THE EFFECTS OF PROBLEM-BASED LEARNING MODULE IN ENHANCING SCIENCE CONCEPTUAL UNDERSTANDING AND HIGHER-ORDER THINKING SKILLS AMONG 6TH GRADE JORDANIAN STUDENTS

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by

FADEL ALI ABDALLAH OBEIDAT

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LIST OF ABBREVIATIONS

CU	Conceptual Understanding
CUT	Conceptual Understanding
FI	Fluid Intelligence
FIT	Fluid Intelligence Test
HOTS	Higher - order thinking Skills
HOTST	Higher - order thinking Skills Test
PBL	Problem - based learning
PBLM	Problem - based learning Module

LIST OF APPENDICES

KESAN MODUL PEMBELAJARAN BERASASKAN MASALAH DALAM MENINGKATKAN KEFAHAMAN KONSEPTUAL SAINS DAN KEMAHIRAN BERFIKIR ARAS TINGGI DALAM KALANGAN PELAJAR JORDAN GRED 6

ABSTRAK

Kajian ini bertujuan untuk membangunkan Modul Pembelajaran Berasaskan Masalah (PBLM) secara integrasi dengan kemahiran ‘fluid intelligence’ dan minat mengikut jantina, kemudian menilai kesannya dalam meningkatkan kefahaman konseptual (CU) dan kemahiran berfikir aras tinggi (KBAT) mengenai topik kerja dan tenaga untuk pelajar gred enam (lelaki/perempuan) di Jordan berdasarkan tahap ‘fluid intelligence’mereka yang berbeza. Reka bentuk pengajaran ADDIE digunakan untuk membangunkan PBLM yang merangkumi 5 peringkat (analisis, reka bentuk, pembangunan, pelaksanaan dan penilaian). Reka bentuk penyelidikan kuasi-eksperimen telah digunakan di 4 buah sekolah di Direktorat Pendidikan di Daerah Bani Kenana di Jordan, di mana sampel kajian dibahagikan secara rawak kepada dua kumpulan: kumpulan eksperimen terdiri daripada 94 pelajar yang belajar dengan PBLM, dan kumpulan kawalan terdiri daripada 95 orang pelajar yang dipelajari dengan kaedah pengajaran konvensional (CTM). Ujian matriks piawai Raven untuk kecerdasan bendalir digunakan sekali kepada pelajar. Kesahan instrumen berkenaan telah disahkan oleh pakar dan kebolehpercayaannya diuji sebanyak dua kali pada sampel 23 pelajar (uji dan uji semula) dengan jarak dua minggu di antara penggunaannya, pekali korelasi Pearson diperolehi iaitu 0.848. Untuk mengukur kefahaman konseptual (CU), ujian pra dan pasca telah diberikan kepada kedua-dua kumpulan dalam empat domain (menjelaskan, mentafsir, mengaplikasi dan mengambil perspektif). Kesahan kefahaman konseptual (CU) berkenaan telah disahkan oleh pakar dan kebolehpercayaannya diuji sebanyak dua kali pada sampel 23 pelajar (uji dan uji semula) dengan jarak dua minggu di antara penggunaannya, pekali korelasi Pearson diperolehi iaitu 0.881. Untuk mengukur KBAT, ujian pra dan pasca digunakan untuk kedua-dua kumpulan dalam tiga domain (analisis, penilaian, dan kreativiti), yang telah disahkan oleh pakar dan kebolehpercayaannya diuji sebanyak dua kali pada sampel 23 pelajar (uji dan uji semula) dengan jarak dua minggu di antara penggunaannya, pekali korelasi Pearson diperolehi iaitu 0.891. Analisis ANCOVA, MANOVA dan Ujian-T menggunakan Statistik SPSS versi 24, mendedahkan keputusan berikut: PBLM adalah lebih berkesan daripada CTM dalam meningkatkan CU pada topik kerja dan tenaga, dengan purata 18.36 untuk PBLM pada ujian pasca berbanding 11.69 untuk CTM. Keputusan juga menunjukkan bahawa PBLM lebih unggul dalam ujian pasca KBAT dengan purata 12.24 berbanding 6.81 untuk CTM. Selain itu, cara kedua-dua CU dan KBAT meningkat dengan tahap kecerdasan cecair, jadi min ini adalah lebih tinggi untuk pelajar yang mempunyai kecerdasan cecair tinggi berbanding pelajar dengan kecerdasan cecair sederhana dan rendah. Bagi jantina, kajian membuktikan purata ujian CU bagi pelajar perempuan adalah lebih tinggi berbanding pelajar lelaki, manakala purata ujian KBAT tidak dipengaruhi oleh perbezaan jantina, kerana ia sangat rapat antara lelaki dan perempuan. Hasil kajian juga menunjukkan kesan signifikan interaksi antara kaedah pengajaran dan kecerdasan cecair terhadap CU memihak kepada kecerdasan tinggi berbanding kecerdasan sederhana dan rendah. Selain itu, terdapat kesan signifikan interaksi antara kaedah pengajaran dan tahap kecerdasan cecair terhadap KBAT yang memihak kepada kecerdasan tinggi berbanding kecerdasan rendah. Manakala kesan interaksi antara kaedah pengajaran dan jantina pelajar terhadap kedua-dua CU dan KBAT belum dapat disahkan. Kajian

mengesyorkan memasukkan PBLM dalam kurikulum sains gred 6 dan menggesa guru melaksanakannya. Kajian ini juga mengesyorkan untuk menyiasat kesan PBLM terhadap seluruh mata pelajaran sains di pelbagai peringkat pendidikan.

