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Teaching and Learning Bucket Model: Experimented with Mechanics Baseline Test

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Abstract: Mechanics, as a large part of physics, shows the most basic concepts we encounter in our daily lives. With this regard, we implemented the mechanics baseline test (MBT) to the University of Rwanda - College of Education before and after the teaching mechanics module to track students learning. About 38 students participated in this study. We found the instructional strategies used to fit in a model we named "teaching and learning bucket" (lecturer backing and learners owning learning) during data analysis. The results showed that the performance occurred only in 12 out of 26 MBT items at a $p<.001$, and Cohen's D effect size of 1.26. Such analysis also allowed us to identify areas of mechanics that need teaching improvement, such as (a) constant acceleration, (b) average velocity, (c) the first law of Newton, (d) work and energy, and (e) energy conservation. There was also a positive correlation ($r=0.58$) between students' confidence in answering questions and correct answers provided and vice versa. Therefore, the research significantly informs lecturers to use various teaching approaches to effectively employ the teaching and learning bucket (TLB) model.

Keywords: *Mechanics, TLB model, MBT, URCE students.*

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Introduction

A mechanics baseline test (MBT) is a universal test covering most introductory mechanics from high school to university level (Hestenes & Wells, 1992). Many studies have evaluated its effectiveness in comparing various instruction modes. For instance, researches have proved that students performed well in the MBT after being taught through active learning methods (Eijkelhof, 2011; Hestenes & Wells, 1992; Jackson, 2003; Mashood & Singh, 2013) by their lecturers. There are several tests related to MBT. One is its predecessor, force concept inventory (Hestenes et al., 1992); another is its successor: force and motion conceptual evaluation (Thornton & Sokoloff, 1998). All of these inventories aim at improving students' mechanical concepts understanding. The force concept inventory (FCI) improves learning and the teacher's knowledge and approaches (Savinainen & Scott, 2002). Together with FCI, MBT investigates the preconceptions mismatched with physics courses (Hestenes et al., 1992).

Many researchers have also investigated difficulties in students' understanding of mechanics concepts. For instance, in their multiple-choice test of energy and momentum concepts, Singh and Rosengrant (2013) found that most students had difficulties interpreting basic principles related to energy and momentum qualitatively, and they were not able to apply them in physical contexts. Interpreting linear, rotational, and rolling motion challenges students (Rimoldini & Singh, 2005) and teachers (Mashood & Singh, 2012b). During the understanding of the kinematics graphs test, the preconceptions and learning gains of students were evaluated, and authors found that first-year engineering students are challenged by drawing and interpreting kinematic graphs (Vaara et al. 2019). Some results visualize challenges arising between concept inventories and their use to evaluate the curricular reforms (Caballero et al., 2012). It should, therefore, emphasize that concept inventories often do not affect core course content. Thus a careful "comparison between courses with and without reform can be made only on content that is present both in courses, and the composition of the evaluation instrument itself represents a particular selection of content and goals (Caballero et al.,

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2012, p. 643)." In their study (Mashood & Singh, 2012a) of rotational kinematics of a particle, there was a poor performance on related inventory even among highly ranked academic people such as teachers and doctoral students. This fact informs the instructors who teach to test to advocate for declining unimaginative and rote learning habits. The cognitive theory of Piaget (1964) explains this well. Specifically, the cognitive learning theory emphasizes active learning among students and fully exploits their minds (Piaget, 1964; Tennyson & Rasch, 1988). Most of its ideas are to build on existing knowledge to accommodate new information. This theory is multifaceted, such that various psychologists have come with supporting theories. For instance, Jerome Bruner showed how teaching is the input while learning is the output of mental processes (Bruner, 1990).

Although mechanical inventories such as MBT have improved students' conceptual understanding, well-crafted active learning strategies should be employed to overcome related difficulties. Several approaches have shown a positive impact. For instance, peer instruction (Mazur & Hilborn, 1997) has demonstrated active learning of physics along ten years of the study (Mazur, 2001). Interactive engagement excites students' collaboration (Eijkelhof, 2011; Hake, 1998), classroom demonstration entertains students (Crouch et al., 2004), and just-in-time teaching engages students before class (Sayer et al., 2016). Real-time physics active laboratory and interactive lecture-demonstration allow students to hand-on laboratory equipment (Sokoloff, 2012; Thornton & Sokoloff, 1998). They have all showed remarkable results towards the performance of concept inventories. Therefore, to teach scientific concepts, teachers and lecturers must be well equipped with well-designed and selective effective instructional strategies, among others. It is the reason why we were interested in investigating the Lecturer's instructional strategies implemented in the mechanics' module. Due to the limited literature comparing students' rating difficulty of MBT, the present study measured the linkage between MBT score and students' confidence in performance to show what works and what does not so that lecturers matter on selective instructional strategies delivering lessons. They also should be aware of which areas of mechanics need further or specific improvement.

Therefore, the specific research questions were to:

i) What areas of mechanics are improved by the teaching and learning bucket model?

ii) What is the linkage between students' MBT performance and their confidence?

iii) What would be the role of lecturer backing and learners owning learning during mechanics learning?

