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Exploring Engineering Students' Misconceptions About Motion and Forces Using Concept Cartoons

Randel D. Estacio[1], Erlee Angel S. Reyes[2] and Niña C. Apusaga[3]

[1]College of Education, Quezon City University
[2]College of Business Administration and Accountancy, Quezon City University
[3]College of Engineering, Quezon City University
[*]Correspondence: E-mail: randel.estacio@qcu.edu.ph

ABSTRACT

Misconceptions are viewed as barrier to students in learning concepts. Instruments like concept cartoon is one of the tools that may be used to examine students' science misconceptions. The study aims to identify the common misconceptions of selected engineering students at Quezon City University during the second semester of the Academic Year 2021-2022 using concept cartoons and explore the its applicability, appropriateness, and practicability. The study utilized a mixed-method approach. A total of 241 students and 7 science teachers participated in the study. Three types of concept cartoons were used to determine students' misconceptions in the topics motion, forces, and Newton's laws of motion. A validated survey questionnaire was used to determine the concept cartoon's applicability, appropriateness, practicability, and advantages and disadvantages. Results shows that concept cartoons are considered as applicable, appropriate, and practical tool in diagnosing students' misconceptions. It overcome the weaknesses of other diagnostic instruments. However, it offered similar weaknesses such as issues on longer testing time, students' response-rate, and teacher training in developing a well-constructed item. Study shows that in selecting suitable instrument to diagnose student's science misconceptions, instruments' applicability, appropriateness, and practicability should be considered.

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1. INTRODUCTION

Soeharto et al. (2019) described misconception as a well-known barrier to students in learning science. Science misconception according to the book titled Understanding Evidence-Based Treatment for Trauma-Exposed Children: Definition, Development, And Misconceptions. In B. Allen & M. Kronenberg (Eds.), Treating Traumatized Children: A Casebook of Evidence-Based Therapies, is personal information that has no relevance to scientific principles or has no meaning according to informal events or educational experiences. In other wordgas, science misconception is characterized as student notions from informal or real experiences that are poorly structured and give a scientific term a false interpretation.

In 1997, the National Research Council stressed that misconceptions in science serve as a major impediment to students' ability to understand the subject since they frequently prevent them from coming up with the right theories that serve as the foundation for further advanced learning. Similarly, King in 2010 revealed that misinterpretations in the Earth Science textbook affect students' comprehension of scientific materials and make it challenging for them to comprehend further information or knowledge as readers. Likewise, Moodley and Gaigher (2019) mentioned that science teachers may also have misconceptions when attempting to teach physics, chemistry, or biology subjects, which invariably results in misconceptions among students. Thus, misconceptions hinder students' and teachers' ability to learn science effectively and comprehensively.

Studies shows that misconceptions can be classified as either preconceived thought, non-scientific opinions about conceptual misunderstandings, conceptual misunderstandings, vernacular misconceptions, and factual misconceptions (Keeley, 2012; Leaper et al., 2012; Morais, 2013; Murdoch, 2018). And these classifications are simple to find, and there are probably many more. In addition, some science misconceptions are tenacious, resistant to change, and firmly embedded in some ideas. Thus, it is imperative to eliminate or correct misconceptions as soon as possible.

According to studies, multiple-tier and multiple-choice examinations, interviews, or combinations of these instruments are frequently used to diagnose students' misconceptions in science (Adimayuda et al., 2020; Gusmalini & Wulandari, 2020; Pikoli, 2020). As a result, a variety of test instruments are employed in conjunction with one another to generate insightful results about student misconceptions. Although both written and spoken instruments have advantages and disadvantages, like for example in a review and comparison of diagnostic instruments in science conducted by Gurel, et al. in 2015, they mentioned that the interview method provides an in-depth information but it requires a large amount of time to obtain and analyze the data; similarly an open-ended test provides respondents the chance to give new and valuable answers which are not thought the researcher before, but scoring them is one of the main problem; in a multiple choice test (ordinary, two-tier, three-tier, and four-tier) on the other hand, Gurel, et al. (2015) stressed that it is time efficient in terms of administering the test but it is open for guessing. They suggested that combining them effectively can improve the process of analysis used to gather data and eradicate any flaws present in a single instrument or develop an instrument that are more appropriate to serve the teacher's purpose.

The concept cartoon, created by Keogh and Naylor in 1999, is one of the tools that may be used to examine students' misunderstandings of science (Ceylan & Yiit, 2018). A concept cartoon is a visual tool with three or more characters that explores a concept that is relevant to daily life. One of the characters provides the proper ideas, and the other

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characters demonstrate the bad views (Yilmaz, 2020). According to studies, these concept cartoons can be useful in spotting students' misconceptions in fields of study such as chemistry (Kusumaningrum & Indriyanti, 2018), biology (Yong & Kee, 2017), physics (Atasoy & Ergin, 2017), earth science (Serttaş & Türkoglu, 2020), and mathematics (Karaoglan Yilmaz, et al., 2018).