THE EFFECTS OF PROBLEM - BASED LEARNING MODULE IN ENHANCING SCIENCE CONCEPTUAL UNDERSTANDING AND HIGHER - ORDER THINKING SKILLS AMONG 6TH GRADE JORDANIAN STUDENTS

ABSTRACT

This study aimed to develop an educational Problem - Based Learning Module (PBLM) in integration with fluid intelligence skills and gender interests, then evaluate its effects in enhancing both conceptual understanding (CU) and higher - order thinking skills (HOTS) on the topic of Work and Energy for sixth graders (males/females) in Jordan in light of their different levels of fluid intelligence. ADDIE instructional design was used to develop PBLM which includes 5 stages (analysis, design, development, implementation and evaluation). A quasi-experimental research design was applied in 4 schools in the Directorate of Education in the Bani Kenana District in Jordan, where the study sample was randomly divided into two groups: an experimental group consisted of 94 students that studied with the PBLM, and a control group consisted of 95 students studied with conventional teaching method (CTM). The standard Raven's matrix test for fluid intelligence was applied once to the students. Its validity was verified by experts and its reliability was piloted on a sample of (23) 6th grade students twice (test and retest) with a two-week interval between applications, the Pearson-correlation coefficient was 0.848. To measure CU, a pre- and post-test was administered to both groups in four domains (explaining, interpreting, applying and perspective-taking). The validity of CU was verified by experts and its reliability was piloted on a sample of (23) 6th grade students twice (test and retest) with a two-week interval between applications, the Pearson-correlation coefficient was 0.881. To measure HOTS, a pre- and post-test applied to both groups in three domains (analysis, evaluation, and creativity), HOTS test was validated by experts and its reliability was piloted on a sample of (23) 6^{th} grade students twice (test and retest) with a two-week interval between applications, the Pearson-correlation coefficient was 0.891. ANCOVA, MANOVA and T-Test analysis using SPSS® Statistics version 24, revealed the following results: PBLM is more effective than CTM in enhancing CU on the topic of Work and Energy, with an average of 18.36 for PBLM at posttest compared to 11.69 for CTM. The results also indicated that PBLM was superior in the HOTS posttest with an average of 12.24 compared to 6.81 for CTM. Also, the means of both CU and HOTS increased with the level of fluid intelligence, so these means were higher for students with high fluid intelligence compared to students with medium and low fluid intelligence. As for gender, the study proved that the average of the CU test for female students was higher than that of male students, while the average of the HOTS test was not affected by the difference in gender, as it was very close between males and females. The results also showed a significant effect of the interaction between the teaching method and fluid intelligence on CU in favor of high intelligence compared to medium and low intelligence. In addition, there was a significant effect of the interaction between teaching method and fluid intelligence level on HOTS in favor of high intelligence compared to low intelligence. While the interaction effect between teaching method and students' gender on both CU and HOTS has not been confirmed. The study recommends including PBLM in the 6th grade science curriculum and urging teachers to implement it. The study also recommends investigating the impact of PBLM on the rest of the science subjects at various educational levels.

CHAPTER 1

INTRODUCTION

1.1 Introduction

International standards for science education consider conceptual understanding (CU) to be one of the most important aspects of learning, but it is not sufficiently integrated into subject curricula (Russell, 2002). Not to mention that students' performance in science and physics classes in particular does not live up to expectations, this may be because higher-order thinking skills do not receive enough attention (Benefits, 2020; Jennifer, 2013).

Traditional education programs pay excessive attention to content, but what is important at the present time is the shift towards designing more real-world problems as foundations. Learners achieve expected learning outcomes through solving procedures, and thus educational units based on problem-based learning (PBL) enhance conceptual understanding. And acquiring higher - order thinking skills (HOTS). Since it is important to invest in students' intelligence skills to reach high levels of learning, the best way to invest them is to integrate them into scenarios of problems and ways to solve them (Tan, 2021). Since fluid intelligence describes the ability to solve new problems without prior knowledge of them, it makes sense to classify the levels of fluid intelligence among students before they undergo PBL in order to measure its effect on enhancing higher-order thinking skills (Ng et al., 2010). It is also important to use the PBL approach in basic education classes because it focuses on the student, while the role of the teacher is as a facilitator and guide of the learning process, thus giving the student an opportunity to learn independently, which enhances his thinking skills through analysis, evaluation, and creativity (Etherington, 2011). The feasibility of this educational approach has been proven in mathematics and science subjects such as physics, chemistry, and biology (Ramadhani et al., 2019).

The gender difference in interests and preferences for learning science appears from early childhood and becomes more apparent with age until adolescence. Therefore, it should be taken into account when designing learning activities, because it may affect the career inclinations of male and female students in the future (Steegh et al., 2019). To get rid of the gender gap between males and females in learning, active learning strategies must be used (Aguillon et al., 2020). It seems that designing lessons according to PBL may improve the interaction of male and female students in the learning process, which may positively affect learning outcomes (Khan & Sobani 2012).

Although the most important goals of education in Jordan are to enhance conceptual understanding and develop higher-order thinking skills among students, results are still lower than expected. The results of the Trend in International Mathematics and Science Analysis (TIMSS) indicate that Jordan ranked below the global average in physics (National Center for Curriculum Development, 2020). It is necessary to develop conceptual understanding and higher - order thinking skills to use effective teaching strategies based on problem - based learning (Harahsheh, 2017).

The aim of current study is to assess the impact of a developed module of Problem-Based Learning (PBL) in the topic of Work and Energy included Jordan's 6th science curriculum on both Conceptual Understanding (CU) and Higher - Order Thinking Skills (HOTS), considering the different genders of students and their fluid intelligence levels. The first chapter of the study discusses the study's background, problem statement, objectives, research questions, hypotheses, significance, and limitations. In conclusion, operational definitions are provided.

1.2 Background

The development of science curricula at all levels of education in Jordan, including the sixth grade, aims to provide students with an understanding of the basics of science and its practical applications in their daily lives by providing students with the knowledge and skills necessary to adapt to the educational situations they face. The new version of the sixth-grade science curriculum includes an educational unit on Work and Energy taught for the first time, divided into two lessons: mechanical energy and its conservation, and simple machines. These topics are characterized by the connection between concepts of work and types of energy. It also contains various applications for simple machines in practical life. To learn and understand it, the student practices several skills, including experimentation, investigation, verification, solving realistic problems, and solving mathematical problems (NCCD, 2019).