Methodology

Research design

The study employed a quantitative method. It was experimentally designed, where a small class (sample of 38 students) of freshmen[†] students at the University of Rwanda - College of Education (URCE) during a period from November 2019 to February 2020 was used. Thus, a one-group pretest-posttest design (Fraenkel et al., 2012) was used, where we observed the students from a single class, measured their prior knowledge, exposed them to the treatment of some sort, and then after measured the attained knowledge (see Figure 1).

Figure 1 Flowchart of Research design

We requested them to perform the MBT before starting the mechanic's course (module of PHY 1141). This module covers the primary content of mechanics with an increment of calculus. For instance, about eight chapters are taught within three months, where the whole module is given 100 hours; among them, 32 hours are provided to the Lecturer in terms of lectures. Sixteen hours to seminars/workshops, practical classes/laboratory, and structured exercises, while the rest of the hours are reserved for students' self-reading, self-directed study, assignments, and examination. These eight chapters are (a) Vector operations, (b) Physical quantities and Measurements, (c) Kinematics of a particle. (d) Dynamics of translation motion of the rigid body, (e) Work and Energy, (f) Dynamics of rotational motion of the rigid body, (g) Gravitation motion, and (h) Mechanical oscillations. During the lessons, we observed how the Lecturer taught and how the learners learned; however, there was no tool used (Ndihokubwayo et al., 2019) as we were not interested in collecting qualitative data nor document classroom practices apart from the test on MBT and MBT survey (see Appendix). After studying, we asked the students to retake the same test. Alongside retaking the MBT test, students took an attitude test on how they were confident while answering each test item.

[†] These students were in their first year at college

Preliminary results

According to Hestenes and Wells (1992), MBT fits well in post-testing after covering specific content. However, teachers are allowed to administer it even before teaching to check prior knowledge regarding advanced university courses as long as they avoid teaching to the test. Therefore, Figure 2 shows the results of URCE students' performance before starting PHY 1141 Mechanics module.

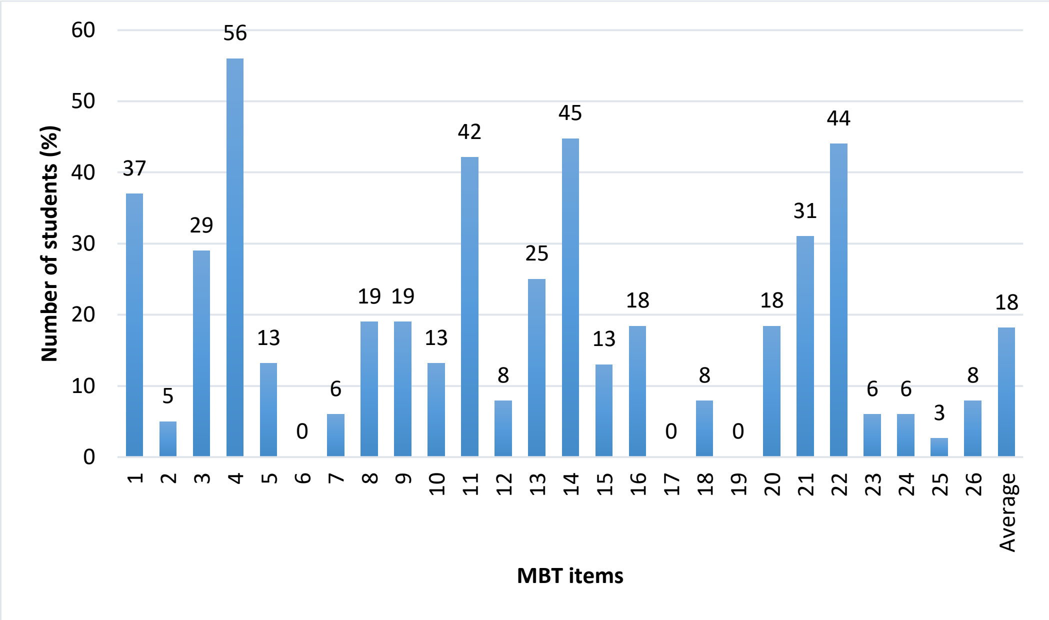

Figure 2. Students' performance before starting Mechanics module (PHY 1141)

We can observe that except for item 4, where more than 50% of students successfully performed it, below half of the students (18%) performed the test correctly. In 11 items (2, 6, 7, 12, 17, 18, 19, 23, 24, 25, and 26) only below 10% of students were able to get correct answers.

The MBT consists of 26 items covering about 17 concepts (Table 1). In this table, the questions under the 'selected items' column (12 items) are ones we considered for evaluating our teaching instruction. The reason for this was that we found there was no improvement after teaching the mechanics module in the rest of the items. Thus, in the results section, we present the results of about 12 MBT items. In their study (Cardamone et al., 2012), a limited subset of the highest quality questions on the MBT returns accurate measures of students' skills. Therefore, through item response theory, student skills were compared to the traditional measurement of the raw score, and a comparable measure of learning gain was confirmed to be calculated.

