newton's first law and the moment of inertia, the conditions for the coconut in a state of equilibrium are: 1) The resultant force acting on the coconut must be equal to zero ($\sum F=0$); 2) The moment of force acting on the coconut is equal to zero ($\sum T=0$). The balance of a rigid body based on its stability value can be divided into three conditions: 1) Stable equilibrium is the condition of the stability of an object that can restore its position when a force or disturbance is imposed on it, and the object only experiences an increase in its gravitational position; 2) Unstable equilibrium is the condition of the stability of objects that are unable to restore their position when the force or disturbance is removed, and the object experiences a decrease in its position of gravity; 3) Indeferent stability is the stability of objects that cannot be maintained because they change their position but their center of gravity remains.

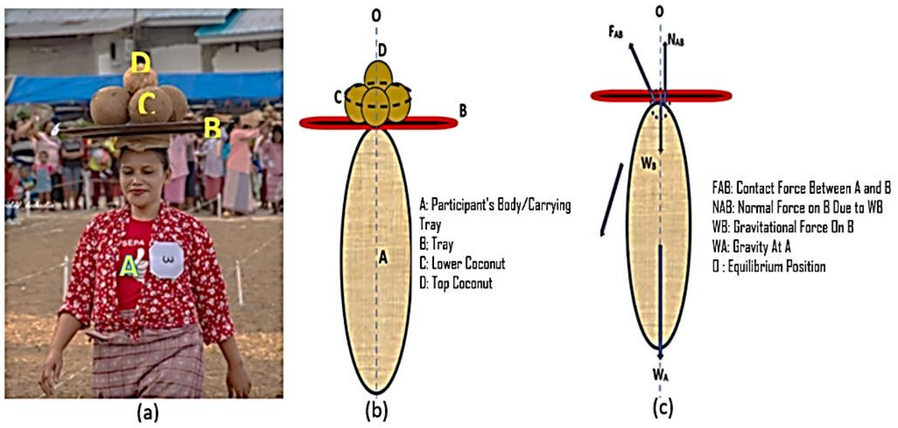

Figure 3. a) Participants of the keku competition in negeri ema kota ambon, b) categorization of participants as a system into subsystems, c) classification of forces working on the participant's body and interaction with the tray

Based on the three conditions of balance or stability of objects, a participant in the coconut keku competition can be considered as a system consisting of subsystems (body, tray, lower coconut, upper coconut) that have connectivity and influence each other. These subsystems have different balances based on their positions, which can be described in 4 categories, namely:

1. The body (category A) has stability or indifferent balance because its movement only changes position without experiencing a shift in its gravitational position; the movement conditions only experience translational movement.
2. Trays (category B) are in Neutral stability because they change their position, and the tendency of their movement will change their position of gravity; namely, when the tray falls, the position of its center of gravity will shift downward. The movements in Category A and Category B always coincide because these two categories are connected by a cloth coil whose nature provides a contact force or binding force so that the position of the tray (category B) is very strong. It is done so that participants can control the movement of the tray properly and in a balanced position.

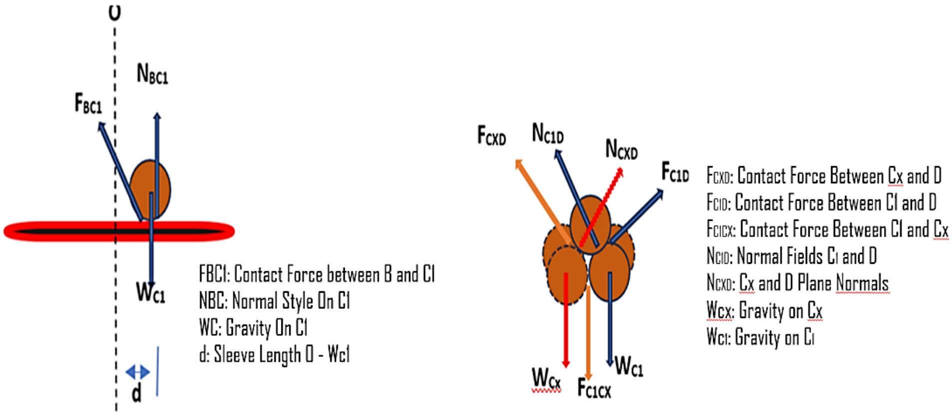

Figure 4. Distribution of forces acting on coconuts; a) forces acting on one coconut with tray; b) forces acting on coconuts and contact interactions between coconuts

