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Effect of scaffolding strategies and guided discovery on higher-order thinking skills in physics education

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Abstract

Embedding higher-order thinking within science education, particularly in teaching physics, can equip students to learn physics at a deeper level and to become active learners who can analyze and solve problems independently. The present research aimed to assess the effectiveness of scaffolding strategies along with a guided discovery approach on students' higher-order thinking skills (HOTS) at technical colleges in Saudi Arabia. The study employed a quasi-experimental design to involve 104 students enrolled in the physics 101 course in two groups: an experimental group (EG) (n = 54), which experienced scaffolding strategies and guided discovery approach during the instruction, and a control group (CG) (n = 54), which received the instruction through conventional teaching methods. All participants took a pre- and post-test consisting of a HOTS test. Data analysis using inferential statistics revealed significant differences in the test scores between CG and EG. The results indicated that students in the EG performed better on the HOTS test in comparison to the students in the CG. Based on these results, it is concluded that the scaffolding strategies and guided discovery have a positive effect on students' HOTS. The study's findings have significant implications for enhancing science instruction, particularly teaching of physics in Saudi technical and vocational colleges.

Keywords: higher-order thinking, scaffolding strategies, guided discovery, technical colleges, physics

INTRODUCTION

One of the most important skills that education should foster is higher-order thinking skills (HOTS). HOTS involves the ability to analyze, evaluate, and create rather than just memorize and repeat information (Zain et al., 2022). These skills are essential for problem-solving, decision-making, and innovation (Kim et al., 2019). They help individuals become independent learners and critical thinkers who can adapt to new situations and challenges. Jailani et al. (2017) argue that HOTS have been one of the forms of more complex thinking activities. HOTS are necessary for the development of self-directed learners who can take responsibility for their own learning, set goals, and monitor their progress.

HOTS are especially important in science education. Science is not just about learning facts and figures but also about understanding the underlying principles and being able to apply them in new situations. HOTS allows students to analyze data, evaluate evidence, and make predictions (Sun & Lavonen, 2022). They help students develop the ability to think like scientists, which is essential for success in the field. According to a study by Barak and Shakhman (2008), HOTS in science education promotes scientific literacy and equips students with the skills necessary to understand and engage with complex scientific issues.

Two important instructional approaches that support developing students' HOTS are scaffolding strategies and a guided discovery approach to learning. The following sections further explain the concept of HOTS, followed by a detailed description of how scaffolding strategies and guided discovery approaches are defined in the literature and in what ways they are considered

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Contribution to the literature

- This study fills a gap in the existing literature by providing empirical evidence on the effectiveness of scaffolding strategies and guided discovery in promoting HOTS within the context of technical and vocational colleges in Saudi Arabia.
- By establishing the positive impact of scaffolding strategies and guided discovery on students' HOTS, this research adds to the validation of these instructional approaches within the field of science education.
- The study's findings hold implications for educational policy and practice, particularly in terms of informing curriculum development and instructional practices in technical and vocational colleges.

positive instructional approaches for HOTS within science education.

Higher-Order Thinking Skills

Educators in the scientific disciplines are expected to do more than only impart knowledge and cultivate the fundamental abilities of their students in science subjects. Particularly, teachers of science in the 21st century are advised to focus on developing their students' HOTS (Sari et al., 2021). HOTS refers to individuals' cognitive abilities that go beyond basic comprehension of information and involve the ability to analyze, evaluate, and create new knowledge (Lewis & Smith, 1993). By mastering HOTS, students may become critical, creative, and accustomed to solving the problems they face in their academic, personal, and professional lives (Miri et al., 2007; Sari et al., 2021; Widiawati et al., 2018).

The most important framework that helps educators understand, identify, develop, and assess HOTS among students is Bloom's taxonomy (Cullinane, 2010). This taxonomy is used to identify and classify the many stages of reasoning, study, and comprehension in humans. Bloom's taxonomy has traditionally been used by instructors to influence or direct the design and development of curricula (modules, courses, assignments, and other learning activities), assessments (tests and other evaluations of student learning), and instructional approaches, including questioning techniques (Cullinane, 2010).

Bloom's taxonomy of educational objectives is one instrument that has received high praise and had much success in the past (Bloom et al., 1956). In his research, Benjamin Bloom discovered that 95% of the queries have been from inferior stages of cognitive processing (Lord & Baviskar, 2007). These findings led Bloom and his group of education professionals to develop Bloom's taxonomy, a system of three distinct categories for categorizing educational goals, in 1948. This study discovered that most educational goals could be categorized into one of three domains–affective, cognitive, or psychomotor. Bloom and his colleagues released only the affective and cognitive categories. Other pedagogical scholars like Simpson (1972) subsequently created the psychomotor category. Other psychomotor taxonomies include Daves psychomotor domain and Harrow's taxonomy (Andreatta, 2019).

Bloom's taxonomy acts like a ladder for learning, with lower levels representing basic knowledge and higher levels signifying more complex thinking. Lower levels involve remembering facts and grasping concepts. These are the building blocks for HOTS, which reside on the top three levels. Here, learners are not just recalling information, and they are actively analyzing it, breaking it down, and identifying connections. They also make judgements and evaluations and ultimately use their knowledge to create new ideas or solutions. By encouraging students to climb this ladder of learning, Bloom's taxonomy helps educators foster critical thinking, problem-solving, and the ability to learn independently throughout life.

Ciardiello (2000) emphasized that readers who operate on higher cognitive regions in mental capacities indicate that they could produce considerable originality in communication, diverse thoughts, and use innovative and critical knowledge. Teaching HOTS is crucial for enhancing scientific proficiency in classroom settings. Instructors may help students develop their scientific and critical thinking abilities. Students' accomplishment in science is improved by using instructional techniques that develop thinking abilities. However, conventional teaching of science-oriented courses is usually designed with reference to the "content" only, without explicit consideration of the cognitive demands that the subject presents to the learner (Hugerat & Kortam, 2014).

Educators have tried many different approaches to teaching students to think critically about scientific topics. Science aptitudes and thinking skills influence one another to support students' learning processes. According to Hugerat and Kortam (2014) and Saido et al. (2018), a fundamental aim of science education is to assist students in developing their HOTS, allowing them to cope with everyday challenges. Past research suggests that teaching science using inquiry methods like case studies and reading scientific research articles promotes HOTS among college students (Hugerat & Kortam, 2014). Zoller (1993) critiques traditional lecturing methods for their effectiveness in fostering higher order cognitive skills. The study argues that conventional lecture-based approaches are more suited for lower order cognitive skills and less effective for developing critical thinking and problem-solving skills, which are essential in science education. Zohar and Dori (2003) conducted interventions with low-achieving tenth graders, integrating higher order thinking into the science curriculum. The findings suggest that with appropriate teaching strategies, even low-achieving students can improve their higher order thinking skills in science subjects. This counters the common assumption that HOTS are only for high-achieving students. Sulaiman et al. (2017) conducted a study examining the perceptions of Malaysian science teachers in the implementation of HOTS in teaching science. They found that science teachers are cognizant of HOTS, and they often include it in their lessons. They feel, however, that they are hampered by certain limitations. Similarly, Ab Halim et al. (2021) suggested that science teachers did not explore various strategies and approaches in implementing HOTS.

