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# Appropriate TPACK Components for Overcoming Misconceptions on Force Concept Inventory Test

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**Abstract:** Misconception is one of the obstacles in the achievement of physics learning and must be immediately corrected so that there is no retention of misconceptions in subsequent knowledge. One way to prevent and reduce misconceptions that occur is with the teachers skill of Technological Pedagogical and Content Knowledge (TPACK). Teachers who integrate TPACK in learning can prevent misconceptions and find solutions to overcome the misconceptions. This study aims to determine the TPACK skill of teachers in overcoming misconceptions and the appropriate TPACK components to reduce misconceptions based on concepts on the three tier test of FCI (Force Concept Inventory). The research method used is mixed method with concurrent embedded design. The main data in this study is TPACK which is qualitative data and supporting data is students misconception which is quantitative data. The results showed a decrease in misconceptions after being given an understanding of the concept using the teacher's TPACK skill. The components used during the teacher's reduction of misconceptions based on the concepts in the FCI three tier test of FCI are TPACK and PCK components. So it can be concluded that the teacher's TPACK skill can reduce the misconceptions that occur in the three tier test of FCI.

**Keywords:** Misconception; Newton's law; TPACK

## Introduction

Teachers have several basic competencies regulated in Law Number 14 of 2005 concerning teachers and lecturers, namely pedagogic competence, personality competence, social competence and professional competence. Pedagogic competence is the teacher's ability to manage learning, teachers are responsible for learning planning, implementation, assessment, change and improvement of learning programmes (Mulyani, 2021; Sulfemi, 2019). Personality competence is a teacher's personal competence that shows the personality of someone who is mature, authoritative, stable, noble and can be an example for students. Social competence is the way teachers interact with students, fellow professionals, parents/guardians of students and the community around the teacher (Ashsiddiqi, 2012). Meanwhile, professional competence is the ability of teachers related to professions that demand expertise in the fields of education and teaching (Dudung, 2018). In professional competence, teachers are expected to be able to master learning content, and it is important for teachers not to experience misconceptions so that misconceptions do not decline to their students (Admoko et al., 2023). One competency that distinguishes teachers from other professions is pedagogical competence (Akbar, 2021). In addition to pedagogical knowledge, teachers must also have content knowledge and technological knowledge. The relationship between Technological Knowledge, Content Knowledge and Pedagogical Knowledge is presented as Technological Pedagogical and Content Knowledge (TPACK) which is the main component of the teacher (Koehler et al., 2013).

Teachers who integrate TPACK in learning can reduce or even prevent misconceptions (Imansari, 2019) and improve the quality of learning in accordance with demands and changes (Nuruzzakiah et al., 2022).

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Teachers with TPACK skills are also able to find solutions to overcome misconceptions by activating prior knowledge (Şahin et al., 2021). Teachers' PCK skills can even improve motivation, learning outcomes and learning achievement, and students' cognitive abilities (Assa'adah, 2021; Dirgahayu, 2020; Fitriani, 2022; Kumala et al., 2020; Sanjaya, 2017), where motivation and the aspects mentioned are one of the causes of high and low student misconceptions (Harso et al., 2021). The use of technology in learning can also reduce misconceptions in students. For example, the use of e-book technology can reduce student misconceptions by 48% (Afriwardani et al., 2023), the use of comic-based e-module technology reduces student misconceptions by 26.77 (Mukramah et al., 2023) and the use of PhET simulation technology reduces misconceptions by 29.44% (Rafika et al., 2023).

