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Conceptual Change and Developing Mental Motivation in Physics: Effects of Transformational Learning Theory

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This study to investigate the effect of using transformative learning theory (TLT) -based teaching model on a conceptual change and developing mental motivation in Physics for secondary school students. The study follows the descriptive, analytical, and experimental method with a quasi-experimental design for experimental and control groups. sample consisted of (70) students from 1st-grade secondary school who are divided into two groups: the experimental group (34) students and the control group (36) students. To achieve the objectives of the study, A Conceptual Change Test (CCT) and A Mental Motivation Scale (MMS) were constructed. The results revealed that a TLT-based teaching model has effects on changing concepts and developing mental motivation in Physics. Moreover, there is a statistically significant correlation (r= 0.358) between the growth of mental motivation and the inducing of a conceptual change in physics for secondary school students. In light of the results, the study recommended conducting further studies on transformational learning theory (TLT) and conceptual change and mental motivation in various fields and learning stages.

Keywords: conceptual change, mental motivation, transformative learning theory, physics, learning

INTRODUCTION

Physical concepts and conceptual structure formation

Physics must be viewed as a content of concepts that are organized together in the form of a network of scientific relationships that contribute to achieving a deep understanding of physical concepts (Tolba, 2023; 2007). Concepts are packages of semantics and associations occurring within them (Novak, 1996).

Concepts are packages of meaning, and they capture the regularity, patterns, or relationships between things, events, and other concepts (Novak, 1996). Every concept is a human invention, a way of organizing the world. Concepts are formed, not through

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the interaction of associations, but through an intellectual process in which mental functions such as memory, attention and inference are involved and in which language is involved as a guide (Cakir, 2008).

And the physical concepts will remain the central unit of the knowledge-building of physics, and in light of it other units are formed, such as generalizations, principles, laws, and theories, and it is the factor responsible for the occurrence of effective learning (Tolba, 2023; 2006). Once the physical concepts acquire meanings and semantics, the links are formed between them to build a conceptual network, or what is known as the conceptual structure (Ausuble, 1968).

The conceptual structure plays an important role in learning new concepts. It represents Ideational Anchors on which learning new physical concepts is based. If the new physical concepts conflict strongly with previous concepts and ideas, or if they are not related to them at all; the new concepts and ideas derived are not combined with the previous concepts and ideas, nor are they preserved (Tolba, 2013; Ifenthaler et al., 2011).

The conceptual structure that the learner possesses, and its impact on the learning process is evident through the following: Restructuring; where new knowledge is reconstructed in long-term memory differently, Elaboration of the conceptual network; which leads to multi-rich retrieval paths in cognitive representation, and Accessibility, conceptual structures increase access to knowledge, thus reducing working memory overload, and processing more concepts in a shorter period, Availability; the richness of the learner's conceptual structure increases with the integration of new concepts inside it, and this conceptual abundance is recallable during a new learning attempt (Tolba, 2023; Blankenstein et al., 2013; Anderson et al., 2000; Rothbart et al.; 1979; Shavelson, 1972).

Conceptual Change

One of the most crucial learning outcomes for organizing physical knowledge into a meaningful form is the development of physical concepts. Therefore, students' acquisition of these concepts has become a major goal of learning because they increase the learner's ability to explain many natural phenomena and give a semantic meaning to these interpretations (Tolba, 2023).

Many studies have proven that physical concepts are complex, characterized by abstraction, difficult to teach and learn, and the learner cannot build a deep understanding of them. Also, not properly understanding these concepts will lead to a decline in students’ interest in them, and the construction of misconception; Studies indicate that students have misconceptions (Prodjosantoso et al., 2019).

Consequently, their performance in physics decreased (Bello et al., 2018; Obafemi and Onwioduokit, 2013).. Consequently, their performance in physics decreased (Bello et al., 2018; Corradi et al., 2013; Obafemi and Onwioduokit, 2013; Nkwo et al., 2008). Conceptual difficulty and failure to understand physical concepts lead to a distortion of the process of their formation and become a prelude to the formation of misconceptions about them or what is known as alternative perceptions (Liu and Nesbit, 2018; Sokrat et al., 2014; Sözbilir & Bennett, 2007; Cakmakci et al., 2006).