Scaffolding Strategies in Education

The term 'scaffolding' used in education originates back to the 1970s. The work of Vygotsky (1978), a Soviet psychologist, is often linked to scaffolding. Generally, scaffolding is seen as assistance provided by an educator to a pupil while carrying out a job the student could not do independently. The metaphor of scaffolding, employed to describe the nature of assistance and guidance in learning, is a well-known practical application of Vygotsky's (1978) theory and may help instructors comprehend and improve such methods. Vygotsky's (1978) socio-cultural theories of human education propose that learning takes place for humans on two levels: first, it occurs via interacting with other people, and then it becomes a permanent part of the individual's psychological makeup.

According to Turner and Berkowilz (2005), scaffolding involves "setting up the game, providing a scaffold to ensure that the children's shortcomings may be recovered or corrected by effective interventions, and then removing the scaffolding piece by piece as the reciprocal building can exist by itself" (p. 60). In numerous other contexts, "scaffolding" refers to preparing a situation for a student to enter before he lacks the requisite skills to manage it. The concept of scaffolding stems from the belief that students can do a great deal more when they are first guided through acquiring new knowledge or abilities (Turner & Berkowilz, 2005). Providing a safe learning environment for students is one advantage of scaffolded instructions. The instructors' material is no longer merely received by the students; instead, they actively build on past knowledge and develop new knowledge on their own with the instructor's and peers' feedback. In other words, a classroom had a helpful learning atmosphere since the children could ask their professors and other students for assistance. As a result, in the end, students can complete the work on their own. In other words,

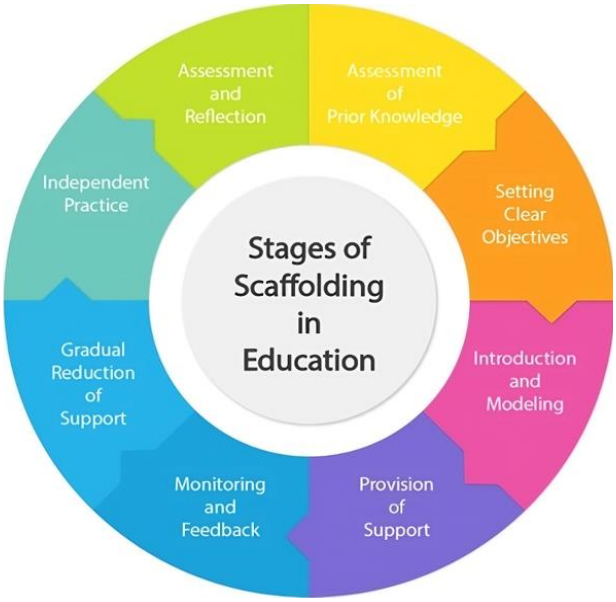

Figure 1. Stages of scaffolding in education (Source: Authors' own elaboration)

teachers want their students to be curious, to provide criticism, and to help their classmates learn new things. Breaking instructions into smaller steps helps decrease the student's irritation (Van der Stuyf, 2002).

Larkin (2002) stated that scaffolding is among the fundamentals of an effective educational system, enabling teachers to personalize their teaching for each student. Students are encouraged to participate more actively in their learning when it is delivered in this manner. Students may take on a more active role in learning and teaching by using scaffolding that supports them to go beyond their current levels of knowledge and ability. Because of the students' increased involvement in the learning process, they are given more control over their academic destinies. While using scaffolded teaching methods, teachers need to transition from being the dominant subject matter experts to becoming open-minded educators keen to use new approaches in the classroom, including such scaffolded instructions.

Scaffolding strategies can play a crucial role in the development of HOTS in science education. These strategies involve breaking down complex tasks into smaller, more manageable parts and providing appropriate support and guidance for students as they work through each step (Van de Pol et al., 2010). The basic tenet of scaffolding is to collaboratively engage learners in challenging or uncommon tasks by allowing them to complete those tasks on their own (Alrawili et al., 2021; Wartono et al., 2019; Wass et al., 2011). This type of instruction helps students build their HOTS gradually and efficiently as they gradually shift from relying on more basic skills and knowledge to engaging in more advanced reasoning and problem-solving activities (Sukatiman et al., 2020). **Figure 1** shows the stages of scaffolding in education.

Guided Discovery Approach to Learning

Another teaching-learning approach supporting HOTS is guided discovery. The guided discovery is a cognitive learning model that is used to build students learning under the supervision of a teacher where the teacher creates situations that can make students be active in discovering their own knowledge so that they solve complicated and abstract concepts (Janssen et al., 2014). This learning model is related to inquiry-based, problem-based, and constructivist learning. It is found helpful for students with low learning outcomes to build knowledge, attitudes, and skills independently, systematically, critically, and logically (Muhali et al., 2021).

Guided discovery is also known as an inductive approach. At this stage, it is essential to distinguish between deductive and inductive reasoning. The learning method of guided exploration sits somewhere on the continuum between learning focused on the students and education centered on the instructor (Villanueva, 1976). Students are presented with introductory challenges, issues, or subjects to investigate in their respective areas (Ormrod, 2023). students comprehend the material via experiential learning, logical deliberation, and self-reflection. The primary responsibility of instructors is to provide students with foundational knowledge and work resources. Another essential component is for instructors to engage in questioning, advice, and encouragement while providing feedback (Rowe, 2004). Rowe (2004) also stated that participating in a group makes the learning process easier to navigate. A learning method known as guided discovery is one in which the teacher plays a role in posing the dilemma, then helps to guide the student in discovering the solution to the issue through the use of instructions or worksheets provided by the teacher, and finally, the students follow the instructions and develop their solutions.

In the guided discovery approach to learning, students are actively involved in the learning process rather than just being passive recipients of information. They are encouraged to explore, ask questions, and make connections. The teacher acts as a guide, providing support and feedback but also allowing students to make their own discoveries (Padesky, 2022). This approach helps students develop critical thinking skills, problem-solving abilities, and the ability to apply knowledge in real-world situations.

The guided discovery approach has been shown to be effective in promoting HOTS in science education in several ways. First, it encourages active learning and the development of self-directed learners. By allowing students to explore and make their own discoveries, the approach helps them take responsibility for their own learning and develop autonomy. Second, the guided discovery approach promotes the development of critical thinking and problem-solving skills. By encouraging students to ask questions and make connections, the approach helps them develop the ability to analyze, evaluate, and create. This approach to teaching has been shown to promote the development of critical thinking and problem-solving skills in science education (Fahmi et al., 2019). The guided discovery approach promotes the transfer of knowledge. By allowing students to construct their own understanding of scientific concepts, the approach helps them develop a deep and meaningful understanding of the material. As per Padesky (2022), the guided discovery approach has been shown to promote the transfer of knowledge, allowing students to apply their understanding in real-world situations.