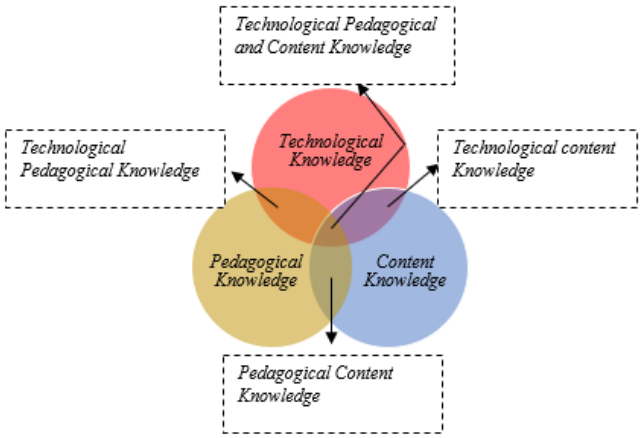


**Figure 1.** The relationship between technological knowledge, pedagogical knowledge and content knowledge

A Lesson that utilizes technology in the delivery of material is included in the realm of TPACK. TPACK has been proven to be used in various situations to improve students' concept understanding. However, in previous studies, the analysis of TPACK abilities in teachers was only carried out in general, without being specific to reducing students' misconceptions. This study aims to determine how the teacher's TPACK ability when faced with students' misconceptions in physics learning which is a subject with a high level of misconception (Santoso et al., 2021; Triastutik et al., 2021; Wahyuni et al., 2019) along with the appropriate TPACK components used to reduce misconceptions based on concepts on the three-level Force Concept Inventory (FCI) test.

## Method

This research uses a mixed method research method with a concurrent embedded design, where qualitative data and quantitative data are collected at almost the same time (Creswell, 2017). In this research design there is one main data (qualitative) and one supporting data (quantitative). The subjects of this research consisted of 28 students of class XI MIPA 2 SMA Negeri 5 Banda Aceh who had studied and passed the material of Newton's Law and 1 physics teacher of SMA Negeri 5 Banda Aceh. Data collection on student misconceptions was carried out with a three-level diagnostic test based on the force concept inventory (FCI) which can describe student misconceptions on Newton's law material (Astuti et al., 2023). The FCI three-level test is given in two stages, namely pretest and posttest, Pretest is given to students who have studied and passed Newton's Law material, the pattern of student answers is identified into three categories namely (1) Understand the concept; (2) Misconception; and (3) Do not master the concept. With interpretation as in Table 1.

**Table 1.** Interprestation of Students Responses

| Tier 1 (Conception) | Tier 2 (Reason) | Tier 3 (Level Of Confidence) | Interpretation Of Categories |
|---|---|---|---|
| Correct | Correct | High (>2.5), Very confidence | Mastering Concept |
| Correct | Wrong | High (>2.5), Very confidence | Misconception |
| Wrong | Correct | High (>2.5), Very confidence | Misconception |
| Wrong | Wrong | High (>2.5), Very confidence | Misconception |
| Correct | Correct | Low, (≤2.5), not sure | Not Mastered of Concept |
| Correct | Wrong | Low, (≤2.5), not sure | Not Mastered of Concept |
| Wrong | Correct | Low, (≤2.5), not sure | Not Mastered of Concept |
| Correct | Wrong | Low, (≤2.5), not sure | Not Mastered of Concept |

The misconceptions experienced by students will be reduced by the teacher with his TPACK skills. During the process of reducing misconceptions, the teacher's TPACK data was collected using lesson observations during the teacher's reduction of misconceptions, teacher interviews and TPACK perception questionnaires. Then students were given a posttest to see the improvement of their concept understanding, followed by analyzing misconception data using SPSS, N-Gain Test to measure the significance of differences between two groups of paired pretest and post-test data.

## Result and Discussion

Result and Discussion in this study is explained in two parts, part one explain about the identification of misconceptions and part two explained the

identification of TPACK components that are suitable for overcoming misconceptions.

*Misconception Identifications*

The process of identifying misconceptions was carried out in three steps, namely the pretest to determine students' misconceptions on Newton's Law concepts, then the reduction process by utilising the teacher's TPACK ability and the posttest to see the improvement of students' concept understanding after going through the reduction process. The results of students' pretest and posttest on FCI three tier diagnostic test can be seen in Table 2.

**Table 2**. Pretest and Posttest Score

| | Mastering The Concept (%) | Misconception (%) | Not Mastered The Concept (%) |
|---|---|---|---|
| Pretest | 2.62 | 36.19 | 62.38 |
| Posttest | 73.81 | 24.52 | 2.619 |

Based on Table 2, it can be seen that the misconceptions experienced by students during the pretest were 36.19% and during the posttest decreased to 24.52%. However, what is very significant is the comparison of students' concept understanding scores, from 2.6% at the pretest to 73.8% at the posttest. Misconceptions can be obtained by students initial concepts which can arise from personal experience or from the knowledge provided by the teacher (Dewi et al., 2021), students' interest in learning, students' ability to understand lessons, learning media (Rianti et al., 2021), the learning methods used by teachers or the differences language used in learning (Busyairi et al., 2020). Misconceptions that occur in each FCI concept before and after being given concept understanding can be seen in Table 3.