Table 1. MBT covered items (last column). MBT items column was arranged by Hestenes and Wells (1992)

	MBT covered content	**MBT items**	**Selected items**
1	Constant acceleration	1, 2, 3	
2	Average acceleration	18, 23	23
3	Average velocity	25	
4	Integrated displacement	24	24
5	Tangential acceleration	4	4
6	Normal acceleration	5, 8, 12	8
7	$a=v^2/r$	9, 12	9
8	The first law of Newton	2	
9	Second law of Newton	3, 8, 9, 12, 17, 18, 21	8, 9, 21
10	Third law of Newton	12, 13, 14	13
11	Superposition principle	5, 7, 13, 19	7, 13, 19
12	Work and energy	20	
13	Energy conservation	10, 11	
14	Impulse and momentum	16, 22	22
15	Momentum conservation	15	15
16	Gravitational free-fall	6, 26	6
17	Friction	9	9
	Total	26	12

Since this mechanics module's general objectives are to enable students to gain knowledge, develop the capacity to observe, analyze, apply, interpret, and perform hands-on activities related to mechanics (Baziruwiha & Ntivuguruzwa, 2011), during teaching this module, various instructional approaches were employed. We have analyzed and classified them into two main directions making a teaching and learning model named "teaching and learning bucket (TLB)."

This model shows three elements that a lecturer was occupied with and three elements that learners were occupied with. We have structured the three elements that the Lecturer employs as lecturer backing with three elements that learners hold as learner owning learning.

Lecturer backing (LB)

Lecturer backing means assistance, support, or back-up provided by the Lecturer. It is backing because the Lecturer does not seem to act directly, instead waits for students doing and acts indirectly to support where and when needed. In pure lecturer backing, the Lecturer explained the learning content, demonstrated the content on the whiteboard using a graphical representation, conventional laboratory, or any other technological tool (such as YouTube videos, computer simulation, etc.), and supported learners to understand learned content. In short, it was an explain-demonstrate-support (EDS) cycle.

Learner owning learning (LOL)

Learner owning learning occurs when the learner feels he/she can participate in his/her learning. It is an attitude to maintain, hold, or possess the capacity to learn. In pure learner owning learning, learners read books or lesson notes and made a summary, present to their classmates, and reflected on their lesson by answering questions raised by any of their classmates. In short, it was a homework-presentation-reflection (HPR) cycle.

Actually, due to the constructivism theory (Piaget, 1970), these two approaches would not sustain if they did not connect to each other (see Figure 3).

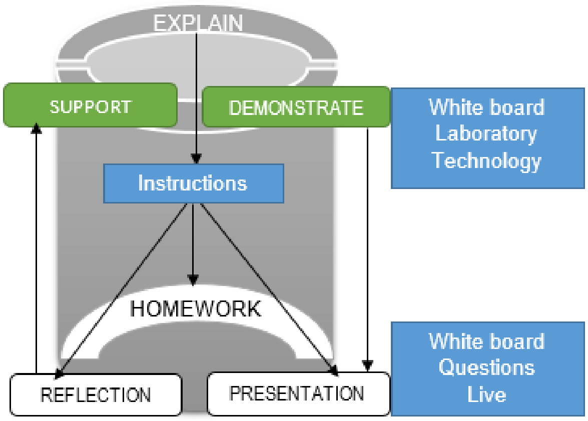

Figure 3. Teaching and Learning Bucket Model

Only the lecturer backing could self-sustain, but learner owning learning always needed lecturer backing. Therefore, it showed the importance of the instructor. However, both approaches could give a good outcome if used interconnectivity. For instance, at the beginning (first step), instead of the Lecturer explained, he/she provided instructions on what to do. The Lecturer assigned homework to learners. The homework was in the form of reading notes and summarizing before coming to class (just-in-time teaching, JiTT (Formica et al., 2010)). It was also researching other sources of information such as books, experts, or the internet. The assignment was about any work indirectly related to learning content (e.g., natural phenomena related to mechanics, inspiration from inventors found in mechanics, etc.).

The cognitive learning theory promotes the teaching and learning bucket model as it calls the Lecturer to intervene in his/her students' learning only when needed. Otherwise, students are given room to learn by themselves first before seeking support from their instructor. This theory shapes various learning strategies. For instance, Jean Piaget emphasized the learner-centered pedagogy that puts learners in the center of learning and nominates teachers as guides (Piaget, 1964, 1970). David Ausubel distinguished meaningfully from rote learning so that adding a piece of new information is easy when it is added on relevant knowledge, and each task should have a purpose in learner learning (Ausubel, 1960).