Most of the educational practices followed by teachers in Jordan when teaching science to the sixth-grade focus mainly on teaching facts and assessing students' memorization and viewing knowledge as the ultimate goal without paying much attention to developing students' thinking skills. It was also noted that there was a lack of interest in providing educational opportunities and directions to students that would enable them to accomplish mental tasks and activities that contribute to answering their mental questions and solving their problems (Al-Sharari, 2017). Many studies conducted in Jordan indicated that students in the basic stages have deficiencies in understanding science concepts, such as identifying and interpreting scientific concepts and deducing relationships between them, as well as applying and using them in the real world (Al-Maqdadi, 2019; Al-Hawamdeh, 2018; Shamli, 2016). Jaradat, 2013).

Regarding Work and Energy as one of the science courses, Al-Khatib (2017) highlighted that primary school students struggle with conceptual understanding of the topic of Work and Energy, while Saklan Arslan and Kurnaz (2011) confirmed that students still struggle with understanding the concepts of Work and Energy. Although they are able to provide a clear definition of the concept of energy, they are unable to represent the relationships between concepts related to Work and Energy. Furthermore, they are unable to apply the theoretical knowledge they were expected to possess when discussing the concept of energy in the context of a real-world scenario. To overcome the difficulties of learning concepts related to Work and Energy, and to improve students' abilities to comprehend them, teachers must move away from teaching them in the unconventional methods which based on the constructivist philosophy, including research, experimentation, and the use of the mind by linking experiences to reach meaningful learning (Bara & Tarawneh, 2004; Ibrahim & Saleh, 2011; Al-Momani et al., 2015).

According to Macunu (2012), the most prominent aspects that students find difficult to understand are how to use the theory of Work and Energy, kinetic energy, the principle of conservation of mechanical energy, and practical applications of Work and Energy. It is also difficult for students to understand energy sources and how they change (Salama et al., 2019; Al-Baraa & Tarawneh, 2004). Hence, it is necessary to know what is meant by conceptual understanding and its fields, so that students' weaknesses in it can be addressed. According to Wiggins and Mctighe (2002) Conceptual Understanding (CU) is the extent to which the learner possesses six axes or dimensions of understanding (explanation, interpretation, application, perspective taking, empathy, and self-knowledge). In physics in particular, students should be able to understand concepts that will enable them to solve problems related to explaining phenomena in everyday life.

Students who have a solid grasp of a scientific concept can more effectively plan and present solutions to the problems they encounter. However, numerous students still struggle to understand concepts and have trouble explaining them, making it impossible to use the concept in their problem-solving (Pratiwi et al., 2019).

Thereby, it can be stated that conceptual understanding is the fundamental component of meaningful learning which leads to deep learning. The term "Meaningful Learning" is of prominent importance in science education because of its connection with educational psychologist David Ausubel's discussions in the 1960s to refer to learning as opposed to rote learning (Gunstone, 2015). Meaningful learning has been defined as the student's desire to comprehend the material, as well as the processes of linking and organising new concepts with past experience and knowledge exploring for essential principles, weighing relevant evidence, and critically assessing knowledge (Vallori, 2014). As students develop a better conceptual understanding, they acquire facts and procedures in a manner that is more relevant and applicable to the actual world. To aid in the growth of students' conceptual knowledge, it is vital to offer them with chances to contrast their concepts with those of others, which may result in conceptual change through cognitive conflict (Farrokhniaa et al., 2019).

Since science is full of abstract notions related to difficult-to-see forms, including atoms and molecules, they cannot be comprehended without developing interrelationships; therefore, the student must construct a concept and mental models that enable him to visualise these unseen worlds. The learner attempts to comprehend scientific concepts by engaging in a mental activity focused on comprehending the concept’s attributes and, as a result, transforming sensory images into abstract images in the mind, keeping them in memory, then apply the knowledge more deeply in new educational situations. Consequently, educators were interested in learning how to quantify comprehension as a product of the educational process (Algarni, 2016). Deepening conceptual understanding is also based on constructivism theory, which holds that a learner constructs his or her own body of knowledge and that doing so necessitates the growth of mental capabilities that inspire him or her to explain phenomena, come up with appropriate answers to scientific conundrums, and learn new ideas (Nashwan, 1992; Balut, 2013; Al-Nimr, 1997), Problem-based learning is one of the most significant teaching strategies that emphasise constructivism.