**Table 3.** Misconception Base on Concept FCI

| Concept | Pretest Misconception (%) | Post-test Misconception (%) | Reduction Misconception (%) |
|---|---|---|---|
| Free Fall Motion | 58.92 | 14.28 | 75.55 |
| Uniform Acceleration | 32.14 | 24.99 | 2..00 |
| Uniform Speed | 28.56 | 19.04 | 28.17 |
| Parabolic Motion | 33.92 | 26.78 | 20.83 |
| Circular Motion | 33.92 | 17.85 | 47.77 |
| Average | | | 39.26 |

Based on Table 3, the percentage of misconception reduction on concept of the three tier diagnostic test FCI varies greatly. This shows that misconceptions still occur even though they have been reduced. This can happen because changes in students' conceptual beliefs cannot occur directly. The process of exchanging misconceptions with new concepts occurs gradually, systematically and accurately (Addido et al., 2022). The average misconception that has been reduced in multiple-choice diagnostic items is 39.26% The highest misconception reduction on the Free Fall Motion concept.

After the data on the pretest and posttest results are obtained, the next step is to conduct the N-Gain test of the students' test results. This N-gain test is used to see whether there is an increase in concept understanding before and after treatment. The results of the N-gain test using SPSS can be seen in Table 4.

**Table 4.** N-Gain Score

| Descriptive Statistics | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| N-Gain_Score | 28 | 0.47 | 0.93 | 0.7252 | 0.11551 |
| N-Gain_Percentage | 28 | 46.70 | 93.00 | 72.5153 | 11.55109 |
| Valid N (listwise) | 28 | | | | |

From the N-gain test results in Table 4, it is known that the N-gain value is 0.72. This result shows that the N-gain value meets the requirements <0.7 which means it is in the high category. The high category indicates that there is an increase in students' concept understanding or a decrease in misconceptions after being given an understanding of the teacher's TPACK-based concept. So that the teacher's TPACK ability can overcome the misconceptions of students of newton's law material. The increase in students' concept understanding based on the Ngain analysis test can be seen in Figure 3.

Based on Figure 3, more than half of the students experienced a high increase in concept understanding with an N-Gain value > 0.7. These results are in line with research conducted by Prastiyan et al. (2023), that is TPACK integrated learning can improve students' concept understanding. Teachers with good TPACK competency are able to identify problems experienced by students in understanding concepts, using modeling,

showing concepts visually and showing concrete evidence of abstract concepts (Ndiaye et al., 2022).