Alternative concepts are a mixture of the student's knowledge and ideas in his cognitive repertoire that is inconsistent with the correct concepts associated with the learning contents and may hinder learning, because they represent a mental model in the learner's mind that is difficult to replace with correct concepts (McLeod, 2018; Taber, 2017; Kummer et al., 2016; Vosniadou, 2013; Sanger and Greenbowe, 1997; Chambers and Ander, 1997).

According to Vosniadou (2013) and Hewson (1992), conceptual change is a mental process whereby students become aware of how their concepts fit into their cognitive structure. It is a change of the alternative conceptions in response to a circumstance that causes a conflict between these ideas and the recently learned information (Taber, 2017; Tobin, 1992). White and Johnston (1989) indicated that conceptual change is replacing the old principle or belief with the new one. Conceptual change is defined as the process of altering unimportant beliefs that students have about a scientific concept and still have a passable understanding of it. Through this process, conceptual change is created (Larkin, 2012; Novak, 2002).

According to Posner et al., (1982), several prerequisites must be met before a conceptual change may occur (Misconceptions are replaced with Correct concepts), but the most crucial of them is that the student is not convinced of his misconceptions. Additionally, the student should be able to understand the new concept and be persuaded by it. The student should also be able to apply the new concept to solve difficulties that he has been unable to handle using his patterns of misunderstanding.

Mental Motivation

Motivation and mental skills have an important place in learning and performance. These are strongly linked neuropsychological processes. More precisely, developing students' mental skills is developing their motivation. (EL Oirdi et al., 2023). The process of conceptual change requires more effort from the learner and mental focus and possession of mental motivation and enthusiasm to make this change. Mental motivation is one of the most important aspects of the human motivation system, because of its vital role in stimulating creative abilities and mental skills such as critical thinking skills, and plays an important role in shaping cognition, building a skilled self, self-confidence, awareness of ability, and the desire to continue performance (Shenhav et al., 2021; Abdul- Ameer et al., 2020); It is responsible for the individual being curious, inquisitive and creative (Özdemir and Demirtaşlı 2015), and can solve problems, Issues and make decisions (Ames, 1992; Graham & Golan, 1991). Mental motivation also works on expanding and enriching the learner's cognitive structures with many experiences, and a willingness to use intellectual resources (Heilat & Seifert, 2019).

Accordingly, Mental Motivation is viewed as a stimulant of behavior, because it is an important part of the educational process and creating behavioral change in a unique way; It improves the learner's ability to retrieve and process knowledge at a deep level, makes knowledge more stable in memory, and also enhances the Entrepreneurial Spirit in changing the way of thinking and viewpoints when learning scientific concepts (Pestana et al., 2022; Wiyono & Wu, 2022; Gehr, 2019; Ryan & Deci, 2017).

There is a positive relationship between mental motivation and academic achievement. It is associated with the desire for self-satisfaction, pleasure in learning, or achieving a certain goal; thus, it is necessary for self-learning, autonomy, and competence (Zambuk, 2021; Gehr, 2019; Bilbrey, 2017). It also expresses autonomy and goal-directed behavior and the free will to do the learning tasks (Ryan & Deci, 2017).

Bilbrey, (2017) defined it as the will or motivation that motivates a person to do something, achieving a kind of happiness and pleasure. Also; McInerney & Etten (2001) defined mental motivation as the internal mental stimulation of an individual to engage in cognitive activities that require extensive use of mental processes to find solutions to problems and discrepancies and evaluate learning process.

The level of mental motivation determines the amount of effort an individual is willing to invest based on the difficulty and benefits of performing the learning task, It is similar to intrinsic motivation in that it motivates the individual to do an activity and enjoy achieving the learning goal, and reflects a psychological need related to competence (the feeling of acquiring skills for challenging activities) and independence (the feeling that the behavior is authentic and not disturbed) (Herlambang et al., 2021; Kurzban et al., 2013).

The owners of the cognitive trend believe that mental motivation is responsible for the process of learning, makes the learner active and persistent, and has strong motives represented in seeking to understand the events that surround him and trying to discover knowledge related to the subject of learning (or a scientific phenomenon) to build conceptual understanding (Heilat & Seifert, 2019).