Purpose of the Study

In essence, the primary concern of this study revolves around assessing the effectiveness of scaffolding strategies and guided discovery in enhancing the learning experiences of Saudi Technical College physics students. Meanwhile, acknowledging the broader challenges facing the educational system in Saudi Arabia, the aim is to explore the specific implications of these pedagogical approaches in science teaching. In specific terms, the research aims to develop an instructional module focusing on scaffolding strategies and guided discovery and to determine the effectiveness of the module on physics students' HOTS in the context of technical and vocational training in Saudi Arabia. The following key research question was addressed in this study: Do scaffolding strategies and guided discovery instructional approaches have an effect on students' HOTS in physics?

The findings of this study provide insights into the effectiveness of the instructional approaches in improving physics students' higher order thinking skills in technical and vocational education. The study contributes to the literature on effective teaching strategies in this context and provides several important implications for educational practice, policy, and further research.

MATERIALS AND METHODS

Research Design

Research design is a critical aspect of any study, as it provides a framework for ensuring that the research is conducted effectively and efficiently (Asenahabi, 2019). The current study used a quasi-experimental pre-/post-test design with a control group (CG) and a quantitative analytic strategy. A quasi-experimental research design is a research method that involves studying the effects of an intervention or treatment on a group of participants without randomly assigning them to CG and EG (Reichardt, 2009). It was preferred to use existing groups

Table 1. Quasi-experimental design

Groups	Pre-test	Treatment	Post-test
Experimental group (EG)	HOTS	Instruction with scaffolding strategies and guided discovery	HOTS
Control group (CG)	HOTS	Conventional instruction	HOTS

of physics classes over forming fresh groups so that the disruption to the learning atmosphere in the research context (selected technical and vocational college) could be avoided. The quasi-experimental approach provided the basis to determine the effectiveness of the instructional module that used scaffolding strategies and guided discovery as the core elements of instruction.

We implemented several methodological safeguards to minimize threats to validity and reliability helping to enhance the study's robustness. To control internal validity, this study utilized a quasi-experimental design with both CG and EG. This approach allows for a clear comparison between students exposed to the intervention and those receiving traditional instruction, helping to isolate the effects of the scaffolding and guided discovery methods on HOTS. The inclusion of pre- and post-tests further strengthens this approach by establishing a baseline and measuring changes over time, thereby accounting for any pre-existing differences in knowledge or skills between the groups. By conducting the study in two classes within technical colleges, we likely increased the generalizability of the findings. This wide sample selection helps ensure that the results can be applicable to other settings within Saudi Arabia, enhancing the external validity. In order to remove threats associated with data collection tool, the HOTS test (**Appendix A**) used in the present study was not only validated by the experts in the field. It was also pilot-tested with the potential participants. Both the pre- and post-tests were carried out similarly. For assessment purposes, the tool had a specified/standardized format to avoid biasness of the data collector (instructor). **Table 1** provides a quick overview of the research design employed for the current investigation.

Research Setting

The research took place at Riyadh College of Technology, a public sector technical and vocational college in Saudi Arabia that offers diploma programs in various trades. Riyadh College of Technology is one of the biggest government training colleges in the country. It is situated in Riyadh, the capital city of Saudi Arabia. The college comes under the administrative control of Technical and Vocational Training Corporation (TVTC). Currently, there are approximately 1,750 students who study physics in 50 classes in the first semester of academic session 2023-2024. The Riyadh College of Technology was purposefully chosen as the venue to conduct this experimental study for the following reasons:

1. The college is one of the biggest technical and vocational colleges in the country. It is situated in a suitable geographical area that enables the researchers to control the non-EG by preventing them from mixing with their counterparts in the EG. The selected college is located within the borders of the city because the social and economic conditions were similar, and this reduced the differences between students.
2. The college operates under the administrative control of TVTC, a government agency responsible for technical and vocational training in the country. So, the college is well equipped with the necessary infrastructure and resources required for the implementation of this experimental study, i.e., a well-equipped physics laboratory, a modern computer lab, classrooms, etc.
3. One of the researchers is a lecturer at the selected college and he has got formal approval from the college administration to conduct the study.

Description of Treatment

The study was implemented with four classes of physics 101 in the first semester of academic session 2023-2024. Making a total sample of 104 students. Half of the students (two classes, n = 52) formed the EG, whereas the remaining half (two classes, n = 52) formed the CG of this study. The course consists of 06 credit hours, including 04 hours for theory and 02 hours for practical. The treatment for the EG in this study involved the integration of scaffolding strategies and guided discovery approaches into the teaching of physics 101. These instructional methods were designed to enhance students' HOTS by promoting active engagement, critical thinking, and problem-solving abilities.

The experiment was applied to the second unit of the course that covers the topics of motion, force, work, and energy. The unit takes approximately 30 teaching hours to be completed in five weeks. All classes, including the CG and EG, were supposed to cover the same content (topics). However, the teaching-learning activities in CG and EG were different. **Table 2** provides an overview of specific instructional activities for each of the five weeks of the experiment.

Research Instrument

The study participants were given a quantitative instrument to test their knowledge of the intervention unit of the physics 101 course, i.e., motion, force, work, and energy. The unit covered sub-topics such as

Table 2. Week-wise instructional activities of the CG and EG

Week	Lesson topic	EG activities	CG activities
Week 1	Rectilinear motion	-Interactive group activity includes volunteer demonstrations to explore distance, displacement, velocity, and acceleration. -Rectilinear motion interactive simulations (https://www.physicsclassroom.com/Physics-Interactives/1-D-Kinematics/Vector-Walk) -Group activity 1: (My home to school roadmap) -Group activity 2: (Velocity and acceleration)	Traditional method using TVTC textbook -Lecture and solve textbook problems
Week 1	Kinematic equations	-Providing visual aids and real-world examples to help students discover the concept of uniformly accelerated motion. -Worksheet 1: (Uniform accelerated motion) -Group activity 3: (Motion with constant acceleration)	Traditional method using TVTC textbook -Lecture and solve textbook problems
Week 2	Newton's 1st laws of motion	-Providing visual aids and real-world examples to help students discover the concept of inertia and to compare balanced and unbalanced forces. -Group activity 4: (Practical demonstration: Inertia) -Perform Newton's 2nd law experiment (https://www.walter-fendt.de/html5/phen/newtonlaw2_en.htm)	Traditional method using TVTC textbook -Lecture and solve textbook problems
Week 2	Newton's 2nd laws of motion	-Engage students in thinking critically by exploring the relationship among force, acceleration and mass. -Group activity 5: (Practical demonstration to determine the relationship of force, mass, and acceleration)	Traditional method using TVTC textbook -Lecture and solve textbook problems
Week 3	Newton's 3rd laws of motion	-Providing visual aids and real-world examples to help students discover the concept of Newton's 3rd law. -Group activity 6: (Balloon rocket experiment)	
Week 3	Work	-Designed activities and provided visual aids to understand work in physics to engage students in identifying and analyzing situations where work is done by examining real-life scenarios. -Worksheet 2: (Work) -Group activity 7: (Work or no work?)	Traditional method using TVTC textbook -Lecture and solve textbook problems
Week 4	Power	-Interactive group activity (walking up and running up the stairs) includes volunteer demonstrations to explore the concept of power and its relationship with time. -Worksheet 3: (Power) -Group activity 8: (Practical demonstration: Who is the most powerful?)	Traditional method using TVTC textbook -Lecture and solve textbook problems
Week 4	Mechanical energy	-Engaging students to analyze figures to explore the concept of energy and its transformations. -Interactive simulations (potential energy and kinetic energy): (https://phet.colorado.edu/sims/html/energy-skate-park/latest/energy-skate-park_all.html) -Worksheet 4: (Mechanical energy)	Traditional method using TVTC textbook -Lecture and solve textbook problems
Week 5	Law of conservation of energy	-Interactive group activity includes volunteer to explore the concept of the law of conservation of energy -Providing visual aids and demonstrations to explore potential energy and kinetic energy with a dropped ball. -Worksheet 5: (The law of conservation of energy)	Traditional method using TVTC textbook -Lecture and solve textbook problems