Concept cartoons are also a useful technique for identifying students' misconceptions and are efficient at eliciting students' opinions without diluting other viewpoints. In light of the fact that concept cartoons can be used to uncover misconceptions among students, it is therefore anticipated that it will be able to identify students' misconceptions regarding forces and motion.

However, despite the number of available studies on the use of concept cartoons in science and mathematics education, research on concept cartoons as instruments to explore or identify students' misconceptions about motion and forces at the tertiary level, particularly among engineering students is extremely limited. Thus, to explore the common misconceptions of students and the use of concept cartoons in diagnosing students' misconceptions, this study was conducted.

Particularly, this study aims to determine the common misconceptions of selected engineering students at Quezon City University during the Second Semester of the Academic Year 2021-2022 using teacher-made concept cartoons and explore the views of students and teachers towards the applicability, appropriateness, and practicability of concept cartoons in diagnosing students' misconceptions. The study hypothesize that no significant difference exists between the students' and teachers' views towards the use of concept cartoons in terms of applicability, appropriateness, and practicability in diagnosing students' misconceptions.

On the other hand, the study is limited in exploring misconceptions of selected engineering students on the topics: Motion, Forces, and Newton's Laws of Motion, using teacher-made concept cartoons. The views of the students and teachers towards the use of concept cartoons as instrument in diagnosing students' misconceptions.

The significance of the present study lies in its contribution to the literature with the critical overview on how concept cartoons as instrument in diagnosing students' misconception in science is use. It provides an avenue for science teachers to examine their teaching practices and consider using concept cartoons as instrument in detecting students' science misconceptions and is critical in substantiating assertions made by recent studies that concept cartoons are equally good at revealing students' misconceptions.

2. METHOD

The study utilized a mixed-method design, particularly the concurrent triangulation design, in collecting and analyzing the data to address the primary objectives of this study. It was conducted in Quezon City University, Quezon City, Philippines during the second semester of the Academic Year 2021-2022.

The general population of the study refers to all first-year engineering students, either enrolled in the program Bachelor of Science in Industrial Engineering (BSIE) or Bachelor of Science in Electronics Engineering (BSEE) in Quezon City University during the second semester of the academic year 2021-2022. The total population is equivalent to 643 students, it is composed of four hundred seventy-nine (479) first-year BSIE or 74.49% and

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one hundred sixty-four (164) first-year BSEE students or 25.51%. From the total population, the researchers calculated the number of sample respondents using the Raosoft sample size calculator (http://www.raosoft.com/samplesize.html), where the margin of error is 5%, the confidence level is 95%, and the response distribution is 50%. Based on the calculation, the recommended sample size is 241 respondents.

In terms of the sampling procedure, to obtain the computed sample size, the respondents employed the stratified random sampling technique. A total of one hundred eighty (180) or 74.49% BSIE students and sixty-one (61) or 25.51% BSEE students are requested to participate in this study.

On the other hand, the total population of teacher respondents of this study refers to all science teachers in Quezon City University who are officially connected either full-time or part-time faculty member and handles Physics for Engineers subject during the second semester of the academic year 2021-2022. Since there are only seven (7) science teachers who handled the subject Physics for Engineers during the conduct of this study, the researchers employed the purposive sampling technique to obtain the sample.

To determine students' misconceptions, a total of fifteen (15) concept cartoons, five (5) concept cartoons each topic (Motion, Forces, Newton's Laws of Motion), were developed and classified into three different types. The first type of concept cartoon consists of a question with four options **(Figure 1)**. The student will choose the best answer and then write a short explanation why he or she chose that answer. On the other hand, the second type of concept cartoon present a concept or a question and two correct statements about the given concept or question **(Figure 2)**. There is one empty speech bubble where the student put his or her idea/s towards the given concept or question. The two correct statements aim to provide leading ideas for the student to come up with a relatively correct statement or answer. And the third type of concept cartoon present a concept or question accompanied with diagram and three empty speech bubbles **(Figure 3)**. The student needs to create a simple dialogue between the three characters that pertains to the concept and the diagram.

Figure 1. Sample concept cartoon with four options.

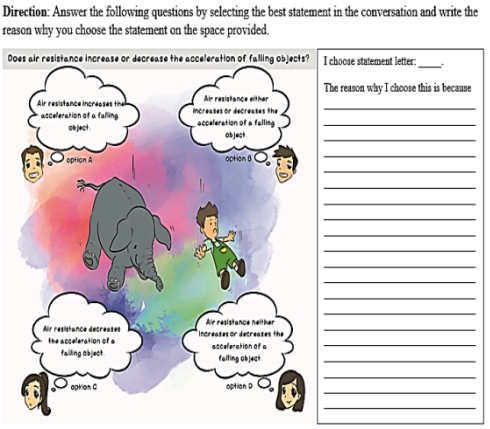

Figure 2. Sample concept cartoon with one empty speech bubble.