3. 4 Coconuts (category C) is based on the case of the coconut strength race is instability or unstable balance on the condition that all coconuts are considered to be in one subsystem so that the tendency of its movement is only downward movement or falling, in this case, the coconut has not experienced position deconstruction. However, when a reference is an object in category B, the coconut is in an indifferent equilibrium and, in its movement, can perform translational and rotational movements or still follow the movements in categories A and B. But in this category, the deconstruction of the coconut's position is very dependent on the movements made by the participant's body in category A and category B. Changes in momentum in category A objects will cause changes in momentum in category B and will further cause changes in momentum in category C objects. Changes in momentum can cause deconstruction of the coconut position, causing the coconut position at the top (category D) to lose balance. When the momentum is significant enough, it will cause the coconut at the top to fall to the coconut position in category C. At that time, the balance of objects in positions B and C will also be disturbed, meaning the difference is in neutral balance. The stability of the coconut can also depend on the distance of the coconut distribution position on the tray (d) to the balance point (Point O). It can contribute to the moment of force or torque (T) that works because, with a large coconut distribution distance (d) or, known as the force arm, the torque will be large with a small change in momentum (ΔP), which ultimately causes the moment of force or torque (ΔP), which ultimately causes the moment of force or torque not equal to zero ($\sum T \neq 0$), besides that the balance of coconut (category C) can be influenced by the selection of coconut size and wind conditions, coconut size can affect the magnitude of the gravity disparity of the force acting on the coconut and the influence of wind pressure as an external factor can change its momentum.
4. 1 Coconut (category D) is in steady balance when viewed from its position with other coconuts. It is because 4 coconuts in all four positions support the object in category D. Hence, the coconut in this position is very dependent on the four coconuts in category C, and the object in category D has a steady balance due to the accumulation of contact forces from the four coconuts as a manifestation of interaction and normal force on each coconut. The condition of coconuts in category D is highly dependent on the presence of coconuts in category C as a support and external factors, namely wind because the wind provides pressure oriented towards changes in position and impetus that contribute to changes in the momentum of coconuts in category D and can affect the coconuts underneath (category D).

Therefore, a coconut race participant must maintain a position and balance condition so that the coconut in the coconut does not experience a change in momentum where the translational and rotational motion must be equal to zero ($\sum F = 0$) and ($\sum T = 0$) by:

1. Forward movement is done with a straight trajectory, and the speed must be constant so that the forces acting on the coconut have a resultant equal to zero ($\sum F=0$).

2. Avoid any movement that can affect the balance of the tray and coconut to minimize changes in system momentum.
3. Coconuts should be selected with a proportional shape and small size to reduce the influence of wind.
4. The coconut arrangement pattern of the tray balance position must be considered close to the center point of the tray, if possible, so that the arm length (d) can be minimized, reducing the potential torque (∑T).

Concepts are the cornerstone of the knowledge base in all disciplines, and a solid understanding of concepts plays a vital role in helping learners develop their knowledge base and structure, apply correct concepts to problem-solving, and thereby develop expertise and competence in their profession (Streveler et al., 2008). However, conceptual misconceptions, also known as misconceptions, are widespread in many learners, especially novice learners, and often result in poor or incorrect knowledge base and structure. Misconceptions are reported as one of the main reasons for poor academic performance or problem-solving skills in many disciplines, particularly in science, mathematics, and engineering. Further research shows that students' conceptual misconceptions can be solid and rugged to correct (Li et al., 2023). Some misconceptions stem from students' previous experiences and can be traced back to high school or early college. Students come into the classroom not as blank slates but with long-lasting and robust preconceptions associated with their previous experiences. Some students' preconceptions even violate the basic mathematical and scientific principles instructors teach in the classroom (Liu & Fang, 2016).