This is why, in the second step, the Lecturer gave instructions on how to present their findings or readings, group of learners presented, and learned from each other (classmates). In another form of a class presentation, the Lecturer assigned different questions related to planned teaching content to each group, given time to prepare, and then let them present to the rest of the class. Another form of the presentation came when indirect homework was assigned, and it needs practical or live presentation apart from the whiteboard. For instance, the Lecturer requested students to explain and make real objects using the mechanical concept. Students described the working principle of objects such as the engine, gear, the car, lift, helicopter, etc., and created equipment such as boats to show the density and pressure concept, ropeway transportation to explain friction force, etc. In that case, students created those devices and prototypes and demonstrated live how they work outside class.

In the last phase, the Lecturer allowed learners to ask and answer each other questions or support each other. We observed a similar approach when, for example, the Lecturer showed a YouTube video where he/she should ask the learners to discuss what they learned from it, their excitation, doubt, and new thinking). In this phase, the Lecturer also provided constructive theoretical support so that learners understand fully. Alongside these models, we asked students to rate each method to perform MBT items and their confidence while performing the test.

Data analysis

In the MBT, we recorded students' answer choices in MS Excel sheet, where every student's answered letter (A, B, C, D, or E) was entered alongside MBT items. We computed "COUNTIF" function to get the number of students who selected each letter to visualize those who selected the correct answer or those who selected any of the rest distractors. We then computed "IFEXACT" function to get the test's performance by sum-up the total score each student got in all items and to reveal the difficulty of items by sum up the number of students who performed well on each item. This was done to answer the first question. The inferential statistics such as p-values and effect sizes were calculated to show the Lecturer's instructional strategies.

To answer the second and the last question, an MBT- Survey Questionnaire was used. The survey has two sections to respond to these questions, respectively. In the first section, students would link how they answered the MBT test to their confidence (see Appendix). For instance, the student would say, "I answered item 1 confidently, by guessing (not sure), or I just ticked (no idea at all)." He/she also went ahead to explain the reason why he/she answered by guessing or just by ticked (the Lecturer did not explain it well, it is difficult, I do not remember, or any other reason (write it down instead of tick))." The second section provided students a room to select various teaching strategies (used in their lessons) that might affect how they answered the MBT test. To analyze these data, we recorded their answer in an MS Excel sheet. We computed frequencies and corresponded students' MBT survey answers with their MBT test answers.

Findings / Results

Considering MBT items 4, 6, 7, 8, 9, 13, 15, 19, 21, 22, 23, and 24, Figure 4 presents the students' results before and after the learning mechanics' module.

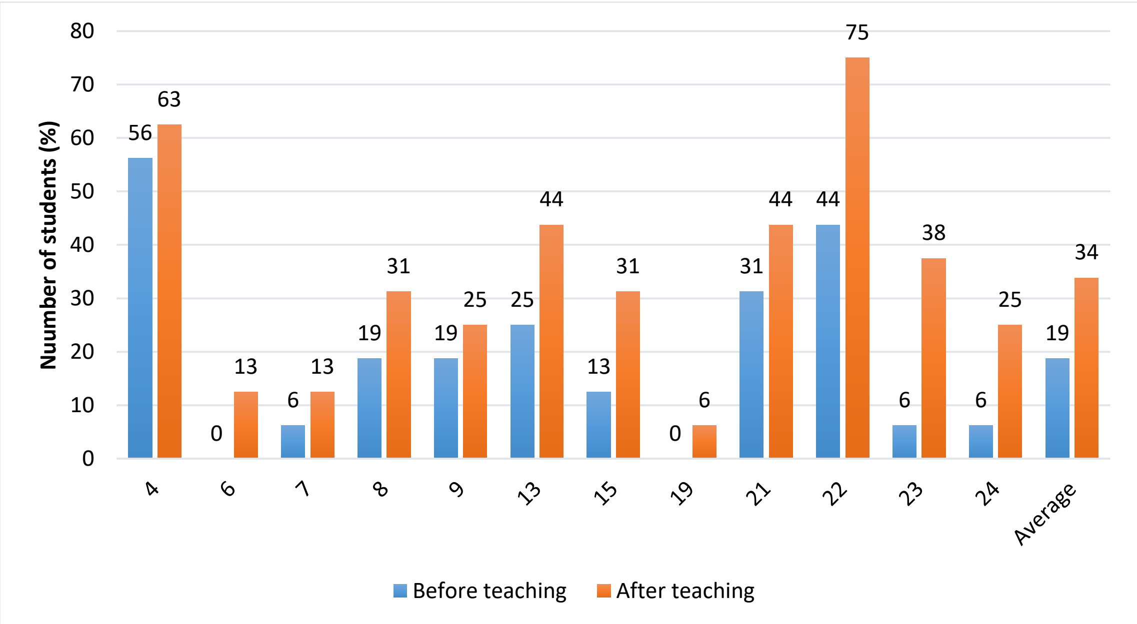

Figure 4. URCE students' performance in selected MBT items before and after teaching the mechanics module

There was an improvement from 19% and 34% of students who succeeded in selected MBT items before and after learning mechanics. Two questions (4 and 22) among 12 were well performed, as above 50% of students succeeded them. However, item 19 did not get at least 10% of students who succeeded it (Figure 3). Statistically, we can infer that there was a statistically significant difference after learning mechanics at a level of p<.001 with an effect size of 1.26 and 0.19 learning gains (Table 2).