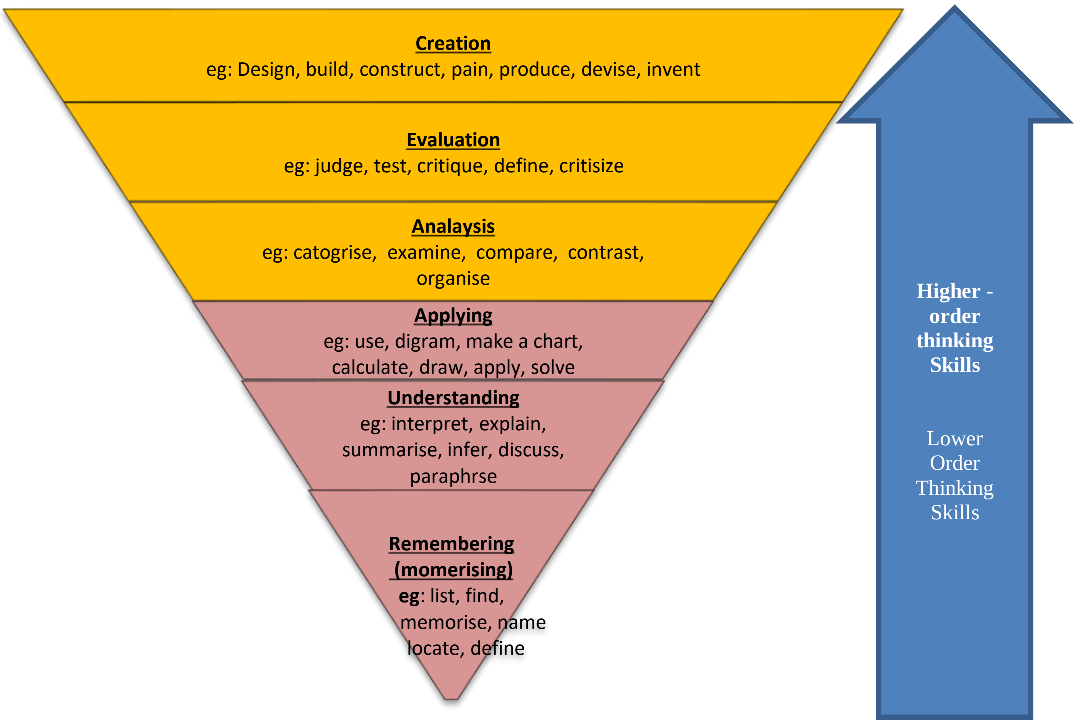
CU of issues related to Work and Energy is just one area where students struggle, as they also struggle with Higher - Order Thinking Skills (HOTS). They have difficulty employing HOTS (analysis, evaluation, and creativity), especially when evaluating how to implement the conservation law, considering the relationship between distance and work done in terms of mechanical energy (Permatasari1 et al., 2018), and use this conservation law to determine an object’s speed (Putranta, 2021). As a result, effective educational tools and exercises that improve students’ capacity to deal with HOTS are required in physics curriculum (Zaini et al., 2017). The National Test for Quality Control of Education results in Jordan for the primary stage (including the 6th grade) showed inadequate levels of acquisition of abilities related to HOTS (Jordan Ministry of Education, 2007). Al-Olimat (2019) further demonstrates that students in Jordan struggle to use higher - order thinking skills when dealing with problems and phenomena related to mechanical physics, such as force, motion, and mechanical energy.

According to Brookhart, the concept of higher-order thinking skills (HOTS) includes the following three categories: First, those who interpret HOTS in terms of transfer (which, when it occurs, implies meaningful learning), which calls for students to do more than just retain what they have studied; they also need to be able to make sense of it and put it to use. Second, according to those who define it in terms of critical thinking, it involves reasonable, reflective thinking that is centred on determining what to believe or do and contains reasoning, questioning and examining, viewing and explaining, comparing and linking, discovering complexity, and exploring viewpoints. Third, those who describe it in terms of problem solving, which may entail recalling facts, absorbing lessons, analysing concepts, coming up with original solutions, and successfully communicating (Collins, 2014).

Figure 1.1 shows that the top three levels of Bloom's Taxonomy, "Analysing, Evaluation, and Creating," correspond to higher - order thinking skills, while the bottom three levels, "Remembering, Comprehending, and Applying," correspond to lower order thinking skills (Suprapto et al., 2017; Higgins, 2017).

Figure 1.1

Bloom's Taxonomy (Suprapto et al., 2017; Higgins, 2017)



Critical and creative thinking are also included in HOTS. Critical thinking is characterised by careful analysis and evaluation, while creative thinking is characterised by designing or inventing new ideas. HOTS require students to be proactive and optimistic, so they should attempt to analyse, evaluate, and create, which will inevitably reflect in their academic success (Conklin, 2012). Higher - Order Thinking, according to Ismail et al. (2017), entails the acquisition of complicated judging skills such as critical thinking, creative thinking, reflective thinking, and problem solving.

However, there is a HOTS level classification known as (Marzano HOTS) that comprised of 13 levels: Comparing, Categorising, Inductive Reasoning, Deductive Reasoning, Analysing, Building, Abstracting, Analysing Viewpoints, Decision

Making, Examination, Problem Solving, Experimental Inquiry, and Invention (Yeea et al., 2015).

HOTS stands for high-level thinking ability, which means the ability to think rather than just memorise, restate, or recite. HOTS, on the other hand, may transfer one notion to another, process and execute information, identify links from diverse information, process information to solve problems, and critically analyse ideas and information. According to the knowledge dimension, HOTS refers not just the factual, conceptual, or procedural knowledge but also to metacognitive knowledge. The learner’s capacity to link various concepts, interpret, solve problems, make discoveries, and make decisions is characterised by the metacognitive dimension (Supeno et al., 2019).

Many students struggle with dealing with ideas related to Work and Energy, as they include the three higher levels of thinking (analysis, evaluation and construction) according to Bloom's taxonomy. Most of these difficulties lie in analyzing the application of the law of conservation of mechanical energy, evaluating the relationship between the distance to the work done, building Work and Energy relations in daily life, and developing Work and Energy theory in daily life (Permatasari et al., 2018). Anwar (2016) confirm that it is beneficial to use problem -based learning (PBL) to develop HOTS compared to the conentional method.

HOTS skills that are widely available in phenomena and relationships related to mechanics topics, including Work and Energy, require students to recall skills related to fluid intelligence when practicing problem-solving related to such phenomena (Shekoyan et al., 2017). Higher-order thinking skills (analysis, evaluation, and creation) include several examples on the topic of Work and Energy, including:

analyzing applications of the law of conservation of mechanical energy, examining the relationship between work and potential energy, and creating relationships for Work and Energy in everyday life (Permatasari et al., 2018).