rectilinear motion, distance and displacement, Newton's laws of motion, work, and energy. The test was created in collaboration with an experienced physics teacher who participated in the study as a teacher for the CG and EG. The test focused on students' HOTS in terms of the higher levels of Bloom's taxonomy of the cognitive domain, namely analysis, evaluation, and creation (Brookhart, 2010). The test comprised 18 multiple-choice questions (MCQs), including 6 items for each of the three levels of higher learning. Each correct answer on the HOTS test awarded test takers one point, while the wrong answer was awarded 0 points. The MCQs were structured to present a scenario or problem and ask the student to choose the best solution, requiring the student to think critically and apply their knowledge meaningfully.

Content validity is an important concept in test development and research studies. It refers to the extent to which a test instrument measures the content that it is intended to measure (Delgado-Rico et al., 2012). In other words, it is the degree to which a test accurately represents the subject matter or construct being studied. Content validity is crucial because it ensures that the test is measuring what it is supposed to measure and that the

Table 3. Discrimination index (DISI) and difficulty index (DIFI) values for the HOTS test

Item	DIFI	DIFL	DISI	DISL
Analyzing				
Ana1	0.29	Acceptable	0.41	Acceptable
Ana2	0.25	Acceptable	0.30	Acceptable
Ana3	0.52	Acceptable	0.39	Acceptable
Ana4	0.38	Acceptable	0.52	Acceptable
Ana5	0.34	Acceptable	0.21	Acceptable
Ana6	0.24	Acceptable	0.33	Acceptable
Ana7	0.25	Acceptable	0.26	Acceptable
Evaluating				
Eva1	0.30	Acceptable	0.28	Acceptable
Eva2	0.29	Acceptable	0.47	Acceptable
Eva3	0.20	Acceptable	0.21	Acceptable
Eva4	0.35	Acceptable	0.36	Acceptable
Eva5	0.39	Acceptable	0.22	Acceptable
Eva6	0.34	Acceptable	0.39	Acceptable
Eva7	0.38	Acceptable	0.52	Acceptable
Creating				
Cre1	0.32	Acceptable	0.30	Acceptable
Cre2	0.23	Acceptable	0.26	Acceptable
Cre3	0.46	Acceptable	0.26	Acceptable
Cre4	0.35	Acceptable	0.31	Acceptable

Note. DIFL: Difficulty level & DISL: Discrimination level

results are accurate and reliable. When developing a test instrument, content validity is established through a systematic process that involves a thorough review of the test items by experts in the subject matter. This process, known as content validation, involves evaluating each item on the test to determine whether it accurately reflects the content or construct that it is intended to measure. The experts examined the items to ensure that they were clear, relevant, and comprehensive and that they accurately represent the content domain being assessed.

After preparing the first draft of the HOTS test is ready, in order to establish the content validity of this instrument for the current study, we sought feedback on the test from two professor level subject/assessment experts. After the test had been revised on the basis of the feedback received from the experts, the test was pilot-tested with a small group of potential participants (30 students from a physics 101 class) in the college selected for this investigation. The purpose of piloting is to evaluate the quality and effectiveness of the test instrument, to identify any issues or errors that may arise, and to make necessary revisions or modifications to ensure that the test is valid, reliable, and fair (Summers, 1993).

During the pilot study, participants were asked to complete the HOTS test under controlled conditions, typically within a single class period. Based on the findings of the pilot study, some minor adjustments were made to the HOTS test items. This involved revising or rewording a few items and clarifying test instructions. As an additional measure of validity and reliability check certain statistical tests were performed. The item difficulty index was calculated for each MCQ item in the HOTS test to assess the proportion of students who answered each item correctly. Moreover, the item discrimination index was calculated for each MCQ item in the HOTS test to assess the ability of the items to differentiate between high-performing and low-performing students. The results of both the item difficulty index and item discrimination index suggested that the index values were within acceptable range (see **Table 3**). Furthermore, reliability of the instrument was assessed using Cronbach's alpha, which measures internal consistency. The overall reliability of the test was found to be high, with a Cronbach's alpha coefficient of 0.83. This indicates that the instrument is consistently measuring the intended constructs.

Data Analysis

The collected was analyzed quantitatively using various statistics. All data analysis was performed using SPSS (statistical package for social sciences) version 26. The data analysis involved both descriptive and inferential statistical tests. Descriptive statistics such as mean (M), frequency distribution, and standard deviation (SD) were used to analyze demographic information and to generate factor scores. Similarly, inferential statistics tests such as the independent sample t-test and analysis of covariance (ANCOVA) were used to analyze the relationship between the independent and dependent variables of the study.

Ethical Considerations

Ensuring ethical compliance in research is essential for maintaining the research integrity and protection of participants' rights. We employed needful procedures to address the ethical aspects of the data collection process. Firstly, the research proposal was reviewed and approved by the Institutional Review Board at the National University of Malysia. This approval confirmed that the study met ethical standards for research involving human subjects. Prior to the study treatment and data collection, informed consent was obtained from all participants, and they were provided with detailed information about the study's purpose, procedures, potential risks, and benefits. They were informed of their right to withdraw from the study at any time without any penalty.