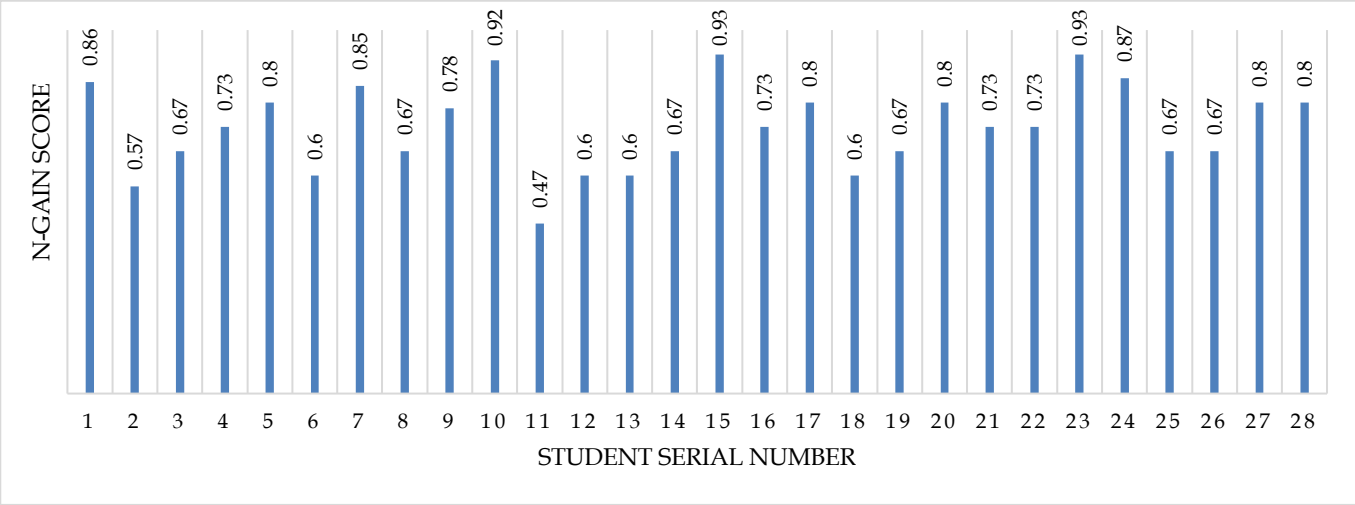


**Figure 2.** N-gain score of increases students' understanding of concept

*Analysis of TPACK Component That Overcome Misconception*

The TPACK components that are suitable for reducing misconceptions are obtained by means of lesson observations, interviews and questionnaires. In assessing the components that are suitable or not suitable is by looking at the decrease in misconceptions that occur in the concept of Newton's Law in the FCI test. The TPACK component is declared inappropriate to overcome the misconceptions that occur if the percentage reduction in misconceptions is low. The interpretation of the percentage of misconception reduction can be seen in Table 5.

**Table 5.** Interpretation of Misconception Reduction

| Percentage (%) | Categories |
|---|---|
| $0 \leq P \leq 30$ | Low |
| $30 \leq P \leq 60$ | Medium |
| $60 \leq P \leq 100$ | High |

TPACK consists of 7 components, which are Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Technological and Pedagogical Knowledge (TPK), Pedagogical and Content Knowledge (PCK), Technological and Content Knowledge (TCK) dan Technological Pedagogical and Content Knowledge (TPACK). Overall, the teacher's learning process uses TPACK, but if analysed based on each misconception that the teacher reduces based on the concept of Newton's Law, the components used in the FCI question are TCK and PCK. PCK is the teacher's ability to manage the class by choosing learning strategies according to the learning material, while TCK is the ability to use appropriate technology to deliver the material. The following are the results of the analysis of the appropriate components used to overcome misconceptions in the FCI three tier diagnostic test.

*Free Fall Motion Concept*

There are two indicators used to measure students' concept understanding on the concept of free fall motion, namely determining the time it takes for an object to reach the ground and determining the distance the object falls. In both indicators students have misconceptions because they assume that objects with a larger mass will fall faster than objects that have a smaller mass. These misconceptions occur due to students' daily experiences and lack of ability to connect science concepts with real life (Malagola et al., 2023). To reduce the misconceptions that occur in the concept of free fall motion, the teacher repeats the free fall motion material and emphasises on the free fall motion equation that the mass does not affect the time the object falls.

$$t = \sqrt{\frac{2h}{g}} \quad (1)$$

To prove the theory of free fall motion, the teacher also showed a YouTube video about the free fall motion of two objects that have different masses but are in a frictionless space. In the process of reducing misconceptions that occur, teachers have used the TPACK components, namely Technology, Pedagogy and Content where there is the use of technology used in the form of proving concepts using realistic videos that can support students' understanding of concepts. The reduction in misconceptions in this indicator is 73% in the first indicator and 78% in the second indicator, which means that the teacher's technological, pedagogic and content knowledge can be used to reduce misconceptions that occur in indicators 1 and 2 on the free fall motion concept. Showing a real picture of the

correct concept from prior knowledge will evoke the assimilation process to think about forming a new understanding (Putra et al., 2015).