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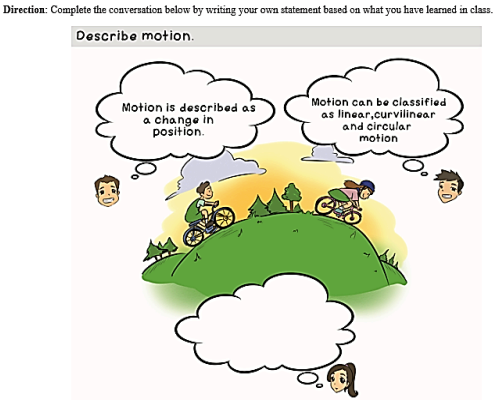

Figure 3. Sample concept cartoon with three empty speech bubbles.

Concept cartoons were given to the sample student respondents during the 18th week of the semester. And the collected responses were evaluated by the researchers using the holistic rubric guides developed by the primary author in 2017. Students' misconceptions were recorded, summarized and analyzed by the researchers. The evaluated concept cartoons were showed to students for them to determine their correct and incorrect answers, and the copy of results were also forwarded to the teacher respondents for them to see the common misconceptions of the students.

To determine the views of the students and teachers towards the use of concept cartoons in terms of its applicability, appropriateness, and practicability, a validated and reliable researcher-made survey questionnaire was given to the student and teacher respondents. The survey questionnaire is divided into two parts, the first part is composed of nineteen (19) items that explore the respondents' agreement on the concept cartoons' applicability, appropriateness, and practicability in diagnosing student's misconceptions and it is structured in a Likert format. The second part includes an open-ended question about the advantages and disadvantages of concept cartoons as instrument in diagnosing students' misconceptions.

Students' misconceptions were summarized and grouped according to themes and presented in a narrative and tabular form. The responses of student and teacher to the survey questionnaire were analyzed using descriptive statistical tools like mean and standard deviation. To test the null hypothesis presented in this study, the researchers employed Welch's Test for Unequal Variances or Welch's t-test (Zimmerman, 2004; Ruxton, 2006). And the perceived advantages and disadvantages of the use of concept

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cartoons as instrument in diagnosing student's misconception were also summarized and presented in a narrative form.

3. RESULTS AND DISCUSSION

3.1. Common misconceptions of students in the topics Motion and Forces

Table 1 revealed the students' common misconceptions on the topic motion, forces, and Newton's laws of motion as revealed by using concept cartoons.

Table 1
Students' common misconception as revealed in the concept cartoons

Topic	Students' Common Misconception as Revealed in the Concept Cartoons	N	%	Science Concept
Motion	"*In order to keep an object moving, force is needed.*"	186	77.18	Motion is modified by forces. When something is moving, no force is required to keep it moving; however, a force is required to stop anything from moving or to cause it to change direction.
	"*A moving object will eventually slow down and stop.*"	163	67.63	A moving object will continue traveling indefinitely if no forces are applied to it.
	"*Speed is the same with velocity.*"	159	65.98	Velocity is a scalar quantity, which includes magnitude and direction, while speed is classified as a scalar quantity which only includes magnitude. Thus, technically, velocity and speed are not the same.
Forces	"*A motionless object is not being affected by any forces.*"	192	79.67	The motionless object is stationary because all forces that act on it cancel out because they have the same magnitude but opposite directions.
	"*The normal force is always equal to the force of gravity.*"	180	74.69	The normal force is perpendicular to the surface of contact and does not necessarily equal or the same with the direction of the force of gravity.

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	"The elephant (heavier object) falls faster than the boy (lighter object)."	178	73.86	Greater gravitational force and lower acceleration are both characteristics of heavier objects. It turns out that these two processes precisely balance each other out to give falling objects of any mass the same acceleration.
Newton's Laws of Motion	*"The passengers act as the response force in the event that the driver abruptly stops the car due to the vehicle's action force when it brakes."*	182	75.52	The passengers' inertia prevents them from turning around even when the car brakes suddenly and encourages them to do so.
	"When something is thrown vertically upward, it briefly floats at its highest point, therefore there is no force applied there."	177	73.44	When an object is thrown vertically upward, gravity is the sole force acting on it if the buoyant force and friction force are negligible.
	"In a tug-of-war, the action-reaction pair force is present between the pull on the opposite end."	173	71.78	The primary driving force behind the game of tug of war is friction. The forces that the third law depicts as an action-reaction pair are commonly misidentified by students. They misidentify the action-reaction pair, which is equal and opposite to one another, as the force acting on a single mass.

Under the topic motion, the most common responses of students include "In order to keep an object moving, force is needed" with almost 186 similar responses out of the two hundred forty-one responses or 77.18%. It is followed by a statement "A moving object will eventually slow down and stop" With 163 similar response or 67.63% and "Speed is the same with velocity" With 159 similar response or 65.98%. These responses might be classified as students' misconceptions since according to facts and basic concepts in Physics, motion is modified by forces, thus when something is moving, no force is required to keep it moving; however, a force is required to stop anything from moving or to cause it to change direction. Also, a moving object will continue traveling indefinitely if no forces are applied to it. And velocity and speed are not the same because velocity is a scalar quantity, which includes magnitude and direction, while speed is classified as a scalar quantity which only includes magnitude.