RESULTS

Prior to conducting the main analysis, we checked for assumptions inherent to our chosen statistical methods, particularly the inferential statistical test, to check the study hypotheses. The assumptions of normality, linearity, homoscedasticity, and independence were satisfied. We computed descriptive statistics such as measures of central tendency (M) and measures of

Table 4. Descriptive statistics of pre- and post-test

Name of the variable	N	M	SD
HOTS_PreTest	104	5.24	2.10
HOTS_Ana_PreTest	104	2.25	1.34
HOTS_Eva_PreTest	104	1.92	1.28
HOTS_Cre_PreTest	104	1.06	.88
HOTS_PostTest	104	7.68	3.53
HOTS_Ana_PostTest	104	3.01	1.60
HOTS_Eva_PostTest	104	3.94	1.59
HOTS_Cre_PostTest	104	2.73	1.22

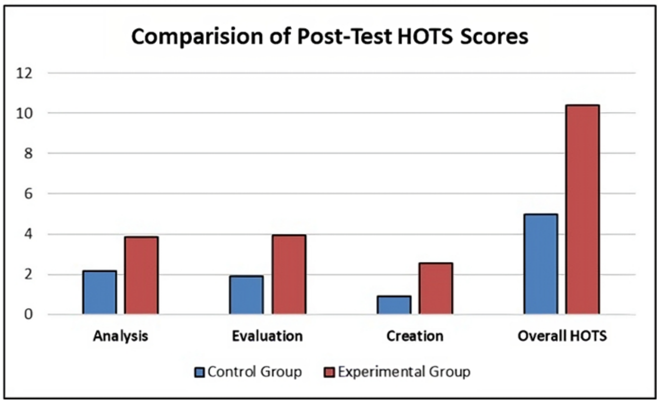

Figure 2. Comparison of HOTS scores between CG and EG (Source: Authors' own elaboration)

dispersion (SD) for the main continuous variables: HOTS_PostTest and HOTS_PostTest (and their respective sub-scales analysis, creation, and evaluation). These statistics offer a snapshot of the data's distribution and variability, providing a context for the deeper analyses that follow. **Table 4** provides basic descriptive statistics for the two variables.

Figure 2 provides a quick comparison of participants' post-test scores on analysis, evaluation, creation, and overall HOTS between the CG and EG.

In order to evaluate if the two groups of students (control and experiment) were significantly different with respect to their HOTS at the pre-test level, an independent sample t-test was conducted. In this analysis, the dependent variable was HOTS_PreTest (containing students' scores on the HOTS test before the intervention), whereas the independent variable was group with two levels: control and experiment. The results of Levene's test were not significant (F = .292, p = .590), suggesting that the variances for the two groups were equal. Given this, the assumption of equal variances was assumed for the subsequent t-test. The results of the t-test revealed that there was no significant difference in HOTS between the control and experiment groups; t (102) = -1.266, p > 0.05 (see **Table 5** for details). Although the descriptive statistics showed that the experiment group had a higher mean (M = 5.50, SD = 2.165) compared to the CG (M = 4.98, SD = 2.015) (see **Table 6**), the t-test revealed that these differences were not significant. These results suggest that both groups of students, the ones in the CG and the ones who were assigned to the experiment group, were almost homogenous with respect to their HOTS before the intervention started.

Table 5. Results of independent sample t-test for variables HOTS_PreTest

t	df	Sig. (2-tailed)	MD	SED	95% CID	
					Lower	Upper
-1.266	102	.208	-.519	.410	-1.333	.294

Note. MD: Mean difference; SED: Standard error difference; CID: Confidence interval of the difference

Table 6. Summary statistics for HOTS_PreTest scores (N = 104)

DV	Group	N	M	SD
HOTS_PreTest	Control	52	4.98	2.015
	Experimental	52	5.50	2.165

Table 7. Results of independent sample t-test for variables HOTS_PostTest

t	df	Sig. (2-tailed)	MD	SED	95% CID	
					Lower	Upper
-12.142	102	.000	-5.404	.445	-6.287	-4.521

Note. MD: Mean difference; SED: Standard error difference; CID: Confidence interval of the difference

In order to evaluate if there was a significant effect of the scaffolding strategies and guided discovery approach on physics students' HOTS, an independent sample t-test was conducted. An independent samples t-test (also referred to as the two-sample t-test) can be used to compare the mean outcomes between the two independent groups (Field, 2013). This helps to determine whether the intervention had a significantly different effect on one group compared to the other. (Field, 2013). In this analysis, the dependent variable was HOTS_PostTest (containing students' scores on the HOTS test after the intervention), whereas the independent variable was the group with two levels: control and experiment.

Prior to conducting the t-test, Levene's test for equality of variances was performed to assess the assumption of homogeneity of variance. The results of Levene's test were not significant (F = .741, p = .391), suggesting that the variances for the two groups were equal. Given this, the assumption of equal variances was assumed for the subsequent t-test. The results of the t-test revealed that there was a significant difference in HOTS between the control and experiment groups; t (102) = -12.142, p < .01 (see **Table 7** for details). Thus, the null hypothesis was rejected, and the alternative hypothesis was accepted.

Specifically, the experiment group had a higher mean (M = 10.38, SD = 2.475) compared to the CG (M = 4.98, SD = 2.044) (see **Table 8**). The mean difference was -5.404, with a 95% confidence interval ranging from -6.287 to -4.521. These results suggest that the scaffolding strategies and guided discovery approach had a

Table 8. Summary statistics for HOTS_PostTest scores (N = 104)

DV	Group	N	M	SD	SEM
HOTS_PostTest	Control	52	4.98	2.044	.283
	Experimental	52	10.38	2.475	.343

Note. SEM: Standard error mean

Table 9. Levene's test of equality of error variances (DV: HOTS_PostTest)

F	df1	df2	Sig.
.313	1	102	.577

Note. Tests the null hypothesis that the error variance of the dependent variable is equal across groups & Design: Intercept + HOTS_PreTest + Group

significant positive effect on students' HOTS, i.e., the students who were taught using the intervention instruction scored much higher on the HOTS test than the students who were taught using the conventional approach.

Although the results of the independent sample t-test above have supported our research hypothesis that the intervention instruction has a positive impact on students' HOTS, we additionally conducted the ANCOVA test to establish further validity to our findings. In the present experimental study, the selection of the ANCOVA as a statistical test of analysis is justified by its robust capability to control for potential confounding variables (in this case, students' scores on the HOTS test at the pre-test level), thereby ensuring a more accurate assessment of the primary independent variable's (group of students: control or experiment) effect on the dependent variable (HOTS). Given that this study involves comparing the effectiveness of the scaffolding strategies and guided discovery approach in comparison to the conventional method, it is crucial to account for the influence of covariates that might otherwise skew the results. ANCOVA allows us to adjust the dependent variable for these covariates, effectively isolating the true impact of the interventions (Field, 2013). This adjustment is particularly important in the current study setting, where variations in baseline characteristics across groups could introduce systematic biases. By employing ANCOVA, we can confidently attribute observed differences in outcomes to the interventions themselves rather than to underlying disparities among the groups (control and experiment). This method enhances the validity and reliability of our findings, ensuring that the conclusions drawn are a true reflection of the interventions' effects, untainted by extraneous variables.

Thus, the ANCOVA was conducted to evaluate the impact of the scaffolding strategies and guided discovery approach on students' HOTS, controlling for their initial HOTS skills as indicated by pre-test scores. For this analysis, the dependent variable was the HOTS_PostTest score, and the independent variable was the students' group (control or experiment). The covariate in our analysis was the pre-test HOTS scores.

Prior to conducting the ANCOVA, the assumptions of the test were verified. The relationship between the covariate (HOTS_PreTest scores) and the dependent variable (HOTS_PostTest scores) was found to be linear. The assumption of homogeneity of regression slopes was satisfied, indicating that the effect of the covariate on the dependent variable was consistent across all levels of the independent variable. The normality of residuals and homogeneity of variances were also confirmed (see **Table 9**).