*Uniform Acceleration Concept*

In this concept, there are 3 indicators to measure student understanding, namely determining the trajectory of motion of objects, determining the speed of motion of objects and determining changes in the speed of objects. In the indicator of determining the trajectory of motion of an object, students are given a case to determine the trajectory of motion of an object that has an initial speed in the right direction and a final speed in the upward direction moving on a slippery plane. Students respond to the case by choosing the answer that the object will move according to the direction at the final speed. To reduce the misconception that occurs, the teacher explains that the direction of motion of the object will be the same as the resultant force of the object. Furthermore, the teacher also proves the direction of the resultant force of the object using Phet Virtual Lab.

Based on the teacher's explanation, the learning process carried out to reduce misconceptions that occur in student's uses technological, pedagogic and content components, which means that the teacher uses all TPACK components to reduce misconceptions in the indicator of determining the trajectory of motion of objects in uniform acceleration concept. The decrease in misconceptions that occur after being given an understanding of the concept using the TPACK component is 13%, this indicates that the use of technology is not sufficient to reduce misconceptions in the indicator of determining the trajectory of motion of uniform acceleration concept. Although technology-integrated learning such as Phet can generally improve learning outcomes or understanding of students' concepts, this could be due to the nature of the misconceptions themselves which are stable (Rieu et al., 2022) or because the learning carried out by teachers tends to be teacher-centered, even though learner-centered learning can improve concept mastery compared to conventional learning (Nagara et al., 2019).

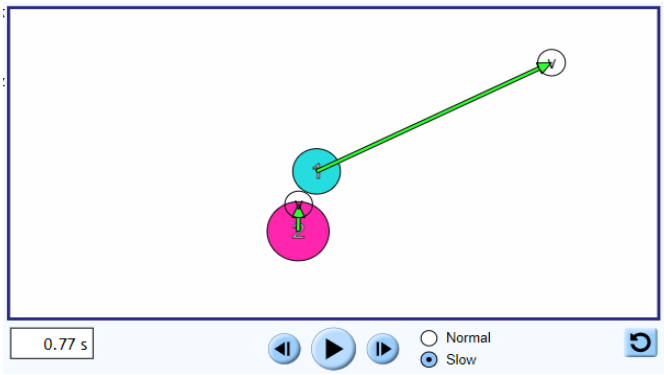


**Figure 3.** PhET virtual lab of force resultant

In the indicator of determining the speed of motion of an object, students are given a case to determine what the speed of the object is shortly after being given the final speed. Students' misconceptions assume that the velocity of the object does not depend on the initial velocity of the object, so the velocity of the object will be the same as the final velocity of the object. To reduce the misconceptions that occur, the teacher re-explains the uniform acceleration material where the velocity of the object depends on the initial velocity and the final velocity of the object. So that the velocity of the object is equal to the resultant velocity v0 and vp. The teacher reduces the misconceptions that occur in this indicator without using technology, so the TPACK component used is only the teacher's Pedagogic and content knowledge or PCK, namely the teacher's ability to manage the class based on the content of the material. The reduction in misconceptions that occur after being given an understanding of the concept using the PCK component is 42.8%, which means that the PCK component is the right component to reduce misconceptions that occur in the indicator of determining the speed of motion of objects.

In the indicator of determining changes in the velocity of objects, students are given questions to determine how the velocity of objects moving on a slippery plane looks like after being given the final velocity. Students assume that objects moving on a slippery plane will have a decreasing speed over time. The teacher explains that if an object is declared to be moving on a smooth plane, the friction force on the plane is ignored, meaning that the object does not experience deceleration. The teacher reduces the misconceptions that occur in students using the PCK component, the reduction in misconceptions that occur is 16.6%, which means that the PCK component is not an appropriate component to reduce misconceptions that occur in the indicator of determining changes in the speed of motion of objects.

*Uniform Speed and Uniform Acceleration Concept*

The indicator used to measure the understanding of this concept is to determine the velocity of the two positions of the object. Students are given a picture of the position of 2 objects with different movement intervals. From the picture, students must determine in which position the velocity of the two objects is the same. An illustration of this indicator case can be seen in Figure 5.