Emphasizing the disparities between male and female students in their approach to science education is of paramount importance. Recent research in neuroscience and brain studies has shed light on these discrepancies, which manifest as variations in brain structure, size, developmental trajectories, and the pace of cognitive development. Genetic factors have also been implicated in the gender-based achievement gap, influencing cognitive processes. Consequently, these gender disparities exert a notable impact on how students engage in the learning process. For instance, girls may excel in verbal and emotional domains, while boys tend to gravitate towards activities with a physical and visual dimension. As educators, it is imperative for us to recognize and comprehend these distinctions to effectively facilitate our students' educational journey (Nasser, 2016).

As we delve into the realm of the learning process, gender differences become increasingly conspicuous in science classrooms. Boys and girls typically approach problem-solving and experiments with distinct strategies. Girls often adhere to the teacher's or textbook's instructions when tackling problems or conducting experiments, while boys relish employing their problem-solving skills and experimenting more freely. Additionally, girls tend to engage more with textbooks, rendering them more susceptible to both the positive and negative influences embedded in the curriculum presented within those pages (Delialioglud, 2003).

Over the past two decades, educators in the field of science have observed gender disparities in various facets of science education, encompassing achievements, attitudes, motivation, attention, and behavior. Some sources, like Chwedes (2003), propose that the standards for mathematics and science tend to be higher for girls compared to boys. Conversely, others argue that the gender gap in science primarily benefits boys (Murphy, 1996, as cited in Hsiung et al., 2003). However, even though certain studies reveal a marginal increase in the average scores of female students compared to males, this difference is often insufficient for broad generalizations (O'Dea, 2018).

In the realm of physics, despite some studies, such as Qubaja (2014), failing to identify significant gender disparities in the conceptual understanding of physics, an ongoing debate persists regarding whether males or females exhibit preferences in grasping physics concepts like Work and Energy. Some research posits that males might have a more innate familiarity with physics ideas than females. Nevertheless, it is plausible to reduce or even eliminate the gender gap in comprehending physics concepts by employing suitable instructional strategies (Bates et al., 2013). Furthermore, it is imperative to consider the conceptual variances between male and female students, which are often shaped by their teachers (Cahyanto & Saputro, 2019). Recognizing that boys and girls frequently harbor distinct perspectives (Mills et al., 1993; Venema et al., 1998), educators should tailor their teaching methods to cater to the unique interests of both genders. Cultivating a supportive environment for female participation in science education may involve group work and minimizing competition for positions. Additionally, linking scientific concepts to real-life experiences of girls and underscoring the significance of female role models can prove highly beneficial (Andersson et al., 2009). For instance, when it comes to science courses like Work and Energy, Al-Khatib (2017) has observed that elementary school children often encounter challenges in grasping these concepts.

To bridge the gender gap, particularly in the primary stages of education, it is imperative to integrate science curricula with activities that align with the interests and needs of both genders, especially in the domain of physics. This approach has the potential to enhance science comprehension among both male and female students, bolster their confidence in learning, and potentially influence their future career choices, especially for female students (Jugović, 2017).

Diverse perspectives abound concerning the gender-based disparities in conceptual comprehension of Work and Energy. Vidak (2020) concluded that males distinctly outperform females in understanding concepts related to Work and Energy, such as the application of the principle of conservation of mechanical energy, and that overcoming this difference may require special attention. Besides assessing the mental models of male and female students, it could be advantageous for teachers to stimulate imagination by enriching their lectures with a plethora of visual models aimed at enhancing the visual-spatial skills of female students. Conversely, Lorenzo and Mazur (2006) have shown that the utilization of interactive teaching methodologies eradicates the gender gap in grasping conceptual aspects of mechanical concepts, such as Work and Energy.

When it comes to assessing the gender-related differences in conceptual comprehension of Work and Energy in Jordanian schools, the researcher was unable to locate pertinent studies. This may be attributed to the separation of male and female schools at the elementary and secondary levels of education, rendering it challenging to conduct studies encompassing both genders.

Regarding the connection between gender and Higher - order thinking Skills (HOTS), several studies have indicated that there is no significant difference between males and females in possessing these skills, even though the level of these skills in the field of science tends to be lower for both genders (Saido et al., 2015). Consequently, the topic of why boys outperform girls in science or why girls exhibit less inclination to pursue science studies remains a complex and controversial issue (Mitrievsky & Zhikov, 2012).

The differences between students in learning science are not limited to gender, as they may depend on their level of fluid intelligence. The theory of fluid intelligence returns to Cattell, this theory challenges the idea of the (G) factor, a generalised theory of intelligence that asserts intelligence is a single construct. Cattell, on the other hand, claimed that there are two types of independent intelligences: fluid intelligence (GF) and crystallised intelligence (GC). Fluid intelligence is the ability to think and resolve issues in novel and unfamiliar situations without reference to prior knowledge, whereas crystallised intelligence is the ability to utilise knowledge acquired through prior learning or experience (Vinney, 2019; Jaeggi, 2008; Geary & Koepke, 2019; Cacioppo & Freberg, 2012). Fluid intelligence, as defined by Cattell-Bate, is a measure of a person's ability to recognise fundamental rules or concepts in novel problem-solving situations (Geary & Koepke, 2019).

The Fluid Intelligence **(**FI) is defined it as a student's ability to recognise the set of rules or ideas in novel problem-solving domains (Geary & Koepke, 2019), it refers to innate intelligence that is linked to how effectively an individual perceives complex relations, forms concepts, and participates in abstract reasoning (Filičková et al., 2015). Therefore, fluid intelligence is the capacity to reason, analyse, and solve problems by employing logic, pattern recognition, and abstract thinking to address novel difficulties. In reality, we employ fluid intelligence when faced with novel, frequently nonverbal activities like puzzles and math difficulties. As shown when someone picks up a paintbrush or a piano without any prior experience, fluid intelligence also contributes to the creative process (Vinney, 2019). Fluid intelligence falls with age, therefore these abilities start to decline as people age, often as early as their twenties, but crystallised intelligence is maintained or increased (Vinney, 2019), as shown in Figure 1.2 (Cacioppo & Freberg 2012).