Therefore, poor performance resulting from motivation indicates an unwillingness to continue actively performing learning tasks (Earle et al., 2015). It becomes important to support autonomy, enhance students' motivation, and engage in learning activities using different teaching strategies and models (Siacor et al., 2024; Nur et al., 2023; Krishan & Al-rsa'I, 2023; Munawaroh et al., 2022; Pambudi, 2022; In'am & Sutrisno, 2021).The dimensions of mental motivation are defined in four components; learning orientation, innovative problem-solving, mental focus, and cognitive integrity (Giancarlo et al., 2004):

1. The learning orientation component; refers to possessing learning goal orientation which is defined as a desire to acquire new skills and knowledge. The individual can generate internal motivation to increase the knowledge base or expand his conceptual structure, appreciate the value of learning for knowledge and expand it, and take it as a way to achieve control over concepts in learning situations, and nourish his mental curiosity through effective search and discovery of the correct knowledge base, and be more Engaged in learning tasks, learning from experiences, continually seeking new knowledge to support his creative performance, showing interest in engaging in challenging activities or situations of conflict, appreciating and evaluating the value of discovered knowledge.
2. Innovative problem-solving component; It describes inclinations to be innovative, imaginative, original, and flexible in thinking about problems, It describes the tendencies to be innovative, imaginative and new in thinking about problems, which is the ability to solve problems with creative and original ideas and solutions when faced with complex problems. Here the learner has a strong sense of self-satisfaction and self-confidence in his ability to solve difficult problems when he has creative solutions.

3. Mental focus component; It describes one's ability to be task-focused when solving problems and to get inside the problem, which is the ability to solve problems with creative and original ideas and solutions when faced with complex problems. It represents the tendency towards intellectual clarity to face tasks and solve problems, self-confidence, and the ability to complete the required tasks in a timely, accurate and specific manner. It also represents the individual's ability to continue performing the task without feeling bored or tired until he reaches a solution to this problem. Here the individual is characterized by determination to get the job done, and a sense of comfort with the problem-solving process.

4. Cognitive integrity component: It refers to the degree to which one considers different points of view for the sake of pursuing truth, and being fair-minded by valuing alternative viewpoints, It is the learner's ability to use neutral thinking skills, where he is neutral towards all ideas, searches positively for the truth, open-minded, takes into account the multiplicity of alternative options, divergent viewpoints, is characterized by cognitive curiosity in acquiring new information, and the ability to confront ambiguous problems, and feeling happy when finding solutions. Cognitive integration consists of: open-mindedness; It expresses the learner's ability to adapt to diverse situations, deal with problems and difficulties encountered, and mental curiosity; It includes the ability to ask questions and practice self-directed learning.

The Transformative Learning Theory (TLT)

For practitioners and scholars in adult education, the Transformative Learning Theory (TLT) is essential. it is a key theory in adult education, learning is a process of communication that shapes the student's whole experience. It focuses on the learner's understanding and how he understands change and transformation in his knowledge, values, beliefs and feelings (Fleming , 2018; Li and Xu, 2016; Christie et al., 2015).

According to Mezirow (1997;1999), TLT is a theory in education that works to change the way students think about knowledge and experiences and help them make wise decisions about changing and transforming them. TLT promotes student's self-reflection on concepts developed through different life experiences leading to a transformative learning experience (Fleming , 2022; Fraser 2015). The student progresses through the stages of the transformation process through critical self-reflection, which begins with his acknowledgment of a puzzling dilemma that prompts him to question his assumptions (Mezirow, 2000).

The Transformative learning is based on several basic principles (Kokkos, 2022; Maiese, 2017; Martins and Strawer, 2017): (1) The constructing meaning experience represents the foundation of the learning process. transformative learning is a process of reinterpreting old conceptual knowledge and prior experiences, Building new meanings to the concepts and experiences (Hatcher, 2004; Mezirow, 1991). (2) reflective thinking, which leads to developing new findings as well as practicing a critical analysis of conceptual knowledge and experience in order to achieve a better understanding (Martins and Strawer, 2017). (3) The logical discourse, which represents the way the learner presents his opinions and viewpoints following a critical reflective thinking (Fleming, 2022; Mezirow, 1999; 2009).

According to Mezirow (2009;1990), transformative learning is the process of creating a new Knowledge or changing the way that experience is interpreted to enhance understanding. Additionally, he argues that the process of creating meaning involves taking stock of prior perceptions, assumptions, and errors, correcting any distortions in these perceptions, and then reevaluating those earlier perceptions that attempted to shape beliefs (Fleming, 2022). Furthermore, he asserts that to create meaning, learner first evaluate his prior views, assumptions, and errors, then correct any distortions in those perceptions. The ultimate goal of Transformative Learning is to review problematic meaning perspectives, Reviewing meaning schemes is a form of transformative learning (Kokkos, 2022).