The adjusted means for the final math scores, after controlling for pre-test scores, were calculated for each group. The ANCOVA revealed a significant effect of the intervention instruction on final HOTS scores after adjusting for pre-test scores, $F(1,101) = 142.400$, $p < .01$ (see **Table 10** for details). The effect size, measured using partial eta squared, was .585, suggesting a moderate effect of the intervention on students' HOTS scores.

Additionally, multivariate analysis of variance (MANOVA) was carried out to see if significant differences exist between participants' scores on the HOTS test across its subscales between CG and EG. Although the differences in the performance of the two groups (control and experimental) were found to be significantly different in terms of the overall HOTS test, it would have been interesting to see if both groups performed significantly differently on each of the three levels of HOTS test namely Analysis, evaluation, and creation at the post-test stage.

MANOVA is a statistical technique used to analyze the differences between means of multiple dependent variables across two or more groups. It extends the analysis of variance (ANOVA) to cases where there are multiple dependent variables (Field 2013). The three

Table 10. Results of ANCOVA for between-subjects effect on the HOTS post-test: $p < 0.05$

Source	Type III sum of squares	df	Mean square	F	Sig.	Partial eta squared
Corrected model	770.221	2	385.111	75.628	.000	.600
Intercept	661.108	1	661.108	129.829	.000	.562
HOTS_PreTest	10.981	1	10.981	2.156	.145	.021
Group	725.122	1	725.122	142.400	.000	.585
Error	514.307	101	5.092			
Total	7,423.000	104				
Corrected total	1,284.529	103				

Note. R squared = .600 (adjusted R squared = .592)

Table 11. Results of MANOVA for between-subjects effect of the research variables: $p < 0.05$

Source	Dependent variable	Type III sum of squares	df	Mean square	F	Sig.	Partial eta squared
Corrected model	Analysis	76.163[a]	1	76.163	41.142	.000	.287
	Evaluation	108.038[b]	1	108.038	70.815	.000	.410
	Creation	71.115[c]	1	71.115	87.032	.000	.460
Intercept	Analysis	942.010	1	942.010	508.852	.000	.833
	Evaluation	900.346	1	900.346	590.143	.000	.853
	Creation	311.538	1	311.538	381.264	.000	.789
Group	Analysis	76.163	1	76.163	41.142	.000	.287
	Evaluation	108.038	1	108.038	70.815	.000	.410
	Creation	71.115	1	71.115	87.032	.000	.460
Error	Analysis	188.827	102	1.851			
	Evaluation	155.615	102	1.526			
	Creation	83.346	102	.817			
Total	Analysis	1,207.000	104				
	Evaluation	1,164.000	104				
	Creation	466.000	104				
Corrected total	Analysis	264.990	103				
	Evaluation	263.654	103				
	Creation	154.462	103				

Note. [a]R squared = .287 (adjusted R squared = .280); [b]R squared = .410 (adjusted R squared = .404); & [c]R squared = .460 (adjusted R squared = .455)

dependent variables in the context of this study were HOTS_Analysis, HOTS_Evaluation, and HOTS_Creation. In MANOVA, the dependent variables are considered together as a set, allowing researchers to examine whether there are significant differences among groups in terms of these variables collectively rather than examining each variable separately. This approach is particularly useful when the dependent variables are correlated, as MANOVA takes these interdependencies into account. The basic idea behind MANOVA is similar to that of ANOVA, where the variation in the dependent variables is partitioned into different sources, such as the between-group variation and the within-group variation (Field, 2013). However, in MANOVA, this partitioning is done simultaneously across all dependent variables.

The HOTS_Analysis, HOTS_Evaluation, and HOTS_Creation subscales of the HOTS test at the post-test stage were the subjects of a MANOVA (2 × 3) in this study, with the independent variables groups (having two levels: CG and EG).

The study has compared the differences between the CG and EG in the HOTS subscales at the post-test stage. The results were found to be significant at all three sub-scales: analysis (mean square = 76.163, F = 41.142, p = .000 < 0.05), evaluation (mean square = 108.038, F = 70.815, p = .000 < 0.05), and creation (mean square = 71.115, F = 87.032, p = .000 < 0.05). Please see **Table 11** for details. Added to this, the mean total score in the dependent variables post-test for the EG was found to be significantly higher compared to that of the CG for specific sub-scales.

From the test results, it can be concluded that a significant difference exists in the mean score in the analysis, evaluation, and creation subscales at the post-test stage between the two groups, where students in the EG reported higher analysis mean score (M = 3.86, SD = 1.53) compared to their counterparts (M = 2.15, SD = 1.16) in the CG. Students in the EG have reported higher evaluation mean scores (M = 3.96, SD = 1.40) compared to their counterparts (M = 1.92, SD = 1.04) in the CG. Similarly, students in the EG have reported higher creation mean scores (M = 2.55, SD = .916) compared to their counterparts (M = .904, SD = .891).

DISCUSSION

The present study was aimed to assess the effectiveness of the scaffolding strategies and guided discovery approach on students' HOTS in the context of technical and vocational colleges in Saudi Arabia. To confirm whether or not there was a significant influence of the intervention instruction on HOTS of the study participants, we carried out inferential statistics tests using independent sample t-test and ANCOVA. Our analysis revealed that the students who were taught using the scaffolding strategies and guided discovery performed better on their HOTS test than the students who did not benefit from the intervention but were taught using the conventional teaching method. In other words, we found that the scaffolding strategies and guided discovery have a significant positive effect on students' HOTS in the context of technical and vocational colleges in Saudi Arabia. Moreover, the results of our study indicated that the mean scores for the HOTS pre- and post-test for the CG were almost identical even after five weeks of conventional teaching. This result suggests that conventional teaching methods, which typically involve lecture-based instruction and rote memorization, may not effectively foster HOTS.

These methods often focus on the passive transmission of knowledge rather than engaging students in active, critical, and reflective thinking. As a result, students in the CG might not have experienced significant growth in their HOTS during the study period.

HOTS are cognitive processes that involve analysis, synthesis, and evaluation. These skills go beyond basic memorization and comprehension to engage students in deeper levels of understanding and application of knowledge. In the teaching-learning process, fostering HOTS is essential for promoting meaningful learning experiences and preparing students for success in an ever-changing world (Alrawili, Osman & Almuntasheri, 2020). By prioritizing the development of HOTS, educators can empower students to become independent learners, effective problem-solvers, and critical thinkers capable of navigating complex challenges in their personal and professional lives. Indeed, HOTS play a pivotal role in the teaching-learning process (Ab Halim et al., 2021). This is because one of the primary goals of education is to cultivate these skills in students, equipping them with the ability to think critically, analyze information, and solve complex problems, particularly within the domains of science such as physics. HOTS empowers students to delve deeper into subject matter, engage in meaningful inquiry, and apply their knowledge in practical contexts. As such, integrating strategies to develop HOTS is essential for fostering a deeper understanding of scientific concepts such as physics and preparing students to tackle the challenges they will encounter both in academia and in their future careers.