The stability of a two-force system in equilibrium can be assessed intuitively at a glance. Static equilibrium is achieved when the two forces are of equal magnitude, have opposite senses, and have the same line of action. However, although all are in equilibrium, the rigid bodies in Fig. 1 have different stability. Assuming constant forces (both in terms of magnitude and direction), it is readily seen (a more rigorous derivation will follow) that stable equilibrium results if the forces are pointing away from each other (1a), whereas unstable equilibrium results if the forces are pointing towards each other (1b). The two application points coincide in the borderline case, rendering the system neutral equilibrium (1c). The point of application of the forces on their line of action is vital to stability, even though it does not affect the static equilibrium itself. In an equilibrium n-force system, the stability judgment is much less pronounced (Herder & Schwab, 2004).

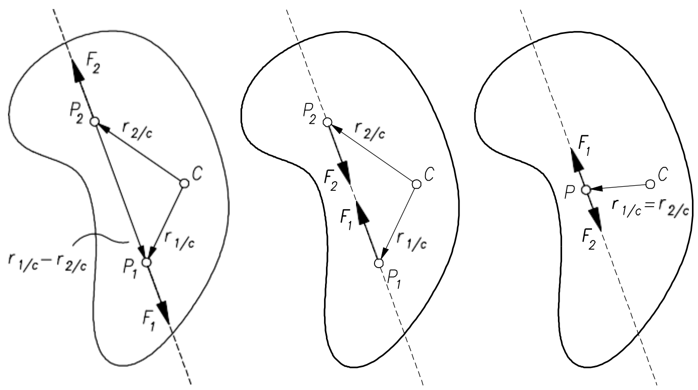

Figure 5. Two-force systems in equilibrium act on a rigid body: (a) stable equilibrium, (b) unstable equilibrium, and (c) neutral equilibrium.

In an equilibrium n-force system, the stability judgment is much less noticeable. Figure 2 shows an example of a rigid body with three forces in equilibrium. One strategy to assess the stability of such systems would be to compose the forces two by two until a two-force system is obtained, the stability of which can then be assessed as above. The conventional force composition procedure is insufficient since it does not yield the point of application of the resultant force. Since the conventional procedure is aimed at equilibrium (not at stability), it yields the statically equivalent force system: an equivalent force for which the point of application on the line of action is irrelevant. Therefore, to find the equivalent stability, a procedure is required to compose forces dynamically equivalently, i.e., the stability contribution of the resultant force is equal to the stability contribution of the two original forces. It implies that in addition to the magnitude and line of action of the resultant force, the point of application is also to be found (Herder & Schwab, 2004).

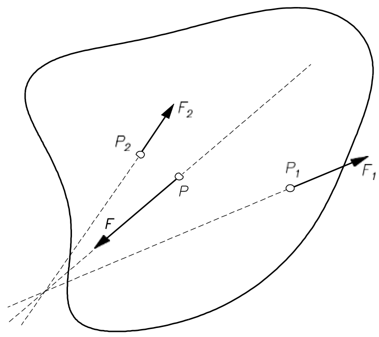

Figure 6. A three-force system acting on a rigid body. Static equilibrium determines the third force's magnitude and line of action, but the stability needs to be readily assessed

The stability of a rigid body receiving two equilibrium forces can be assessed intuitively. A resultant force is considered dynamically equivalent to a given system of forces acting on a rigid body if its contribution to the stability of the body of both force systems is the same. It is shown that the equivalent resultant force of two specific constant forces dynamically applies at the intersection of their lines of action and the circle created by the point of application of specific forces and the intersection of their lines of action. Determining the combined center of mass can be considered a particular case. In general, the design goal of active learning in science is to make students think deeply. Deep learning can improve students' performance in long-term memory and be retained by students (Kavanagh et al., 2017).

▪ CONCLUSION

Based on the findings, students still experience misconceptions about the concept of equilibrium of rigid bodies related to Keku culture. Teachers have not accustomed students to learning from natural phenomena around them and have given scientific questions so that students can search, find, and provide answers and solutions related to these natural phenomena. Teachers mostly explore physics conditions and problems in textbooks and explore things contextual in nature originating from the culture that is found every time. Therefore, teacher teaching must be improved by developing physics teaching using appropriate strategies to encourage students' understanding of concepts to reduce misconceptions. In addition, many physics topics are abstract, such as the state of molecules or particles on the topic of thermodynamics or the concepts of temperature and heat, so students need help explaining these physical phenomena. Therefore, teachers can use video-based simulation media or virtual learning so that students understand the state of physics that occurs. The limitation of this research is that it still measures students' misconceptions on the topic of equilibrium of rigid bodies on a small scale so that in the future, it can measure the misconceptions of primary education or higher education students with other physics topics so that teachers can be evaluated in the future by using the best strategy or way to eliminate students' physics misconceptions in obtaining conclusions. In addition, high-level problems should be provided to students so they are more self-exerting and motivated to search, find, and solve the given physics problems. They are trained to solve the cases given so that they become critical and helpful future scientists in the world of work and the surrounding environment.