However, some research suggests that FI can be developed through training (Vinney, 2019). Jaeggi (2008) conducted a study on four groups of young, healthy individuals did a very demanding working memory (short-term memory) task on a daily basis. The job was completed by the groups over the course of 8, 12, 17, or 19 days The researchers discovered that after the training, participants' fluid intelligence enhanced, and that the more instruction they received, the better their fluid intelligence became.

To determine a student's fluid intelligence, instructors should provide two exams of analogical reasoning (figural and numerical versions). The Figural Reasoning (FR) statements are shown in the form of analogy patterns made of geometric figures, such as Figure 1.3. While the numerical statements are supplied to finish the following number, including (1, 4, 9,...) (Ren et al., 2015). Academic success in educational materials is strongly connected to how the learner handles the educational situation that is presented to him. As there are educational circumstances in which the learner performs well based on the method of instruction he received, there are also educational circumstances that necessitate logical reasoning, particularly in mathematics and physics, in which the learner's performance is dependent on his fluid intelligence level.

According to Cattell’s theory of intelligence, FI is a major predictor of students’ academic achievement and learning efficacy (Soares, 2015; Sanginabadi, 2012; Fuhrmann et al., 2020), as it can substantially anticipate children’s performance when encountered with both standard and real problems that should be solved (Xin & Zhang, 2009). For this reason, it is necessary to incorporate FI skills into the teaching process because of its beneficial effects on improving student accomplishment (Ren et al., 2015).

FI is typically tested using exams that incorporate deductive and inductive reasoning, which represent an individual’s ability to resolve complicated issues using logical reasoning and to reach efficient conclusions (Ali & Ara, 2017). Therefore, there is a strong relationship between the level of intelligence of the questioner and conceptual understanding, as fluid intelligence is nothing more than the individual's capacity to resolve urgent problems through awareness and comprehension of the relationships between the concepts that are associated with the issue. This may result in the acquisition and formulation of new concepts and their application in different situations, i.e. it focuses on individuals’ adaptability and their capacity to assimilate concepts and links between them and cognitively merge them together (Quasha, 2000).

Figure 1.2

Relationship between Crystallized intelligence and Fluid intelligence with age (Vinney, 2019; Jaeggi, 2008).

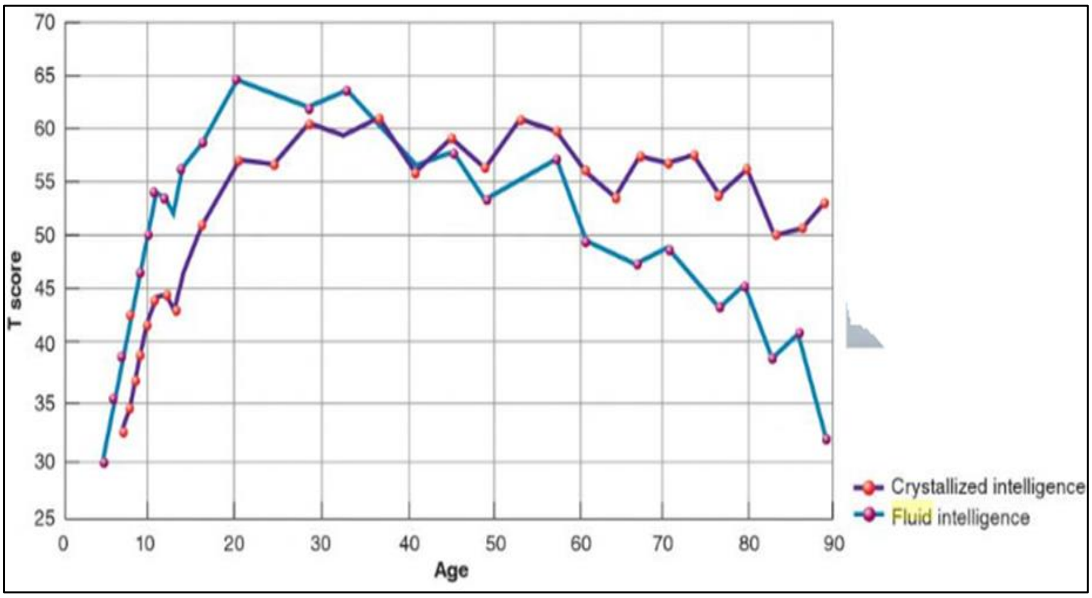
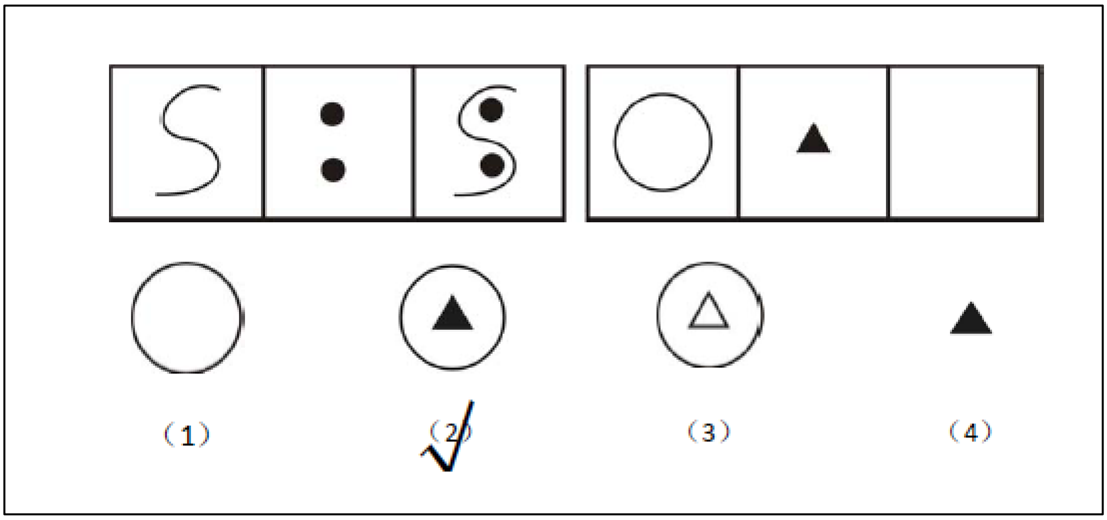


Figure 1.3

Sample of the figural reasoning (FR) statements (Ren et al, 2015).