In the vast landscape of education, rote memorization and regurgitation of facts were once considered the golden keys to success. However, the winds of change are swiftly reshaping this paradigm, ushering in an era where HOTS reign supreme. These cognitive gems, encompassing abilities like analysis, synthesis, and evaluation, are no longer mere embellishments on the learning cake; they are the very flour, eggs, and sugar that make the cake rise. Imagine a classroom where curiosity is not just accepted but actively nurtured. Students are not passive receptacles of information but engaged problem-solvers, weaving webs of connections between seemingly disparate concepts (Akben, 2020). They do not merely parrot historical dates but delve into the motivations and consequences, evaluating diverse perspectives. This is the magic of HOTS in action.

The benefits extend far beyond the classroom walls. By fostering these skills, teachers can equip learners with the tools to thrive in a world full of ambiguity and complexity. They become better at identifying problems, analyzing information, and constructing well-reasoned arguments (Jailani et al., 2017). Whether navigating the digital information jungle or tackling real-world challenges, HOTS becomes their trusty compass, guiding them toward informed decisions and creative solutions. But how do we cultivate this fertile ground for higher-order thinking to flourish? The answer lies in a shift in instructional focus. Moving away from teacher-centered lectures and rote memorization, we embrace open-ended questions, collaborative learning, and authentic problem-solving activities (Khan et al., 2017).

The road to nurturing HOTS is not always smooth. It demands a paradigm shift, both for educators and learners. But the rewards are worth the effort. By prioritizing these cognitive skills, we empower individuals to become lifelong learners, critical thinkers, and problem-solvers extraordinaire. We ignite not just their passion for knowledge but the very fire of intellectual curiosity that will illuminate their journeys in an ever-evolving world. The development of an instructional module that incorporates scaffolding strategies and guided discovery approaches that are aligned with promoting HOTS.

Guided discovery goes beyond mere factual recall. It challenges students to evaluate information critically. By weighing different interpretations, considering alternative solutions, and defending their reasoning, students develop their critical thinking and evaluation skills. The process fosters intellectual independence as students move away from simply accepting given answers and towards forming their own informed opinions. Furthermore, the collaborative nature of guided discovery often involves group discussions and peer review, where students articulate their ideas, explain their thought processes, and learn to navigate complex concepts through shared dialogue. This collaborative learning environment not only enhances understanding but also develops the communication skills necessary for scientific discourse and collaboration.

Similarly, scaffolding strategies also can act as a bridge between students' current understanding and the complex world of higher-order thinking in physics. They help break down abstract concepts into smaller, manageable chunks, starting with foundational ideas and gradually layering on complexity, ensuring students master each step before moving on. Imagine teaching force and motion. Instead of directly introducing complex calculations, begin with simple activities like identifying forces acting on objects or drawing force diagrams. Once these building blocks are solidified, students can progress to solving problems that incorporate them.

The findings of the present study align with existing literature that emphasizes the importance of incorporating scaffolding strategies and guided discovery approaches to enhance students' HOTS in educational settings. Research in the field of education consistently underscores the value of instructional methods that promote deeper levels of cognitive engagement and critical thinking among learners. One body of literature that supports our findings is centered around the concept of scaffolding. Scaffolding, as proposed by Vygotsky (1978), refers to the supportive structures or guidance provided by educators to assist students in mastering new concepts or tasks within their zone of proximal development (Doolittle, 1997). Studies have shown that scaffolding techniques, such as providing prompts, modeling, and feedback, can effectively scaffold students' learning experiences and facilitate the development of HOTS. For example, a study by De Jong (2006) demonstrated that scaffolding interventions led to significant improvements in students' HOTS compared to unassisted learning.

Furthermore, the concept of guided discovery aligns with the principles of constructivism, which posits that learners actively construct their understanding of the world through meaningful interactions with their environment. Guided discovery approaches involve presenting students with opportunities to explore and discover concepts independently while receiving guidance and support from the instructor. This method encourages students to engage in inquiry-based learning, which has been associated with higher levels of critical thinking and problem-solving skills. Research by Khasanah (2016) highlighted the effectiveness of guided discovery learning in promoting conceptual understanding and transfer of knowledge.

Overall, the results of our study contribute to a growing body of literature supporting the effectiveness of scaffolding strategies and guided discovery approaches in fostering students' HOTS. By demonstrating the positive impact of the scaffolding strategies and guided discovery on students' HOTS performance in technical and vocational colleges in Saudi Arabia, this research provides valuable insights for educators seeking to enhance their teaching practices and promote deep learning outcomes among students. Moving forward, continued research in this area can further illuminate the mechanisms underlying effective instructional approaches and inform evidence-based practices for fostering HOTS in diverse educational contexts.

CONCLUSIONS AND IMPLICATIONS

In summary, the findings indicate that the instruction employing a scaffolding and guided discovery approach proves to be more effective than conventional teaching methods in the teaching of physics in technical colleges of Saudi Arabia. Inferential statistics suggested that the students who were exposed to the newly developed teaching module scored higher in tests assessing their HOTS in comparison to their peers who experienced conventional teaching methods. Thus, the positive effects of scaffolding strategies and guided discovery approach were supported in the instruction of physics. Consequently, there is a pressing need to implement an innovative teaching approach in science classrooms, particularly in the teaching of physics, to enhance students' HOTS, ultimately leading to improved academic outcomes. To facilitate the implementation of scaffolding strategies, it is recommended to allocate additional time to physics periods, integrate scaffolding techniques and guided approaches into the physics curriculum, and provide training for physics teachers. Moreover, there is a need to extend the emphasis on learning content that encourages HOTS such as analysis, evaluating, and creating levels. Embracing scaffolding techniques and guided discovery approaches in the educational system can contribute to the development of better science understanding and prepare Saudi students to face future challenges with a positive outlook on science.

Despite the rigorous research approach employed for the present study, it is also important to recognize that the present study is limited to a specific context of physics instruction, i.e., technical colleges in Saudi Arabia. Therefore, the findings of the present study cannot be claimed to be applicable to other educational settings, such as secondary schools and university settings. Therefore, it is recommended that the study should be expanded to other educational levels to assess the effectiveness of scaffolding and guided discovery approach for physics education across all educational contexts. We also believe that a parallel study at technical colleges in other cities of Saudi Arabia would offer additional insights by giving new observations. Sometimes, generalizing research findings can be tricky, especially across different contexts like universities or geographical locations. While drawing broad conclusions might be challenging, the potential for transferability remains valuable.

Additionally, the study employed a quasi-experimental design with pre-/post-test assessments involving two groups: experimental and control. Quantitative methods were utilized to gather data from study participants through content tests. It is suggested that future research could benefit from employing a fully qualitative approach or a mixed-method technique for triangulation. This would allow for a comprehensive exploration of the impact of scaffolding strategies and a guided approach to the main variable of interest (i.e., HOTS) from diverse perspectives.

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Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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APPENDIX A: HIGHER ORDER THINKING SKILLS TEST: MOTION, FORCE, WORK, AND ENERGY

Name:____ **Class number:**______________________________________

Dear student, you have a test for higher order thinking skills in the physics course (Physics 101) in the unit of force, motion, work, and energy.