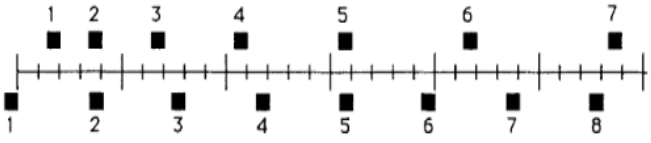


**Figure 4.** Uniform speed and uniform acceleration case overview

Based on the picture given, students assume that objects that have the same position have the same speed. Teachers reduce students' misconceptions on this indicator using without using technology, namely with the teacher's ability to analogize learning material with everyday life. In the misconception reduction process, the teacher calls two students who will practice uniform speed and uniform acceleration. Both students will walk simultaneously at each teacher's command. Student 1 steps from one ceramic block to another ceramic block, while student 2 the first step is on block 1 the second step is on block 3 (stepping over 2 blocks) The third step of student 2 will be on block 6, so on the same command the students' movements will be different. In both examples of movement students are given the opportunity to determine which students reflect uniform speed and which students reflect uniform acceleration. In this misconception process, the teacher utilizes her pedagogical and content skills so that the component used to reduce misconceptions is the PCK component. The reduction in misconceptions that occurred in this indicator was 41.6%, which means that the PCK component is the right component to reduce misconceptions in the indicator of determining the velocity of two positions of objects.

*Parabolic Motion Concept*

In the concept of parabolic motion, the indicator used to measure students' understanding of the concept is to determine the trajectory of the object's motion. In the indicator of determining the trajectory of motion of objects, students are given a case of determining the trajectory of motion if the object is moved like Figure 5.

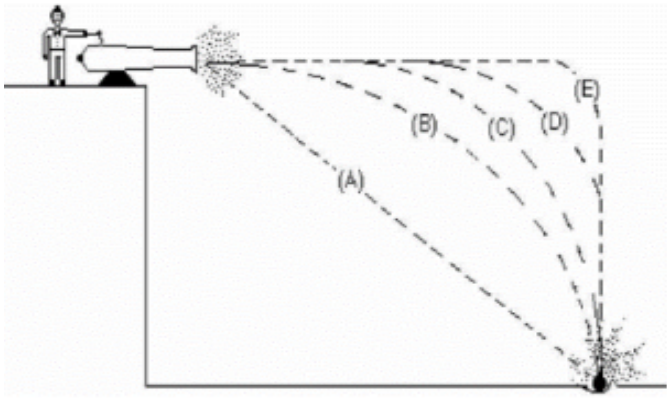


**Figure 5.** Parabolic motion concept case overview

In this case, students assume that the object will move to form a trajectory as described in option D, the teacher here explains that an object given a push at an elevation angle of 0°. then the object receives a push force that leads horizontally and is influenced by the gravitational force that leads vertically. So that the motion curve of the object is described by a parabola. The teacher also practised the event by pushing the eraser off the table, and the students watched the motion of the eraser. The teacher reduces the misconceptions that occur with the PCK component, the percentage reduction in misconceptions in the indicator of determining the trajectory of motion of objects is 27.3%, which means that the PCK component is not an appropriate component to reduce misconceptions in the indicator of determining the trajectory of motion of objects on the concept of parabolic motion.

*Uniform Speed Concept*

The indicator used to measure the understanding of the concept of Uniform speed is to determine the acceleration of the position of the object. The case given to measure students' concept understanding can be seen in Figure 6. Students have misconceptions by assuming that objects that have acceleration are objects with larger position intervals. The teacher explains that in this case to determine whether the object has acceleration or not, it is seen from the change in position at each time interval on each beam. If we see that beam A and beam B have a fixed change in position, which means that the velocity of the two beams is fixed or the acceleration on the two beams is nothing.

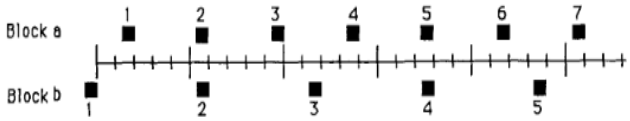


**Figure 6.** Case overview uniform speed

The reduction in misconceptions that occur in this is 42.8%, which means that the PCK component is an appropriate component to reduce misconceptions that occur in the indicator of determining the acceleration of the position of the object.

*Circular Motion*

Indicator used to measure understanding of the concept of circular motion is determining the trajectory of motion of objects. Students are given a case to determine the motion path in Figure 7.