Furthermore, there is a fundamental connection between fluid intelligence and students' use of higher-order thinking skills because fluid intelligence skills demand that students use inference, concept formation, categorisation, hypothesis generation and testing, relationship identification, comprehension of implications, problem-solving, induction, and information transfer (Primi et al., 2010). Tasks requiring analytical ability are also associated with fluid intelligence (analysis of patterns within abstract visual inference tasks). Nonverbal cues are included in these skills, which need the development of new cognitive strategies or the flexible reconstruction of old techniques in response to new conditions (Quasha, 2000).

In addition to the aforementioned, the practice of fluid intelligence skills by students is crucial for learning and accomplishing logical solutions to issues faced by learners, which can have a substantial impact on their educational and professional achievement (Sanginabadi, 2012). According to Pressori et al. (2011), people with high fluid intelligence outperform people with medium fluid intelligence on analogous thinking tasks, and fluid intelligence raises the level of divergent thinking (Patti, 2009).

Although several studies have found a correlation between fluid intelligence and academic achievement in science subjects, including physics (Moehring et al., 2018; Ren et al., 2015; Rahma, 2011). Hafez (2019) notes that other factors, such as teaching method, motivation, economic status, family support, and peer groups, can interfere with intelligence and influence academic achievement. While the researcher did not come across any studies that looked at the association between fluid intelligence level and conceptual comprehension or HOTS in the context of Work and Energy.

Students must practise various scientific processes in order to better understand scientific concepts. These processes involve many different thinking skills, including observation, inference, prediction, asking questions, developing hypotheses, designing experiments, and applying these ideas in scientific contexts. Therefore, the Problem-Based Learning (PBL) method may be suitable for fostering a general comprehension of scientific ideas (Pratoi et al., 2019). Whereas Pratiwi et al. (2019) discovered that problem-based learning improves students' comprehension of physics subjects. This pedagogical strategy may also be effective in physics courses to enhance students' HOTS (Folashade & Akinbobola, 2009).

When applying problem-solving techniques to connect various physics-explainable aspects, such as when comprehending and mastering physics concepts, principles, theories, and laws. In addition to the physics problems that call for higher levels of logical thinking (Sagala, 2017; Ince, 2018).

Howard Barrows developed and applied problem-based learning (PBL) in a medical education context in the 1960s at McMaster University in Canada (Roberto, 2011). Its origins can be traced back to John Dewey's definition of a school in general and a classroom in particular as a laboratory for solving real-world problems. Problem-based learning is a constructivist-based learning strategy. This strategy has an impact on learners in a variety of ways, including: recognising and solving authentic problems, gathering information and developing it into topics, learners learning how to construct a preconceived idea, organising and investigating problems, collecting and analysing data, ordering facts, and establishing a concept to resolve their issues (Wewe, 2017), and working either individually or collaboratively to resolve the issues (Tuncel & Fidan, 2019; Akacay, 2009).

There are many ways to define problem-based learning, but Barrow defined it as learning that results from using the scientific procedures required to comprehend problem resolution (Barrett, 2017). With this strategy, students get the chance to learn while actively tackling important issues (Yew & Goh, 2016).

PBL is defined by Wheatley (1991) as “a type of learning that helps students understand what they learn, construct meaning, and gain confidence in their skills to solve problems.” Delisle (2001) defined it as “an educational strategy that is taught by giving a stance for students, leading them to a dilemma that they must answer.” According to Abdel-Hakim (2005), it is “a model based on constructivist theory of learning, and its designer, Jason Wheatley, is a science and mathematics teacher. The model is made up of three components: tasks, collaborating groups, and sharing.” It is obvious from the above definitions that they all agree that the learner is a generator of knowledge rather than a receiver of it, and that all definitions emphasise that learning occurs via challenges that learners cooperate to solve (Alyagobi, 2010).

PBL is a teaching style in which challenging real-world situations are used to facilitate student learning of principles and concepts rather than the direct presentation of facts and concepts. In addition to the aforementioned benefits, PBL can foster the development of critical thinking, problem-solving, and communication skills. It can also facilitate collaborative work, the discovery and evaluation of research resources, and life-long learning (Duch et al., 2001).

Furthermore, PBL can be implemented in any learning environment. In accordance with the strictest definition of PBL, the method is used as the primary method of instruction throughout the entire semester. Even so, broader definitions and applications range from incorporating PBL into lab and design courses to using it to initiate a single discussion. Additionally, PBL can be used to create assessment items. The real-world problem is the common thread connecting these various applications (Duch et al., 2001).

Regarding the teacher's role in the PBL method, it stems from John Dewey's beliefs that teachers should instruct by appealing to students' "natural instincts to examine and create" (Akcay, 2009). The teacher serves as a guide in assisting the learning process rather than providing knowledge or transferring information (Silver, 2004).

Educators differ on the processes or stages of the PBL technique, however the majority of them (Akacay, 2009; Jones, 2006; Shishigu, 2018; Nilson, 2014; Docktor, 2009; Delisle, 2001) agree on the following core steps:

1 - The problem or scenario (question) that must be resolved is presented.
2 - Students must work in cooperative groups to grasp the problem, establish its dimensions, and what is expected of it.
3- Students plan the solution by gathering data, organising ideas, drawing diagrams, conducting experiments, writing mathematical equations and necessary laws, and so on.
4- Generating potential solutions to the problem.
5- Converging on the best solution as a group
6- Validating the solution and potentially consulting with other groups.