▪ REFERENCES

Acar, Ö. (2019). Investigation of the science achievement models for low and high achieving schools and gender differences in Turkey. Journal of Research in Science Teaching, 56(5), 649–675. https://doi.org/10.1002/tea.21517

AL-RSA ’ I, M. S., Khoshman, J. M., & Tayeh, K. A. (2020). Jordanian pre-service physics teacher ’ s misconceptions about force and motion. Journal of Turkish Science Education, 17(4), 528–543. https://doi.org/10.36681/tused.2020.43

Alharbi, A. M. (2023). Implementation of education 5.0 in developed and developing countries: a comparative study. Creative Education, 14(05), 914–942. https://doi.org/10.4236/ce.2023.145059

Aligo, B. L., Branzuela, R. L., Faraon, C. A. G., Gardon, J. D., & Orleans, A. V. (2021). Teaching and learning electricity—a study on students’ and science teachers’ common misconceptions. Manila Journal of Science, 14, 22–34.

Balta, N., & Asikainen, M. A. (2019). A comparison of olympians’ and regular students’ approaches and successes in solving counterintuitive dynamics problems. International Journal of Science Education, 41(12), 1644–1666. https://doi.org/10.1080/09500693.2019.1624990

Bates, S., Donnelly, R., Macphee, C., Sands, D., Birch, M., & Walet, N. R. (2013). Gender differences in conceptual understanding of Newtonian mechanics: A UK cross-institution comparison. European Journal of Physics, 34(2), 421–434. https://doi.org/10.1088/0143-0807/34/2/421

Bozkurt, E. (2022). Determining the misunderstandings of physics and science teacher candidates about the events related to the buoyancy force. Pegem Journal of Education and Instruction, 12(1), 222–231. https://doi.org/10.47750/pegegog.12.01.23

Brandt, C. B., & Carlone, H. (2012). Ethnographies of science education: Situated practices of science learning for social/political transformation. Ethnography and Education, 7(2), 143–150. https://doi.org/10.1080/17457823.2012.693690

Cappellaro, G. (2017). Ethnography in public management research: a systematic review and future directions. International Public Management Journal, 20(1), 14–48. https://doi.org/10.1080/10967494.2016.1143423

Chen, C., Sonnert, G., Sadler, P. M., & Sunbury, S. (2020). The impact of high school life science teachers' subject matter knowledge and knowledge of student misconceptions on students' learning. CBE Life Sciences Education, 19(1), 1–16. https://doi.org/10.1187/cbe.19-08-0164

Dognia, R., & Dah, M. (2023). Physics students' conceptual understanding of "gravity and free fall." Eurasian Journal of Science and Environmental Education, 3(2), 61–65. https://doi.org/10.30935/ejsee/13444

Else-Quest, N. M., Mineo, C. C., & Higgins, A. (2013). Math and science attitudes and achievement at the intersection of gender and ethnicity. Psychology of Women Quarterly, 37(3), 293–309. https://doi.org/10.1177/0361684313480694

Eriksson, M., Euler, E., Linder, C., Eriksson, U., Govender, N., Eriksson, M., Euler, E., Linder, C., & Eriksson, U. (2022). The variation of university physics students' experience of plus and minus signs in 1D vector-kinematics revisited. African Journal of Research in Mathematics, Science and Technology Education, 26(1), 63–76. https://doi.org/10.1080/18117295.2022.2091327

Fratiwi, N. J., Samsudin, A., Ramalis, T. R., Saregar, A., Diani, R., Irwandani, Rasmitadila, & Ravanis, K. (2020). Developing memori on Newton's laws: For identifying students' mental models. European Journal of Educational Research, 9(2), 699–708. https://doi.org/10.12973/eu-jer.9.2.699

Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. International Journal of Educational Research, 102, 1–13. https://doi.org/10.1016/j.ijer.2020.101586