Table 2. Inferential statistics data

Mean difference	Av STD	Cohen's D effect size	Normalized gains <g>	t-Test	p-value	significance	level
15.10	11.97	1.26	19%	0.0002	<.001	Significant difference	Very high

Among 17 contents covered by MBT (see Table 1), 12 were positively performed by students and improved by the instructional model used during the mechanics' module, as we reported earlier in the methodology section. However, the rest of the five contents show difficulties to be understood by students. These contents were identified as (a) constant acceleration, (b) average velocity, (c) the first law of Newton, (d) work and energy, and (e) energy conservation. This low understanding is related to the instructional model. Therefore, lecturers should take these mechanics areas seriously and implement other possible strategies to cater to them and make their students understand.

Figure 5 presents the answer choices. While the labeled portions are correct answers both before and after teaching the mechanics module, the stacked column charts visualize five answer choices.

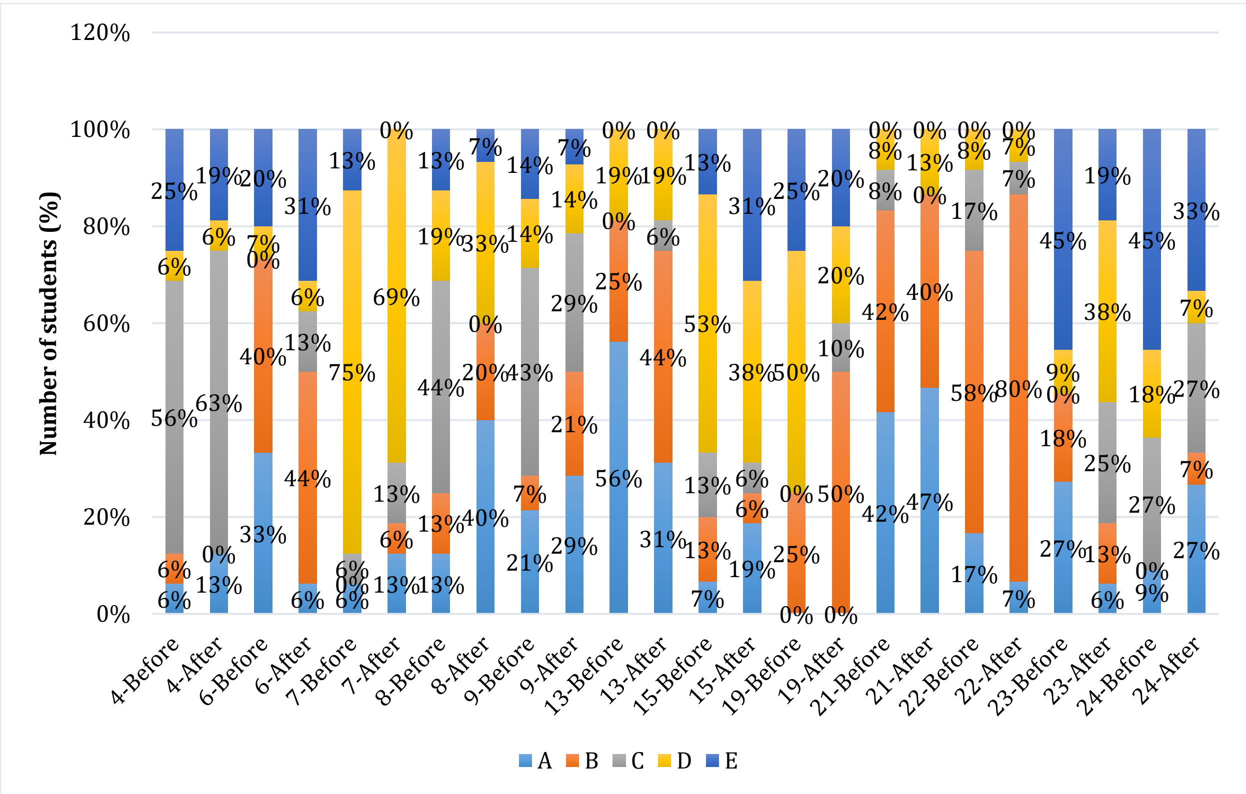

Figure 5. Students' answer choices before and after learning mechanics

Although students have performed well in all 12 items after learning mechanics, however items 6, 7, 8, 15, 19, and 24 still present misconceptions as distractors dominate the correct answer. For instance, students still choose B, "the direction of the acceleration of the block after leaving the lamp at position 3 is horizontal towards the right side instead of downwards" on item 6. Only 6% of students changed the understanding distractor D (F>k and N=W) from 75% to 69% of students before learning the mechanics module. On item 8, misconceptions shifted from distractor C to distractor A as 44% of students thought that the direction of force and acceleration is downwards before learning.

In comparison, 40% of students believed that both force, velocity, and acceleration are directed in the same direction after the learning mechanics module.