In terms of the students' misconceptions under the topic forces, gathered students' responses using concept cartoons revealed that 79.67% or 192 students similarly said that "A motionless object is not being affected by any forces", while 74.69% or 180 of the students claimed that "The normal force is always equal to the force of gravity", and

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73.86% or 178 of the responses collected in the concept cartoon is that "The elephant (heavier object) falls faster than the boy (lighter object)". These three most common responses are considered students' misconceptions because basically, the motionless object is stationary because all forces that act on it cancel out because they have the same magnitude but opposite directions; while the normal force is perpendicular to the surface of contact and does not necessarily equal or the same with the direction of the force of gravity; and greater gravitational force and lower acceleration are both characteristics of heavier objects. It turns out that these two processes precisely balance each other out to give falling objects of any mass the same acceleration.

Table 1 also revealed that when the students are asked to answer concept cartoons dealing with the topics under Newton's Laws of Motion most of them said that "The passengers act as the response force in the event that the driver abruptly stops the car due to the vehicle's action force when it brakes" (N=182 or 75.52%). Students also said that "When something is thrown vertically upward, it briefly floats at its highest point, therefore there is no force applied there" (N=177 or 73.44%) as revealed in their responses using concept cartoon under the topic Newton's Laws of Motion. Lastly, students claimed that "In a tug-of-war, the action-reaction pair force is present between the pull on the opposite end" (N=173 or 71.78%).

3.2. Views on the use of concept cartoons as a tool in identifying student's misconception

Applicability

Applicability of the concept cartoons used in this study refers on the quality of the instrument in diagnosing student's misconceptions in the topic motion, forces, and Newton's laws of motion and how it is relevant or appropriate to achieve the goal of detecting student's misconceptions.

Table 2
Applicability of the concept cartoons as instrument in diagnosing student's misconception as viewed by the respondents

	Statement	Teacher			Student			Over-all			Rank
		X	SD	V.I	X	SD	V.I	X	SD	V.I	
1	Concept cartoons are reliable and useful at validating learner misconceptions.	3.71	0.76	A	4.01	0.82	A	4.00	0.82	A	3.5
2	Concept cartoons provide for in-depth research and the ability for elaboration in order to obtain precise descriptions of a student's cognitive structures.	4.29	0.76	SA	4.06	0.80	A	4.07	0.80	A	1
3	Concept cartoons make it possible to examine how each student's thoughts change over time.	4.14	0.69	A	4.03	0.80	A	4.03	0.81	A	2

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4	Concept cartoons aid in eliciting the thoughts and feelings of the student about the provided visual representation of scientific concepts.	4.14	0.90	A	3.93	0.81	A	3.94	0.81	A	5
5	Concept cartoons provide for the quick and efficient presentation of a wide range of subjects, including motion, forces, and Newton's Laws of Motion.	3.29	0.49	NAD	4.02	0.82	A	4.00	0.82	A	3.5
	Over-all Mean	**3.91**	**0.78**	**A**	**4.01**	**0.81**	**A**	**4.01**	**0.81**	**A**	

Legend:

4.20 - 5.00 Strongly Agree (SA)

3.40 – 4.19 Agree (A)

2.60 – 3.39 Neither Agree or Disagree (NAD)

1.80 – 2.59 Disagree (D)

1.00 - 1.79 Strongly Disagree (SD)

With a computed overall mean value of 4.01 (SD=0.81) and an interpretation of Agree, respondents agreed that concept cartoons serve its function as an instrument to diagnose students' misconceptions in science, particularly in topics related to motion, forces, and Newton's laws of motion.

The concept cartoons specifically, according to the two groups of respondents, allow for a thorough investigation and the potential for elaboration to acquire precise descriptions of a student's cognitive architecture (M=4.07, SD=0.80). Respondents also agreed that concept cartoons are useful in identifying students' misconceptions in a valid and reliable way (M=4.00, SD=0.82) and permit coverage of a wide range of topics (motion, forces, and Newton's Laws of Motion) in a relatively short amount of time (M=4.00, SD=0.82). Concept cartoons also allow for the study of the development of ideas of each student (M=4.03, SD=0.81). Last but not least, teachers and students who utilized the created concept cartoon concurred that the tool aids in eliciting the thoughts and feelings of the learner regarding the provided visual depiction of scientific concepts (M=3.94, SD=0.81).

Appropriateness

The appropriateness of the developed concept cartoons refers to the quality of how it is suitable or able to detect student’s misconceptions in the topics motion, forces, and Newton’s laws of motion.