Halim, L., Yong, T. K., & Meerah, T. S. M. (2014). Overcoming students' misconceptions on forces in equilibrium: an action research study. Creative Education, 05(11), 1032–1042. https://doi.org/10.4236/ce.2014.511117

Hammond, L., & Brandt, C. (2004). Science and cultural process: Defining an anthropological approach to science education. Studies in Science Education, 40(1), 1–47. https://doi.org/10.1080/03057260408560202

Herder, J. L., & Schwab, A. L. (2004). On dynamically equivalent force systems and their application to the balancing of a broom or the stability of a shoe box. Proceedings of the ASME Design Engineering Technical Conference, 2 A, 523–533. https://doi.org/10.1115/detc2004-57188

Hull, M. M., Jansky, A., & Hopf, M. (2021). Probability-related naïve ideas across physics topics. Studies in Science Education, 57(1), 45–83. https://doi.org/10.1080/03057267.2020.1757244

Jusniar, J., Effendy, E., Budiasih, E., & Sutrisno, S. (2021). The effectiveness of the "embe-r" learning strategy in preventing student's misconception in chemical equilibrium. Educacion Quimica, 32(2), 53–73. https://doi.org/10.22201/fq.18708404e.2021.2.75566

Kamcharean, C., & Wattanakasiwich, P. (2016). Development and implication of a two-tier thermodynamic diagnostic test to survey students ' understanding in thermal physics. International Journal of Innovation in Science and Mathematics Education, 24(2), 14–36.

Kavanagh, Y., Hara, N. O., Palmer, R., Lowe, P., & Raftery, D. (2017). Physical physics – getting students active in learning materials science. MRS Advances, 1–7. https://doi.org/10.1557/adv.201

King, C. J. H. (2010). An analysis of misconceptions in science textbooks: earth science in england and wales. International Journal of Science Education, 32(5), 565–601. https://doi.org/10.1080/09500690902721681

Kitrungloadjanaporn, P., Phothong, A., & Precharattana, M. (2018). Seesaw balancing: a hands-on model to understand moment of force in classroom. Applied Mechanics and Materials, 879, 269–275. https://doi.org/10.4028/www.scientific.net/amm.879.269

Kokkonen, T., Lichtenberger, A., & Schalk, L. (2022). Concreteness fading in learning secondary school physics concepts. Learning and Instruction, 77, 1–11. https://doi.org/10.1016/j.learninstruc.2021.101524

Kulgemeyer, C., & Wittwer, J. (2023). Misconceptions in physics explainer videos and the illusion of understanding: an experimental study. International Journal of Science and Mathematics Education, 21(2), 417–437. https://doi.org/10.1007/s10763-022-10265-7

Larsson, J., Airey, J., Lundqvist, E., Larsson, J., & Airey, J. (2021). Swimming against the tide : five assumptions about physics teacher education sustained by the culture of physics departments swimming against the tide : five assumptions about physics teacher education sustained by the culture of physics departments. Journal of Science Teacher Education, 32(8), 934–951. https://doi.org/10.1080/1046560X.2021.1905934

Li, X., Li, Y., & Wang, W. (2023). Long-lasting conceptual change in science education: the role of u-shaped pattern of argumentative dialogue in collaborative argumentation. In Science and Education (Vol. 32, Issue 1). Springer Netherlands. https://doi.org/10.1007/s11191-021-00288-x

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.

Lumban Gaol, N. T. (2023). School leadership in Indonesia: A systematic literature review. Educational Management Administration and Leadership, 51(4), 831–848. https://doi.org/10.1177/17411432211010811

Maison, M., Hidayat, M., Kurniawan, D. A., Yolviansyah, F., Sandra, R. O., & Iqbal, M. (2022). How critical thinking skills influence misconception in electric field. International Journal of Educational Methodology, 8(2), 377–390.

Martín-Blas, T., Seidel, L., & Serrano-Fernández, A. (2010). Enhancing Force Concept Inventory diagnostics to identify dominant misconceptions in first-year engineering physics. European Journal of Engineering Education, 35(6), 597–606. https://doi.org/10.1080/03043797.2010.497552

Meli, K., Zacharos, K., & Koliopoulos, D. (2016). The integration of mathematics in physics problem solving: a case study of greek upper secondary school students.