The test consists of 18 multiple-choice questions, and you must answer all of them accurately and attentively, recognizing that this test will not affect your grades in the evaluation but rather is for scientific research purposes.

Test Instructions

1. The duration of the test is (50) minutes.
2. Each question in this test has four alternatives, only one is correct.
3. Questions are indicated by numbers 1, 2, 3 ... etc. For the answers, they are indicated in letters a, b, c, d.
4. Read the question carefully and precisely before attempting to answer it.
5. A question with two marked will be ignored.
6. After you have finished answering all of the questions, you must go through your responses.
7. Don't forget to write your name and class number.

Question 1: Choose the correct answer in the following sentences by putting a tick (√) in the box.

Table A1. Higher order thinking skills test

1	**Muhammed is preparing for a swimming competition. Every day he swims several laps in a 50-meter pool. Going from one side to the other is one lap. If he swims eight laps, which of the following statement is TRUE? (Analyze)**	
a-		His distance and displacement are both 400 meters
b-		His distance is 400 but his displacement is zero
c-		His distance and displacement are both zero
d-		His distance is zero, but his displacement is 400
2	**A force of 20 N is simultaneously applied to a baseball and a volleyball. The baseball has a mass of 0.3 kg and the other has 0.8 kg. What happens to the motion of the two balls? (Analyze)**	
a-		They will both accelerate at the same rate
b-		The one with a mass of 0.3 kg has the greater acceleration
c-		The one with a mass of 0.8 kg has the greater acceleration
d-		None of the above
3	**A boy jumps out of the boat into a dock. As the boy moves forward to the dock, the boat moves backward. Which of the following laws describes these mutual forces between the boy and the boat? (Analyze)**	
a-		Newton's 1st law
b-		Newton's 2nd law
c-		Newton's 3rd law
d-		Law of inertia
4	**Imagine a place in the *cosmos* far from all gravitational and frictional influences. Suppose that you visit that place (just suppose) and throw a rock. The rock will (Analyze).**	
a-		gradually stop
b-		continue moving with different speed
c-		continue moving with constant acceleration
d-		continue in motion in the same direction at constant speed
5	**Doing work in physics must fulfill three conditions. These are (Analyze).** **I. There must be force acting on an object.** **II. There must be a displacement.** **III. The speed must be constant.** **IV. The force applied on the object must be in the direction of motion**	
a-		I, II, and III
b-		II, III, and IV
c-		I, II, and IV
d-		I, III, and IV

Table A1 (Continued). Higher order thinking skills test

6 **Consider the work to be done to bring up 40 kg bricks to the sixth floor of a building under construction. The floor is about 36 m from the ground. There are three ways by which it can be done. (1) a laborer could carry it up the stairs, (2) a pulley be used, (3) an elevator can be used. The data of the work done, time and power of each way to bring the bricks up the building is on the table below (Analyze).**

Energy source	Work done (J)	Time (s)	Power (Work done per second) (W)
Laborer using stairs	14, 112	600	23.52
Laborer using pulley	14, 112	130	108.56
Elevator	14, 112	30	470.40

How is work related to power?

a- The greater the work the greater the power
b- The greater the work, the lesser the power
c- The lesser time the work is done, the greater is the power
d- The greater time the work is done, the greater is the power

7 **If we analyze a ball falling from a table (air resistance is neglected), we will find that the kinetic energy of the ball increases while its potential energy decreases during the fall. According to the law of conservation of mechanical energy: (Analyze).**

a- The change in mechanical energy is zero
b- The change in mechanical energy is greater than zero
c- The change in mechanical energy is less than zero
d- The change in mechanical energy minus the work of external forces equals zero

8 **Carefully analyze the motion of the body in these cases:**
I. A bus travelling at 60 km/h on a straight highway.
II. A car moving at 50 km/h around a curve.
III. A typhoon moving at 120 km/h Northwest and then 180 km/h Southwest.
IV. A train approaching a station slows down to stop.
Which has acceleration? (Evaluation)

a- I and II
b- I and III
c- I, II, and III
d- II, III, and IV

9 **What will happen to the displacement of a bus with a constant acceleration of 10 m/s^2 (Evaluation).**

a- It will increase
b- It will decrease
c- It will remain the same
d- It will increase at first and then decrease

10 **Suppose a cart is being moved by a force. If suddenly a load is dumped into the cart so that the cart's mass doubles, what happens to the cart's acceleration? (Evaluation)**

a- It quarters
b- It halves
c- It stays the same
d- It doubles

11 **Muhammed and Khaled are arguing in the cafeteria. Muhammed says that if he flings the spoon with a greater speed, it will have a greater inertia. Khaled argues that inertia does not depend upon speed, but rather upon mass. Who do you agree with? (Evaluation)**

a- Muhammed is correct
b- Khaled is correct
c- Both are correct
d- Neither of them is correct

12 **Study the two pictures below (Evolution).**

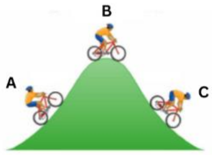
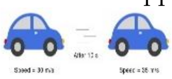
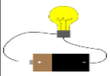

A mother lifting the baby from the crib


A father carrying the baby while walking

Who is doing work on the baby?

a- The mother
b- The father
c- Both the mother and father
d- Neither of the two

Table A1 (Continued). Higher order thinking skills test

13		**A biker went up and down a hill. At what point is kinetic energy maximum? (Evolution)** 
a-		A
b-		B
c-		C
d-		A and C
14		**When a roller coaster is at the top of a steep hill, its potential energy is maximum. When it hurdles down the slope and comes to the bottom, the potential energy reduces greatly. What can you say about the change in potential energy? (Evaluation)**
a-		It is lost in the environment
b-		It is due to the change in speed
c-		It is transformed into kinetic energy
d-		It is transformed into chemical energy
15		**The diagram shows car moving at constant speed. Construct a diagram for a uniformly accelerated motion. Which of the following will be best for your diagram (Creation).** 
a-		
b-		
c-		
d-		
16		**The third law of newton states that when an object exerts a force on another object, the second object exerts on the first a force that has the same magnitude but in opposite direction. This is the same as (Creation).**
a-		Hitting a ball with two different forces. The ball which was hit with a greater force will accelerate faster
b-		The driver of the bus suddenly hit the break. Some passengers are thrown forward
c-		A magician pulls the tablecloth from under the dishes without disturbing them
d-		A ball bounces back when it hit the ground
17		**In your physics class your teacher gave you a project to compose a sentence regarding the power develop when climbing the stairs. The best sentence is: (Creation).**
a-		The work done climbing the stairs slowly is lesser than climbing it quickly
b-		The work done climbing the stairs quickly is lesser than climbing it slowly
c-		Power is greater when you climb the stairs quickly rather than climbing it slowly
d-		Power is greater when you climb the stairs slowly rather than climbing it quickly
18		**If you were to create an illustration wherein potential energy is transferred to kinetic energy, it should be (Creation).**
a-		 An apple on top of a table
b-		 A speeding car
c-		 A light bulb connected to a
d-		 A roller coaster on a ramp