Maiese (2017) defines the transformative learning process as a type of learning that is related to critical thinking and based on presenting information and new evidence as a prerequisite for learning because once the student acquires new knowledge, he may fill in the gaps in his specific world view or set of assumptions he possesses; therefore, he will change his own frame of reference. Taylor (2007) asserts that in transformative learning, the student adjusts his view of the world around him, refines his interpretations, emphasizes self-talk, the importance of reflective thinking.

The importance of transformative learning is evident in: Better problem-solving apps, Critical thinking and experiences are very important when it comes to providing core scientific competencies, The competencies gained through transformative learning are strong enough to accelerate scientific investigations in terms of providing the competencies required, Change the usual views about the learning process and about the learner himself, and Practicing critical thinking and perspective changing techniques (Al Sharifi & Sahib, 2022)

In general, transformative learning theory is an effective model for transforming ways of thinking, and emphasizes the importance of exposing students to situations in which they can change their perspective, question their beliefs, and become effective learners (Rojo et al., 2023). It also emphasizes that learning that leads to a radical change in perspectives and attitudes requires learners to effectively accept complexity as part of the learning process (Smith-Miller & Thompson, 2013).

At the same time, engaging in transformative learning represents a strong indicator of internal motivation, openness to experiences, self-exploration, contemplation of new perspectives, meaningful dialogue with self and others, mindfulness, self-compassion, and academic self-efficacy (Pedigo et al., 2023). Transformative learning prioritizes creativity and innovation (Romano et al., 2022),

Research Problem

One of the most crucial learning outcomes for structuring scientific knowledge in a meaningful way is the development of scientific concepts. Therefore, it improves the student's capacity to interpret and categorize a variety of natural phenomena, events, and circumstances and groups them into easy-to-learn categories. Gaining such concepts by students has become one of the essential learning goals (Tolba, 2006).

According to Liu and Nesbit (2018), students' thoughts and impressions about natural phenomena frequently conflict with scientific viewpoints before they are taught in the classroom. Due to the wrong beliefs, the student holds as a result of his different worldviews, learning new concepts will be challenging. These alternative conceptions are characterized by some traits, including coherence and quick diffusion among students. They also developed as a result of the student's own experiences, including direct observation and the formal learning process in the classroom. It has an impact on students' capacity to learn scientific ideas and their capacity to interpret scientific phenomena (Jiang et al., 2018; Park and Kim, 1998).

Many kinds of research indicated that, students have alternative conceptions when learning physical concepts. It is crucial to change these alternative conceptions and bring about a conceptual change by using teaching models that aim to challenge, modify, and transform previous perceptions within the student's cognitive structure (Smortchkova and Shea, 2020; Mota, and dos Santos, 2018; Liu and Nesbit, 2018; Nadelson et al., 2018; Heddy et al., 2018,).

Several previous studies such as Salame & Casino (2021); Amin et al., (2020); Kalman and Lattery (2018); Purwanto et al., (2018); and Madu et al., (2015) recommended that there is a need to identify and correct alternative conceptions of the student i.e. "reinforcing the transformation process". According to Salame & Casino (2021); Jiang et al. (2018) and Park and Kim (1998), it is challenging to change them using conventional, inefficient methods; Which may emphasize algorithmic problem solving and does not address conceptual understanding of the learning topics. These methods are not sufficient to ensure that students' prior perceptions have changed conceptually or fundamentally.

Conventional teaching methods no longer enable students to critically evaluate their prior concepts and, rethink and organize their cognitive structures to bring about a conceptual change. TLT demonstrates that learning must be transformative, i.e., when a student is dealing with conceptual knowledge, there should be a noticeable shift in their understanding, perspectives, and thinking. Therefore, using customized teaching strategies can be employed to assist in reframe-preconceived notions and introducing new ideas (Chambers and Andre, 1997).

Also, the teaching models should allow the learner to make a cognitive effort, which represents one of the necessary conditions for conceptual change, to be more willing to resolve conceptual contradictions (Park and Kim, 1998); to be motivated by dissatisfaction with current concepts, and to have a tendency and desire to engage in complex cognitive processes (Liu and Nesbit, 2018).