Canadian Journal of Science, Mathematics and Technology Education, 16(1), 48–63. https://doi.org/10.1080/14926156.2015.1119335

Minarni, M., Kurniawan, Y., & Muliyani, R. (2018). *Identifikasi kuantitas siswa yang miskonsepsi pada materi listik dinamis menggunakan three tier-test* (TTT). JIPF (Jurnal Ilmu Pendidikan Fisika), 3(2), 38. https://doi.org/10.26737/jipf.v3i2.578

Msomi, A. M. (2022). Analysis of students ' errors and misconceptions in solving linear ordinary differential equations using the method of laplace transform. International Electronic Journal of Mathematics Education, 17(1), 1–10.

Ndemo, Z., Ndemo, O., Education, M., & Ndemo, Z. (2022). Mitigating errors and misconceptions among Grade 11 learners in algebra through error analysis. African Journal of Teacher Education and Development, 2(1), 1–11.

Newcomer, J. L., & Steif, P. S. (2008). Student thinking about static equilibrium: Insights from written explanations to a concept question. Journal of Engineering Education, 97(4), 481–490. https://doi.org/10.1002/j.2168-9830.2008.tb00994.x

Osman, K., Halim, L., & Meerah, S. M. (2006). What Malaysian science teachers need to improve their science instruction: A comparison across gender, school location and area of specialization. Eurasia Journal of Mathematics, Science and Technology Education, 2(2), 58–81. https://doi.org/10.12973/ejmste/75453

Rossi, I. V., de Lima, J. D., Sabatke, B., Nunes, M. A. F., Ramirez, G. E., & Ramirez, M. I. (2021). Active learning tools improve the learning outcomes, scientific attitude, and critical thinking in higher education: Experiences in an online course during the COVID-19 pandemic. Biochemistry and Molecular Biology Education, 49(6), 888–903. https://doi.org/10.1002/bmb.21574

Seniuk Cicek, J., Ingram, S., Friesen, M., & Ruth, D. (2019). Action research: a methodology for transformative learning for a professor and his students in an engineering classroom. European Journal of Engineering Education, 44(1–2), 49–70. https://doi.org/10.1080/03043797.2017.1405242

Stavrum, L. R. (2020). " Never at rest ": developing a conceptual fram- ework for descriptions of ' force ' in physics tex - tbooks. Nordic Studies in Science Education, 16(2), 183–198.

Streveler, R. A., Litzinger, T. A., Miller, R. L., & Steif, P. S. (2008). In the engineering sciences: Overview and future research directions. Journal of Engineering Education, 97(3), 279–294.

Stylos, G., & Kotsis, K. T. (2023). Undergraduate physics students' understanding of thermal phenomena in everyday life. Contemporary Mathematics and Science Education, 4(2), ep23023. https://doi.org/10.30935/conmaths/13406

Stylos, G., Sargioti, A., Mavridis, D., & Kotsis, K. T. (2021). Validation of the thermal concept evaluation test for Greek university students' misconceptions of thermal concepts. International Journal of Science Education, 43(2), 247–273. https://doi.org/10.1080/09500693.2020.1865587

Vogler, J. S., Thompson, P., Davis, D. W., Mayfield, B. E., Finley, P. M., & Yasseri, D. (2018). The hard work of soft skills: augmenting the project-based learning experience with interdisciplinary teamwork. Instructional Science, 46(3), 457–488. https://doi.org/10.1007/s11251-017-9438-9

Wancham, K., Tangdhanakanond, K., & Kanjanawasee, S. (2023). Sex and grade issues in influencing misconceptions about force and laws of motion: an application of cognitively diagnostic assessment. International Journal of Instruction, 16(2), 437–456. https://doi.org/10.29333/iji.2023.16224a

Wartono, W., Batlolona, J. R., & Putirulan, A. (2018). Cognitive conflict strategy and simulation practicum to overcome student misconception on light topics. Journal of Education and Learning (EduLearn), 12(4), 747–756. https://doi.org/10.11591/edulearn.v12i4.10433

Wartono, W., Hudha, M. N., & Batlolona, J. R. (2018). Guided inquiry and PSR in overcoming students' misconception on the context of temperature and heat. AIP Conference Proceedings, 2014, 1–7. https://doi.org/10.1063/1.5054433