Regarding the comparison of students who got the correct answer and how they were confident, we asked them to rate how they responded to the MBT, either confidently, by guessing (not sure), or if they just ticked (no idea at all). If they tick on "confidently' then they proceed to the next item. Otherwise, they were requested to explain why they answered it by guessing or just by ticking. Among the provided reasons were such as (a) the Lecturer did not explain it well, (b) It is difficult, or (c) I do not remember. Different from these three reasons, we gave students room to write it down instead of ticking. However, there was no other reason claimed in this section. The results are presented in Table 3. The % shows the number of students under each statement and each MBT item.

Table 3. Relationship between students' correct answers and confidence.

Selected items	4	6	7	8	9	13	15	19	21	22	23	24
Correct answer	C	C	C	D	A	B	E	C	A	B	D	A
I answered this question confidently	75%	38%	69%	44%	29%	50%	69%	47%	73%	80%	81%	63%
I answered this question by guessing	25%	56%	31%	44%	50%	38%	19%	20%	27%	20%	19%	38%
I answered this question by just ticking	0%	6%	0%	13%	21%	13%	13%	33%	0%	0%	0%	0%
Student answered it correctly	63%	13%	13%	31%	25%	44%	31%	6%	44%	75%	38%	25%
Student did not answer it correctly	38%	88%	88%	69%	75%	56%	69%	94%	56%	25%	63%	75%
By guessing or ticking because lecturer did not explained it well	25%	11%	40%	13%	10%	50%	25%	29%	0%	0%	0%	0%
By guessing or ticking because it is difficult	25%	33%	20%	38%	90%	25%	25%	43%	33%	50%	0%	67%
By guessing or ticking because I do not remember	50%	56%	40%	50%	0%	25%	50%	29%	67%	50%	100%	33%

Students who confidently answered the questions did believe it and vice versa. For instance, 75% of students who said they answered item 4 confidently, 63% answered it correctly (they chose answer C), as Table 3 shows. Figure 6 shows the scatter plots of correlation among 12 items. A positive relationship rises at 0.58 between answering confidently and answering correctly. A medium positive correlation (r=0.39 and r=49) rises between answering by guessing and answering wrongly, while consecutively, a positive correlation (r=0.39 and r=49) rises between answering by just ticking and answering falsely. Therefore, this correlation matches students' performance, allowing us to confidently confirm that students who performed MBT tests were not randomly. Instead, a student who answered it correctly was confident that he/she answered it correctly, while one who did not answer it correctly was also sure that he/she did not answer it correctly.

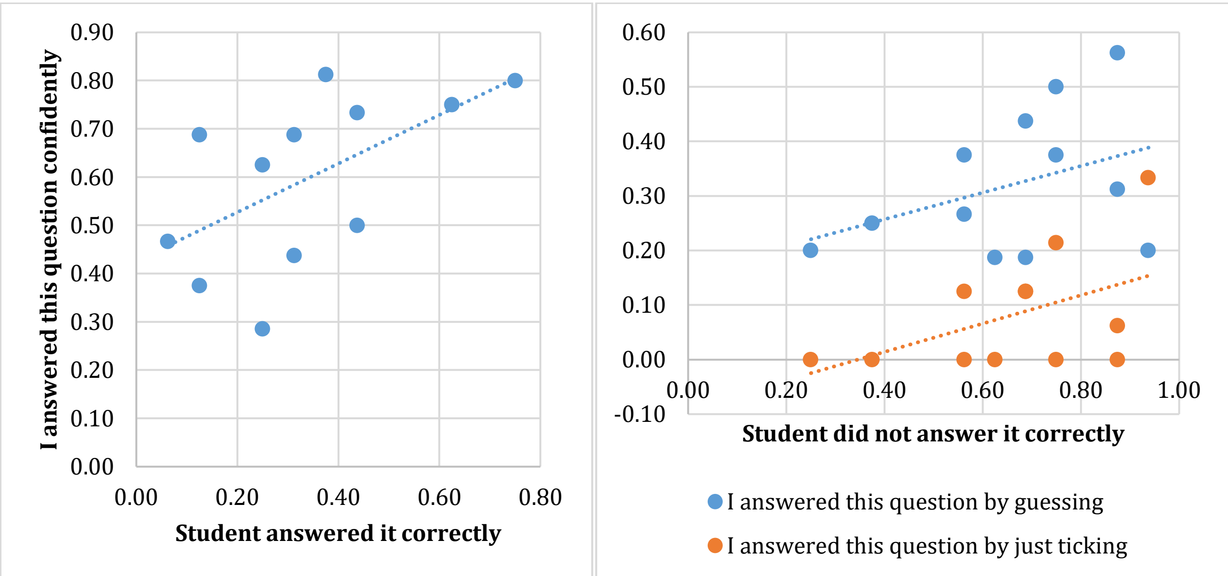

Figure 6. Students' correct answers and their answering confidence

Choosing the answer by guessing or by just ticking was attributed to the Lecturer' insufficiency of explanation (item 13), the difficulty of MBT (item 9, 22, and 24) as more than 50% of students outlined those items to be difficult, and retention as more than 50% students said they did not remember item 8, 15, 21, 22, and 23 (Table 3). However, these items falling in the difficulty and retention categories did not belong to low performed items except item 9. Therefore, we were not able to reveal the reason why they claimed them difficulty or retention.