Hence the importance of building motivational constructions alongside cognitive constructions in promoting the conceptual change process, and therefore motivational constructions (Mental Motivation) must be built in actual learning situations because they represent one of the aspects affecting the process of conceptual change for the learner (Sinatra, 2005).

Although many studies have emphasized the importance of using teaching models to bring about a conceptual change among students (Kalman and Lattery, 2018; Jiang, et al., 2018; Purwanto, et al., 2018; Madu and Orji, 2015); however, should focus on teaching models that support the interaction between motivational (mental motivation) and cognition structures (Stevens-Long et al., 2012; Henderson, 2012; Stevens et al., 2010; Sinatra, 2005; Gregoire, 2003; Dole and Sinatra, 1998).

Sujarwanto et al., (2022) points out that teaching models based on transformative learning theory enhance mental alertness, subjective well-being, self-motivation, self-efficacy and intention to engage in many learning activities and tasks, creates a dynamic relationship between the teacher and students, and includes procedures that inspire and encourage students to achieve maximum performance.

Also, Billings –Padiachey & Motsisi (2023); Mezirow (2009) and Briese et al., (2020) points out that transformative learning theory is a vital component of teaching, as it provides systematic ways to view the learning process and frameworks for designing educational experiences, and enhances the teacher-student dynamic in transformative teaching and learning.

In Transformative teaching provides learners with an opportunity to think critically, enables behavior change and instills positive values in students In transformative learning, Transformative teaching provides learners with an opportunity to think critically, enables behavior change and instills positive values in students. Whereas in transformative learning, the learner benefits from relevant experiences, peer dialogue, and self-reflection in order to respond to the challenges he faces in his life or during the learning process.

Therefore, the current study to investigate the following research question: what is the effect of TLT-based teaching model on a conceptual change and developing mental motivation in Physics for Secondary school students? This main question is divided into the following questions:

1. What is the effect of TLT-based teaching model on inducing a conceptual change in Physics for Secondary school students?
2. What is the effect of TLT-based teaching model in developing mental motivation in physics for Secondary school students?
3. What is the nature of the correlation between the growth of mental motivation and the inducing of a conceptual change in physics for secondary school students?

METHOD

A quasi-experimental design (pre- post-test design for experimental and control groups) is used in this study to measure the impact of the independent variable (use TLT) on the dependent variables (Conceptual Change and Mental Motivation). Thus, this study employs the quasi-experimental design, The experiment group is taught using TLT, While the control group is taught using the Conventional method.

Participants of the research

The research sample consisted of (70) students from 1st-grade secondary school who are divided into two groups: the experimental group (34) students and the control group (36) students. The Conceptual Change Test and Mental Motivation Scale have been administered to these two groups.

Building a TLT-based teaching:

Research and studies that dealt with transformative learning theory (Billings –Padiachey & Motsisi, 2023; Briese et al., 2020; Li and Xu, 2016; Christie et al., 2015; Mezirow, 2009; Taylor, 2007) were reviewed to identify transformative learning, its stages and goals. According to Mezirow, the stages of transformative learning are defined in the following points: (1)The existence of a problem (a confusing dilemma), (2) Self-examination, (3) Critical evaluation of assumptions, (4) Linking or sharing, (5) Explore new roles, (6) Development of the action plan, (7) Acquisition of knowledge and skills, (8) Experimenting with and evaluating plans, (9) Developing competence and self-confidence in new roles, and (10) Reintegration into life based on new horizons (Fleming, 2022; Al Sharifi & Sahib, 2022; Kokkos, 2022; Mezirow, 2009).

The teaching procedures for the experimental group were determined according to a suggested TLT-based teaching model; Which consists of the following stages:

Identifying misconceptions Or alternative conceptions; At this stage, the teacher poses a set of open-ended questions to identify the concepts, knowledge, experiences, and alternative conceptual representations that the learner possesses.

Building a contradictory event; At this stage, the teacher constructs a contradictory event, to create confusion and imbalance, which leads to disturbance, dissonance, or conflict in the learner's cognitive structure or between the previous knowledge stored in the cognitive structure and the new knowledge included in the new event..