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Table 3.
Appropriateness of the Concept Cartoons As Instrument in Diagnosing Student's Misconception As Viewed By The Respondents

	Statement	Teacher			Student			Over-all			Rank
		X	SD	V.I	X	SD	V.I	X	SD	V.I	
1	Concept cartoons are adaptable and can be used to gauge various levels of knowledge and cognitive ability.	4.00	1.00	A	4.01	0.79	A	4.01	0.79	A	5
2	Concept cartoons are appropriate for item analysis, which allows for the determination of numerous qualities.	3.86	0.90	A	3.90	0.83	A	3.90	0.83	A	8
3	In addition to being a suitable substitute for interviews and other qualitative tools in assessing students' knowledge and identifying the incidence and distribution of misconceptions within a population, concept cartoons also offer useful diagnostic information.	3.86	0.90	A	4.08	0.78	A	4.07	0.78	A	2
4	Concept cartoons are useful for students who are knowledgeable about a subject but have weak spoken skills.	4.14	0.69	A	4.06	0.82	A	4.06	0.81	A	3.5
5	Concept cartoons are objective in terms of scoring and therefore more reliable.	3.43	0.53	A	4.07	0.81	A	4.06	0.81	A	3.5
6	Concept cartoons can distinguish between students' correct answers based on scientific knowledge and those based on speculation.	4.14	0.90	A	3.93	0.79	A	3.94	0.79	A	7
7	Students are encouraged to respond and provide their views freely due to the appropriate graphics and general layout found in the concept cartoon.	3.86	0.90	A	4.00	0.81	A	4.00	0.81	A	6

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According to the overall weighted mean (M=4.02, SD=0.81) of their responses shown in table 3, both teachers and students surveyed for this study agreed that concept cartoons utilized in the study are suitable to identify students' misunderstandings of motion, forces, and Newton's laws of motion.

The two groups of respondents specifically concurred that the concept cartoons used in this study are devoid of biases and judgment, allowing students to respond to the questions based on what they actually know (M=4.13, SD=0.82) and provide useful diagnostic information, making them viable substitutes for interviews and other qualitative tools in assessing students' understanding and determining the prevalence and distribution of misconceptions across a population (M=4.07, SD=0.78). Concept cartoons are ideal for students who are knowledgeable about a subject but have weak public speaking skills, according to respondents (M=4.06, SD=0.81), and they are objective in terms of scoring, making them more dependable (M=4.06, SD=0.81).

The two groups of respondents concurred, according to the results, that concept cartoons are adaptable and can be used to assess various levels of cognitive ability and learning (M=4.01, SD=0.79), and that the graphics and general design of the instrument encourage students to respond honestly and freely (M=4.00, SD=0.81).

The respondents agreed, according to the data (M=3.94, SD=0.79), that the concept cartoons employed in this study may distinguish between students' right answers based on scientific knowledge and those based solely on guesswork. Finally, respondents concurred that concept cartoons are appropriate for item analysis, which may be used to identify various attributes (M=3.90, SD=0.83).

Practicability

An instrument's practicability relates to how well it can be put to use for the intended purpose. This speaks to the ability of the conceptual cartoons to identify students' misunderstandings of the concepts of motion, forces, and Newton's laws of motion. One of the main criteria employed in this study, practicability, also refers to how well the instrument can quickly identify students' misconceptions.

Table 4
Practicability of the concept cartoons as instrument in diagnosing student's misconception as viewed by the respondents

	Statement	Teacher			Student			Over-all			Rank
		X	SD	V.I	X	SD	V.I	X	SD	V.I	
1	With concept cartoons, students have more time to reflect and articulate their own ideas.	3.57	0.98	A	4.00	0.82	A	3.99	0.82	A	4.5

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2	Concept cartoons, which can be instantly graded and utilized for a wide range of subjects, have been used to determine students' concepts.	4.14	1.07	A	4.07	0.83	A	4.07	0.83	A	1
3	Teachers can efficiently evaluate their students' grasp of science by using concept cartoons.	4.14	0.90	A	4.00	0.82	A	4.00	0.82	A	3
4	Concept cartoons are easy-to-administer.	3.57	0.98	A	3.92	0.79	A	3.91	0.80	A	6
5	Students find it reasonably easy to answer to inquiries about the specified topic or concept while using concept cartoons.	4.29	0.76	SA	3.98	0.80	A	3.99	0.80	A	4.5
6	Concept cartoons are more useful and practical for teachers to utilize since they eliminate guesswork, enable widespread administration and simple scoring, and provide insights into students' reasoning.	4.29	0.76	SA	4.05	0.81	A	4.06	0.81	A	2
	Over-all Mean	**4.00**	**0.91**		**4.00**	**0.81**	**A**	**4.00**	**0.81**	**A**	

Regarding the applicability of the instrument, respondents concurred that the concept cartoons employed in the study can identify students' misunderstandings of the concepts of motion, forces, and Newton's laws of motion (M=4.00, SD=0.81).