In Jordan, Batainah and Al-Qadri (2015) applied a strategy for problem-based learning in Jordan on the topic of heat for the ninth grade, while Jaradat and Zeitoun (2013) applied it to the minerals' unit for the ninth grade through three basic steps (tasks, collaborative groups, and participation), and they added evaluation to it to measure educational outcomes. While PBL was not applied in topics related to Work and Energy.

It is evident that PBL procedures require students to practice logical reasoning skills that may be influenced by their fluid intelligence level and how to apply it to problem-solving. Particularly in science and physics education, FI skills are increasingly utilised when solving complex problems in a variety of educational settings. Solving a motion problem similar to a previous question, such as determining terminal velocity from time data, acceleration, and initial velocity using the equation of motion, demonstrates crystallised intelligence. However, if the question is altered to ask for the acceleration based on the initial velocity, final velocity, and time, then this is a solution to a new problem that involves logical thought and demonstrates fluid intelligence. The spatial reasoning connected with vectors and graphs is an excellent predictor of fluid intelligence, which improves conceptual comprehension and higher - order thinking skills (Shekoyan et al., 2017).

Individual differences among students may play an important role in determining how much PBL enhances conceptual knowledge and HOTS in science. According to research, individual variables such as prior knowledge, age, and gender have a significant impact on what students learn. Students of all ages and educational levels frequently begin their study of physics with quite similar notions, many of which contradict physics concepts (McDermott, 1984), although the situation may alter depending on the student’s gender (male and female).

According to some of studies, the interaction between gender and problem-based learning has no effect on the capacity to comprehend physics concepts (Folashade & Akinbobola, 2009). Ajai and Imoko (2015) have emphasised that there is no achievement gap between male and female students in mathematics if problem-based learning and other appropriate teaching methods are used, and that the differences may lie in how students respond to educational situations. (Male or female) favours the suitable types of activities he engages in to resolve the issue (the problem).

The distinctions in the development of logical reasoning ability between males and females recognised by Piaget and Inhelder start to show up around the age of 11 years (Mitrevski & Zajkov, 2012). This is the age of Jordanian sixth-grade students (the place of study).

This study focuses on 6^{th} graders for a number of reasons, including the fact that the Jordanian educational system mandates a compulsory stage, known as the compulsory basic level, which spans the first through tenth grades. In addition, the scientific book for children in the first through eighth grades has a variety of themes (physics, chemistry, biology, and geology), but the science book for students in the ninth grade and beyond until the conclusion of high school contains a separate volume for each field of science (physics, chemistry biology, geology). Accordingly, the 6^{th} grade is a good choice because it marks the end of the lower basic stage and the start of the upper basic stage in Jordan. In addition, its students are at a developmental stage where they need to have a deeper understanding of scientific concepts and higher thinking skills in order to respond appropriately to some of the educational phenomena and scenarios they encounter (Al-Rashidi & Abu Al-Lum, 2019).

Since, according to Vinney (2019), fluid intelligence, which is one of the topics of current research, declines with age, it is suitable to select sixth graders in Jordan, whose ages range from 11 to 12 years.

The following reasons led to the selection of the topic Work and Energy:

First: Since there is only one science book available for each of the four science disciplines (physics, chemistry, biology, and geology) in the sixth grade in Jordan that was selected, it was necessary to select one of the four disciplines. Since the researcher is a physics teacher, he opted to select a subject from physics. The subject (Work and Energy) was picked as the focus.

Second: The topic (Work and Energy) is found in the sixth-grade science book in the first semester, and therefore corresponds to the period of application of the study.

Third: Work and Energy is a new topic for sixth graders within the curriculum of the science textbook for the upcoming school year; consequently, no prior study has been completed on this issue; thus, it would be beneficial to carry out research. To determine how well sixth-grade students understand scientific concepts and higher-order thinking skills in this new subject.

Fourth: The second section of this subject, which focuses specifically on machines, is a new topic in Jordan's main level. The researcher was unable to locate any educational studies detailing the academic achievement of students in relation to conceptual comprehension and higher-order thinking skills.

Fifth: This study concentrates on the two components of Work and Energy - mechanical energy and machines as they are considered as the central axis of physics/science curricula at all levels of school, including fourth, sixth, eighth, and ninth, tenth, secondary, and higher education. The second reason is that the concepts of Work and Energy are especially problematic - they are so complicated and abstract that their comprehension relies so heavily on practical examples and their life applications, and are therefore often troublesome for students in general if taught in conventional ways and without the use of effective learning strategies (Saglam Arslan & Kurnaz, 2011), Jordanian students have a poor comprehension of ideas and principles connected to Work and Energy, its changes, and applications in everyday life.

1.3 Problem Statement

Students in the basic stage in Jordan, including the sixth grade, suffer from difficulties in conceptual understanding and acquiring higher-order thinking skills in science topics, according to the results of the national test for controlling the quality of education (Ministry of Education, 2019), which showed the superiority of female students over male students. This gap between males and females is clearly visible in mechanics topics such as Work and Energy, according to the results of the TIMSS test, female students' results were better, despite their fluctuation between high and low between 1999 and 2019 (National Center for Human Resources Development, 2019).

Although fluid intelligence may have a positive impact on the development of conceptual understanding and HOTS among students (Shekoyan et al., 2017), most studies have linked it to academic achievement. A positive relationship has been found between fluid intelligence and academic achievement in scientific subjects, including Physics (Moehring et al., 2018; Ren et al., 2015; Rahma, 2011), while the study by Habibullah et al. (2010) demonstrated that there is no relationship between fluid intelligence and achievement. Lee and Theriault's (2013) study demonstrated that fluid intelligence has a positive effect on creative thinking. However, after reviewing previous literature in Jordan, there are not sufficient studies that clarify the relationship between fluid intelligence skills and both conceptual comprehension and HOTS