Consecutively, the instructional model used in teaching PHY 1141 (mechanics module) was presented to students and asked them to match them with performed MBT items. The results are visualized in Table 4. The % shows the number of students under each instructional strategy and each MBT item.

Table 4. Students' responses in assigning selected items to the instructional model

	Selected items and % of respondents											
Instructional model	**4**	**6**	**7**	**8**	**9**	**13**	**15**	**19**	**21**	**22**	**23**	**24**
Lecturer backing	43	50	50	58	58	33	50	41	59	75	83	75
Learner owning learning	100	74	100	91	34	75	99	42	58	100	74	91

All students classed 4, 7, and 22 in learner owning learning while 43%, 50%, and 75% of students attributed them to the lecturer backing. Item 13 was most lowly classed in lecturer backing, while item 9 was most lowly classed in learner owning learning. Thus, item 13 is experimentally based, while item 9 is tutorial-based. The Lecturer would improve item 13 as we classified laboratory hands-on in lecturer backing. However, few experiments were performed by these students during our observation. They only did two experiments related to micrometer screw and simple pendulum during the whole mechanic's module period, the reason why 17% of students related item 13 to the pendulum in oscillation. Item 9 requires more teacher support during exercises session, the reason why students highly attributed it to lecturer backing than learner owning learning. However, the encouragement of performing exercises without the presence of the Lecturer should also be enhanced. Note that we were not interested in knowing where students learned a certain concept; instead, evaluating an instructional strategy allowed them to perform a particular item (concept) well. Thus, on the outlined above items, students thought that the Lecturer's explanations allowed them to answer such items. The overall results show that reading books and making summary or JiTT were appreciated by students to perform all items except items 9, 21, and 23.

Discussion

When compared to other inventories, an MBT is complicated for all levels of students. We realized the same in our present study. The students' low score proves MBT's difficulties, and the nature of the test mainly causes this. For instance, while other inventories such as force concept inventory (FCI) can be performed by students without formal education, to perform MBT, students should have a mechanics background (Hestenes & Wells, 1992). Another shortcoming is that MBT is a quantitative and a problem-solving based test, while it tends to assess students' understanding qualitatively.

Not only the low score MBT shows off, but also we realized the low confidence in answering the question in this study. The quiet confidence in answering a question such as "a student answered the question correctly but ranked it 'I answered this question by guessing or just ticking,' or a student wrongly answered the question but ranked it 'I answered this question confidently'" shows the students' misconception (Mashood & Singh, 2013).

In our study, item 15 is related to the conservation of momentum. On this item, the persistence of the distractor D still showed off. This misconception was caused by an inappropriate extension of common procedural practices and visual appraisal of problems (Mashood & Singh, 2012b). Students tried to compare the incident and reflected directions of colliding steel balls and the situations provided, and they found D as best fitting in this situation. However, they did not analyze the meaning of 'best represents the direction' (a case of E) against P's direction, which is in the opposite direction of Q in the case of distractor D. Similarly, item 19 requires vector analysis skills. On this item, misconceptions shifted from distractor D to distractor B, like 50% of students as both respectively chose these answers before and after learning mechanics instead of C-direction. On item 24, while 45% of students before teaching mechanics, 33% of students after learning still answered E (they could not calculate and find a matching answer distance traveled between 0 and 6 seconds) instead of A (20 meters). Cardamone et al. (2012) analyzed MBT item responses and excluded 11 from 26 items as items with very low discrimination and redundant items. These items include 1, 2, 14, 16, and 17 that we also excluded from our study. The authors also found that low-skill students perform better than the average items 4 and 22, and this finding is in line with ours.

The cognitive theory takes source from senses and experiences to absorb and retain acquired knowledge. Therefore, assignment of some tasks such as reading books and present, describing the working principle of some objects (such as the engine, gear, the car, lift, helicopter, etc.), and created equipment (such as boats to show the density and pressure concept, ropeway transportation to explain friction force, etc) helped students to perform well. Jerome Bruner has supported the cognitive learning theory to encourage teachers to let students learn through discovery activities (Bruner, 1990). In this way, if students, like the ones in the present study, were allowed to read books, notes, conduct research, share what they know, these students will acquire and retain much knowledge and skills in a short time and in an effective way.

Related to attribution to the Lecturer backing, Hake has suggested the interactive engagement methods to increase the mechanics' course effectiveness declining the traditional practices (Eijkelhof, 2011). Cognitive learning theory benefits various learning approaches. For instance, it boosts confidence, enhances comprehension, and expands problem-solving abilities (Valamis, 2020). Comprehension, memory, and application are an indicator of cognitive "learning. The fact that students can confirm their confidence in performing the test and the confirmed answers are correct, it shows the level of cognition attained. The problem-solving skills are so important. Thus, students should understand the concepts, fix them in their minds, and reproduce and apply them in real life to solve daily problems.