Particularly, according to respondents, the concept cartoons used in the study are more practical and valuable for teachers to use in terms of reducing guesswork, enabling large-scale administration and easy scoring, and providing insights into students' reasoning (M=4.06, SD=0.81). They can be instantly scored, applied to a wide range of subjects, and used to ascertain students' conceptions (M=4.07, SD=0.83).

Additionally, the concept cartoons employed in the study provide students more time to reflect and write about their own ideas (M=3.99, SD=0.82) and enable teachers to evaluate students' grasp of science more effectively (M=4.00, SD=0.82). The respondents also concurred that students find it rather easy to respond to questions about motion, forces, and Newton's laws of motion when using the concept cartoons employed (M=3.99, SD=0.80). The concept cartoons utilized in the study, according to teachers, are simple to administer (M=3.91; SD=0.80).

3.3 Difference between the students' and teachers' views towards the use of concept cartoons in terms of applicability, appropriateness, and practicability in diagnosing students' misconceptions.

To test the difference between the students' and teachers' views towards the use of concept cartoons in terms of applicability, appropriateness, and practicability in diagnosing students'

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misconceptions, the Welch's t test is used since the samples for each group are not equal and the variance of their responses are unequal as well. Table 5 shows the results of the Welch's t test.

Table 5
Mean difference between the students' and teachers' views towards the use of concept cartoons in diagnosing students' misconception

Variable	Teacher			Student			t (df)	p	Interpretation	Decision
	N	M	SD	N	M	SD				
Applicability	7	3.91	0.78	241	4.01	0.81	-.582 (6)	.581	Statistically Not Significant	Accept H_0
Appropriateness	7	4.00	0.85	241	4.02	0.81	-.312 (7)	.765	Statistically Not Significant	Accept H_0
Practicability	7	4.00	0.91	241	4.00	0.81	-.096 (8)	.926	Statistically Not Significant	Accept H_0

In terms of applicability, results show that the mean response of teachers (M=3.91, SD= 0.78) is almost equal to the mean response of students (M=4.01, SD = 0.81), t(6)= - .582, p>.001. The null hypothesis is accepted. It implies that the response of teachers towards the applicability of concept cartoons in diagnosing student's misconceptions in the topic motion, forces, and Newton's laws of motion do not have significant difference on the responses made by the students.

Similarly, in terms of appropriateness, results show that the mean response of teachers (M=4.00, SD= 0.85) is almost equal to the mean response of students (M=4.02, SD = 0.81), t(7)= - .765, p>.001. The null hypothesis is accepted. It implies that the response of teachers towards the appropriateness of concept cartoons in diagnosing student's misconceptions in the topic motion, forces, and Newton's laws of motion do not have significant difference on the responses made by the students.

Lastly, in terms of practicability, results show that the mean response of teacher (M=4.00, SD= 0.91) is equal to the mean response of students (M=4.00, SD = 0.81), t(8)= -.926, p>.001. The null hypothesis is accepted. It implies that the response of teachers towards the applicability of concept cartoons in diagnosing student's misconceptions in the topic motion, forces, and Newton's laws of motion do not have significant difference on the responses made by the students.

3.4 Advantages and Disadvantages of Using Concept Cartoons

To the question what are the possible advantages of using concept cartoons as instrument in diagnosing student's misconceptions? common response made by the respondents is that the instrument is applicable, appropriate, practical and has the ability to detect student's misconceptions in the topic motion, forces, and Newton's laws of motion. Striking responses of teachers and students in the given question are presented below:

Teacher Responses:

> *"Since the availability of the holistic and analytic rubric guides, assessing and interpretating student's responses is much easier for the checker."*

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"Presented diagrams help the students to provide a correct, sensible and relevant answer."

"Choices presented in the concept cartoon provides a deep insight into student ideas or conceptual understanding. The instrument also encourages the student to give his or her own ideas that may help the teacher to determine the student's misconceptions."

"The instrument minimizes false positive and negative answers. Students who chose the correct answer were able to provide correct justifications. Maybe because the diagram or the scenario helps."

Student Responses:

"I have the freedom to say what they wanted to say on a given concept."

"The day-to-day scenario presented in the concept cartoon allows me to think and come-up with the best possible answer to the question or given statement."

"I am not forced to choose each answer from among a very limited list of options, which allows me to construct, organize and present my own answers."

To the question what are the possible disadvantages of using concept cartoons as instrument in diagnosing student's misconceptions? common response made by the respondents is that the instrument is somehow challenging to administer, because it requires number of papers and it should be printed in colored format, for the students to appreciate the material effectively. Common responses in the given question are presented below:

"The primary difficulty in this kind of instrument (concept cartoons), is in interpreting students' responses if the content, diagram, or scenario of day-to-day activity is not constructed carefully."

"Training in assessing student's response in a concept cartoon is highly needed".

"At some point, language problems, identification of students' misconceptions becomes a little bit challenging since students are generally less eager to write their answers in full sentences."

"It requires longer testing time."