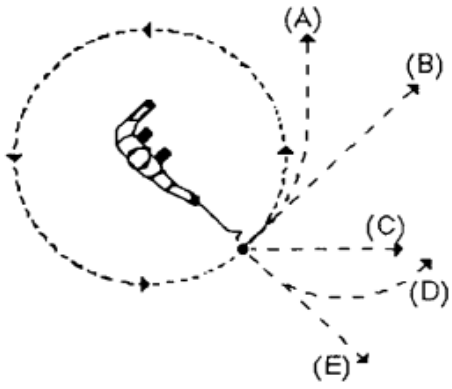


**Figure 7.** Circular motion concept case overview

Students assume that if an object initially moves on a circular trajectory then if the trajectory is suddenly removed the motion of the object will remain circular. The teacher explains again the principle of regular straight motion. The teacher also gives an example from Phet simulation using orbit simulation, where if gravity is removed on both objects then the circular moving object will move away with the trajectory as in Figure 8.

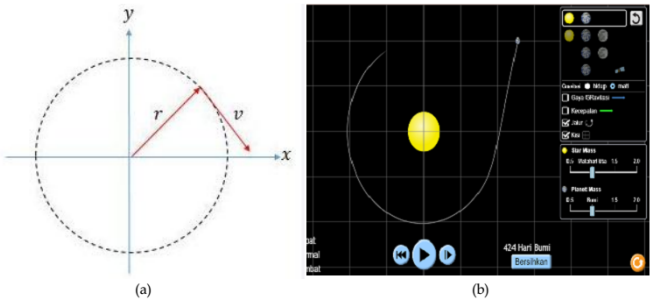


**Figure 8.** (a) Position vector and (b) Circular motion

The reduction in misconceptions after being given an understanding of the concept using the teachers technological knowledge, pedagogical knowledge and content knowledge component is 47.7%, which means that the TPACK component is an appropriate component to reduce misconceptions that occur in the indicator of determining the trajectory of motion of objects on the concept of circular motion. The use of technology is very effective in explaining specific and abstract concepts (Halim et al., 2020). This is also supported by research conducted by Sunarti et al. (2021) with the results According to Sunarti et al. (2021) the use of technology that can visualize the concept of circular motion can help students understand learning concepts. Interpretation of TPACK components used to reduce misconceptions that occur in the concept of circular motion.

Based on the descriptive results on each concept of the FCI test, it can be seen that the TCK and PCK components can reduce several indicators on the concepts of Newton's Law on the FCI test, but there are some indicators that do not decrease misconceptions or the decrease in misconceptions is very low so it is considered not suitable to be used to reduce misconceptions on these indicators.

Research in the same field has been carried out by previous researchers, including regarding misconceptions and thinking styles (Halim, Nurhasanah, et al., 2021), the impact of EduPlasa media on reducing misconceptions (Halim et al., 2020), the effect of E-learning modules on reducing misconceptions (Halim, Mahzum, et al., 2021). Besides, there are also several research results that have utilized the FCI test, including the use of the FCI test to develop level three diagnostic tests (Halim et al., 2020; Resta et al., 2020), to develop atomic model diagnostic tests (Halim et al., 2014), and to see the effect of level one, two and three diagnostic tests (Halim et al., 2017).

## Conclusion

Teachers' TPACK ability is proven to improve students' concept understanding. This can be seen in the N-Gain score >0.7 which means that the increase in concept understanding is in the high category. Teachers' technological knowledge assisted by pedagogic knowledge and mastery of concepts is proven to reduce misconceptions in the indicators of determining the time it takes for objects to reach the ground and determining the distance objects fall on the Free fall moyion concept, determining the trajectory of motion of objects on the uniform acceleration concept and determining the trajectory of motion of objects on the Circular motion concept.

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**Author Contributions**
The lead author, Meisy Adha Rizki, contributed to designing and conducting the research and writing the article. The second and third authors, A.Halim and Hafnati Rahmatan, took part in guiding the writing of the article to completion. The fourth, fifth, sixth, and seventh authors, Muhammad Syukri, Agus Wahyuni, Yusrizal contributed to validating the article instruments. All authors have approved the published version of the manuscript.

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**Conflicts of Interest**
The authors declare no conflict of interest.

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