Similarly, in FMCE (Thornton & Sokoloff, 1998), it has been revealed that students do not commonly understand kinematics and dynamics concepts due to the traditional teaching methods. Just-in-Time Teaching (JiTT) is an instructional strategy whereby a teacher hears from students about what will be taught. It involves feedback from students on pre-lecture activities to design in-class activities to shape students' continuing reactions (Sayer et al., 2016). According to Formica et al. (Formica et al., 2010), the JiTT instructional strategy allowed students to better Newton's third law than students in traditional lecture classes. Morote et al. (2010) found that doing interactive electronic homework correlated with large gains on the final exam during the FCI and the MBT performance. "The MBT tests the application of Newtonian concepts to simple kinematics and dynamics of a single particle (Hestenes & Wells, 1992, p.1 61)." It is an excellent test to evaluate the instructional strategies used. If students do not master kinematics and dynamics content, lecturers should give these instructional strategies room for discussion for the sake of improvement. Nsengimana et al. (2020) have emphasized laboratory activities' role to boost both intended and implemented curriculum. We concur with their recommendation that preservice teachers need to improve their learning through a well-established laboratory to master what they will, in return, teach during their future career. Through learner-centered strategy as shaped by cognitive learning theory, students have to accommodate new information by modifying what they already know, assimilated or arranged the new knowledge inside their brain beside what they already know, and balanced what they already know with the newly accumulated knowledge (Valamis, 2020).

Conclusion

The mechanics module's learning outcomes and competencies require students to demonstrate knowledge and understanding of operations with vectors, use frames of references, and fundamental concepts of Classical Mechanics. They should be able to apply the basic concepts of Mechanics to find the trajectory, distance, speed, velocity, and acceleration. They should use Newton's law of gravity and Kepler's laws to study planetary orbits and cosmic velocities and be able to explain Simple Harmonic Motion and illustrate the examples (pendulums). However, students did not show these competencies during MBT's performance except in some of its items. Within 12 out of 26 MBT items, there was a statistically significant difference between students' scores before and after teaching the mechanics module at 11.97 average standard deviation with 19% of learning gains. However, the performance was low in both periods. For instance, only 19% and 34% mean scores were obtained before and after learning mechanics. A positive correlation of 0.58, 0.39, and 0.49 was found in three groups of tests. One group was between answering confidently and answering correctly (r=0.58), another group between answering by guessing and answering wrongly (=0.39) while the last group was between answering by just ticking and answering wrongly (r=49). Reading books and make a summary before coming for the class, presenting and learning reflection during class have shown a significant impact as many students appreciated (they showed how this method helped them perform several items in MBT).

Recommendations

In this study, we realized that there is still a need for reemphasizing the vector functions to understand the position of a particle best as students showed a low mastery of vectors. This low mastery took the source of difficulty in kinematics. Therefore, a translation from kinematics to dynamics should be taken care of to allow students to master the position of force, velocity, and acceleration. Specifically, five out of 17 contents covered by MBT (constant acceleration, average velocity, the first law of Newton, work and energy, and energy conservation) have shown a low understanding of students even after being taught the mechanics' module. It is in this regard; we recommend lecturers explore these areas with effective instructional strategies. In this study, we have classified the instructional model in "lecturer backing" and "learners owning learning," both making the "teaching and learning bucket" model. We recommend lecturers to employ learners owning learning by backing it with their support to accelerate active learning and students' engagement. However, there is a need to increase laboratory activities as we found that students had only one session in the physics laboratory during three months of studying the mechanics' module.

Limitations

This study was limited in two ways. Firstly, it employed a small sample of 38 students (a small class), and secondary, it did not accommodate all items in its final stage (after teaching). Therefore, these two limitations lead well to future researches.

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Appendix:

A Mechanics Baseline Test – Survey Questionnaire to College Students

1. Please tick where appropriate

I answered this question				Why? (if by guessing or just ticked)			
Question	**Confidently**	**By guessing** (not sure)	**I just ticked** (no idea at all)	**The Lecturer did not explain it well**	**It is difficult**	**I do not remember**	**Other** (write it down instead of tick)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							

2. During our course (Mechanics 1141), we used various teaching strategies. These strategies might affect the way you answered this test. **Please fill where appropriate**

	Teaching strategies	**Questions**
1	The Lecturer **explained** and demonstrated the content on the whiteboard	
2	The Lecturer showed us concepts related to Mechanics through **YouTube videos**	
3	Lecturer gave us **homework** (reading books and make summary) where we learned from each other (our classmates)	
4	Lecturer gave us **homework** about phenomena, Inventors in Mechanics, how things work by searching on the internet	
5	During the class **presentation**, the Lecturer assigned us different questions to each group gave us time to prepare, and then we presented to the rest of the class	
6	**Laboratory** activities	
7	Other (write it here) ………………………………	