3.5 Discussion

Student's misconceptions impede learning or the identification of productive components of these flawed conceptions for other contexts. Identifying these misconceptions in a valid and reliable way is the first step in addressing the issues. In this study, the developed concept cartoons are used to diagnose persistent or recurring learning difficulties that are left unresolved and are the causes of learning difficulties.

Three of the most common misconceptions under the topic motion includes: (1) The presence of force to keep an object in motion; (2) Moving object will eventually slow down and come to stop; and (3) Speed is the same as velocity. These misconceptions about motion also reveals in a study conducted by Kim and Pak in 2002, Reif and Allen in 1992, and Trowbridge and McDermott in the 1980s. These misconceptions can often stem from students' inability to distinguish between velocity, acceleration, and force (Reif and Allen 1992; Trowbridge and McDermott 1980). On the other hand, the three common misconceptions of the students under the topic forces as revealed by the developed concept

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cartoons in this study are: (1) No forces acting on a stationary object; (2) Normal force is always equal to the force of gravity; and (3) Heavier object falls faster than a lighter object. And lastly, the common misconceptions of students in the topic Newton's laws of motion as revealed by concept cartoons are: (1) Passengers reaction when the driver abruptly stops the car is caused by the car's action force when it brakes. This misconception is also revealed in the study conducted by Clement (1982), from book titled Force Concept Inventory. The Physics Teacher by Hestenes, D., Wells, M., & Swackhamer, G. (1992), and Thornton and Sokoloff (1998); (2) Object thrown upward momentarily floats at its highest point, therefore there is no force applied there. This type of misconception also revealed in the study of Pablico in 2010; and (3) In a tug-of-war, the action-reaction pair force is present between the pull on the opposite end.

According to recent studies (Bar et al. 2016; Kavanaugh and Sneider 2007), such as the tertiary engineering students who took part in this study, it appears that the above-mentioned notion is poorly understood at the lower level, and associated misconceptions persist in higher levels of education. Additionally, despite conventional physics training, many of these misconceptions about motion, forces, and Newton's laws of motion have been found to persist, blocking students from understanding new ideas.

In terms of the views of respondents towards the use of concept cartoons as instrument in diagnosing students' misconceptions in the topics motion, forces, and Newton's laws of motion, they claimed that the concept cartoons used in this study served as an instrument to obtain precise descriptions of a student's cognitive structures. Thus, concept cartoons developed in this study are applicable because the instrument is valuable in diagnosing student's misconceptions in the topic motion, forces, and Newton's laws of motion and it is highly relevant or appropriate to achieve the goal of detecting student's misconceptions.

Furthermore, both teachers and students agreed that the concept cartoons used in this study are unbiased and lack of judgment, thus, students are able to answer the questions honestly and based on what they really know. Therefore, concept cartoons used in this study, according to the respondents are appropriate when it come to diagnosing students' misconceptions in the topic motion, forces, and Newton's laws of motion.

Concept cartoons have been shown in research to improve students' critical thinking abilities (Demirci and Özyurek, 2017; Yin and Fitzgerald, 2017). Regarding the fact that they establish a learning environment ideal for the constructivist approach and address challenges that may arise during the teaching process, concept cartoons are recommended as teaching resources to be used in science education quoted from book by Keogh, B., & Naylor, S. (1997). Thinking About Science Posters: Developing Ideas Through Concept Cartoon Posters. Students can explore their ideas in class, challenge their knowledge, and organize their cognitive structures with the use of concept cartoons (Evrekli et al., 2011). Concept cartoons can also be used to correct students' mistakes and enhance their conceptual comprehension (Stephenson and Warwick, 2002).

Results also revealed that the concept cartoons developed in this study are considered as practical by the respondents. Practical in a sense that the concept cartoons are able diagnose students; misconceptions purposely. Concept cartoons are able and quickly identify students' misconceptions of the concepts of motion, forces, and Newton's laws of motion according to the respondents. Particularly, both teachers and students said that the concept cartoons are easily graded and utilized for a wide range of subjects, have been used to determine students' concepts.

Furthermore, data revealed that using the Welch's t test, there is no statistically significant difference between the students' and teachers' views towards the use of concept

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cartoons in terms of applicability, appropriateness, and practicability in diagnosing students' misconceptions. Which means that, concept cartoons as instrument in diagnosing students' misconceptions in the topics motion, forces, and Newton's laws of motion are considered by teachers and students as applicable, appropriate, and practical.

The quantitative data results of this study coincide with the qualitative data results as revealed by the common responses of both teachers and students who answered the question about the possible advantages and disadvantages of using concept cartoons as instrument in diagnosing student's misconceptions. Respondents agreed that concept cartoons are applicable, appropriate, practical and has the ability to detect student's misconceptions in the topic motion, forces, and Newton's laws of motion. Teachers agreed that because of the availability of the holistic and analytic rubric guides, assessing and interpretating student's responses (identifying students' misconceptions) is much easier for them. Respondents also claimed that the presented diagrams help the students to provide a correct, sensible and relevant answer. Studies have shown that students struggle to comprehend and relate fundamental scientific ideas to the outside world, which has interfered with the development of understandable scientific ideas that can be applied in daily life (Oztas & Oztas, 2016; Lewis & Wood-Robinson, 2000). Thus, by the appropriate diagram or scenario given, concept cartoons assist students in connecting scientific concepts, particularly in motion, forces, and Newton's equations of motion. For Oztas & Oztas (2016), studying scientific principles would be more meaningful if they could be applied to actual situations. Additionally, as stated by Ausubel in 1968, meaningful learning occurs when the learning activity can be connected to what the learner already knows in a non-arbitrary and useful way.

When students are given scientific material in a way that does not force them to confront paradoxes and conflicts brought on by their own preconceived concepts and non-science views, conceptual errors occur, claim Miller et al. (2007). Students create flawed models to explain their perplexity, which are typically so inadequate that the students themselves lack confidence in the notions. Data showed that the concepts illustrated in the concept cartoon offer a deep insight into students' concepts or ideas. The tool also invites students to share their own thoughts, which may aid the teacher in identifying the students' misunderstandings.

Similar with other diagnostic instruments, concept cartoons are able to minimize false positive and negative answers. Students who chose the correct answer were able to provide correct justifications, because of the diagram or the scenario presented according to the teacher respondents. Likewise, students claimed that with the use of concept cartoons, they have the freedom to say what they wanted to say on a given concept, and they are not forced to choose each answer from among a very limited list of options, which allows them to construct, organize and present their own responses. Students also claimed that the day-to-day scenario presented in the concept cartoon allows them to think and come-up with the best possible answer to the question or given statement.

Concept cartoons are quite helpful at helping students visualize concepts, participate actively in class, and defend their positions (Morris et al., 2007). Concept cartoons assist students see scientific truths while seeking and encourage them to conduct research (Kabapnar, 2009; Keogh and Naylor, 2000). Students are exposed to different ways of thinking through concept cartoons; misconceptions of students who share the same concepts are exposed; and causes of these misconceptions are examined in the classroom. Concept cartoons' use of visuals that are pertinent to the material being taught helps students pay attention to the material and makes learning enjoyable (Balm et al., 2008).

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The advantages of concept cartoons as instrument to diagnose students' misconceptions mentioned by the respondents in this study address the weaknesses of different diagnostic examination instruments (Gurel, et al., 2015) in diagnosing students' science misconceptions.

On the other hand, common disadvantage of concept cartoons as instrument in diagnosing students' misconceptions includes but not limited to the idea that it is hard to interpret students' responses if the content, diagram, or scenario of day-to-day activity is not constructed carefully. Studies on recognizing misconceptions and how to rectify them (Ozkan & Bal, 2017; Fujita, 2012) have shown that it is essential to provide explanations using a hierarchal categorization system in order to address these misconceptions. said that inaccurate impressions can be caused by prototype samples. Additionally, based on their academic performance, students used the samples that came first. Students were shown to have issues understanding the semantic relationships between words and figures (Roberts, 1995), and quoted from book Preservice Teachers and The Learning of Geometry. In Proceedings of CERME (Vol. 7) by Fonseca, L., & Cunha, E. (2011) Fonseca & Cunha found that they were unable to make conceptual connections even when employing analogies.

Furthermore, since concept cartoons yields various responses from the students, a teacher training is highly needed in assessing student's response made in a concept cartoon and considered to be one of the disadvantages of using concept cartoons in class. Also, identification of students' misconceptions becomes a little bit challenging since students are generally less eager to write their answers in full sentences according to teachers. Both teachers and students also agreed that it requires longer testing time when concept cartoons are used. These challenges are also considered as primary challenges of diagnostic examinations used in identifying students' misconceptions in science according to Gurel et al. (2015).

4. CONCLUSION

Concept cartoons used in this study are considered by teachers and students as applicable, appropriate, and practical instrument in diagnosing students' common misconceptions in the topic motion, forces, and Newton's laws of motion. Concept cartoons help the teachers to easily and quickly identify students' science misconceptions that are persistent among learners until tertiary level and might impedes learning and understanding scientific concepts.

Concept cartoons overcome the weaknesses of other diagnostic instruments used in diagnosing students' science misconceptions such as issues on scoring, students' guessing, minimizing false positive and false negative response, and providing freedom to respond. However, concept cartoons posed similar weaknesses such as longer testing time, students' response-rate, and teacher training in developing a well-constructed item.

As mentioned, concept cartoons have its own strengths and limitations. Therefore, in selecting appropriate instrument to diagnose student's science misconceptions, teachers should consider the instruments' applicability, appropriateness, and practicability. Careful development of appropriate content and design of the concept cartoons is also necessary and needed to master by the teacher to maximize the usefulness of concept cartoons as instrument in diagnosing student's misconception.

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