Practicing the critical thinking and self-reflection of alternative conceptions: At this stage, the learner is given sufficient time to think, observe, and reflect alternative concepts, and conduct a critical analysis and evaluation of the cognitive assumptions (alternative concepts) that he possesses in his cognitive construction.

Seeking knowledge and changing alternative conceptions: At this stage, the learner searches for correct knowledge , and compares knowledge, concepts, new experiences, and alternative perceptions, exploring for the best ideas, resolving conceptual conflict by changing one's thought patterns, and finally building the correct scientific concepts,. This can be accomplished by organizing the "new knowledge" to carefully gain new experience.

Shaping the learning experience as a process of reconstructing meaning or personalizing knowledge: At this stage, the learner reinterprets old experience, forms new expectations, and gives new meaning and a new perspective to old experience. Proposing new explanations or constructing a revised meaning for the new experience, in addition to expanding the correct scientific concept by providing additional examples that demonstrate the possibility of applying the correct scientific concept in new situations, or by making meaningful connections or relationships between the concept that was learned with life situations.

Based on these procedures, a guide was prepared for physics teachers, explaining the teaching of the Force in One Dimension Unit included in the first secondary grade physics textbook using the TLT. This guide includes the objectives of the unit, learning aspects, teaching aids and activities, teaching steps, and evaluation. The appropriateness of the guide was checked by presenting it to eight physics teaching experts and five secondary physics teachers, and it was modified according to their suggestions.

Tools and Data Analysis

Conceptual Change Test

The complex physics concepts included in the Force in One Dimension Unit in the first secondary grade were identified by analyzing the content of this unit . The analysis has produced a list of (12) main concepts (Force and Motion, Contact Forces and Field Forces, Force and Acceleration, Combining Forces, Newton’s Second Law, Newton’s First Law, Using Newton's laws, Drag Force and Terminal Velocity, Identifying Interaction Forces, Newton's Third Law, Forces of Ropes and Strings, The Normal Force). These concepts were used to construct the Conceptual Change Test (CCT).

The conceptual change test was built based on some studies that dealt with the field of misconceptions (Azis et al., 2023; Salame. & Casino, 2021; Desstya et al., 2019; Prodjosantoso et al., 2019). The tool consists of 26 points of two-tiered diagnostic test. The first-tier is a multiple-choice content question, which consists of a number of alternatives or choices, and in the second-tier, each item of the test items consists of a set of choices that represent multiple reasons for the answer given in the first part, which are built and developed through open-ended questions.

The test was presented to a panel of experts in the field of physics education to verify the content validity of the test , and the majority of them agreed on the test content. The test was also applied to an experimental sample of (28) students to verify the validity of the internal consistency by calculating the Pearson correlation coefficient. The CCT items have proven to be statistically related at a significance level (0.05, 0.01). The split-half method was used to calculate the reliability coefficient of the test by calculating the Pearson correlation coefficient between the two halves of the test, which was given (0.77). The correction was performed using the Spearman-Brown prediction equation, the reliability coefficient of which was (0.89). This is a high reliability coefficient.

Mental Motivation Scale (MMS)

The current research used the mental motivation scale prepared by (Giancarlo & Facione, 2000) and defines the California Measure of Mental Motivation. The scale consists of 65 phrases distributed over four main themes: learning orientation (17 phrases), creative problem solving (17 phrases), mental focus (11 phrases), and cognitive integrity (20 phrases). The items are formulated on a quadrilateral scale, graded from (1) to (4). Thus, the lowest score was obtained by the student (65 degrees) and the highest score (260 degrees) on the mental motivation scale.

For this study, used an Arabic version of the CM3 (Maree’ & Nofel, 2008) which has demonstrated acceptable psychometric characteristics. The internal consistency coefficient for the total scale was 0.88 and ranged between (0.75–0.91) for each of the subscales.

In the current research, the reliability of the scale was verified using the Alpha-Cronbach method on a sample of (28) first-secondary grade students, and it was found that it is equal to (0.81), which is a high and acceptable reliability coefficient The correlation coefficient between the dimensions of the mental motivation scale, which ranged between (0.56 - 0.78), and the correlation coefficients between the dimensions of the mental motivation scale and the scale as a whole ranged between (0.50 - 0.84), which indicates that the mental motivation scale has a high degree of validity.

Equivalence between the experimental group and the control group in the pre-test of the conceptual change test and mental motivation scale

Table 1
t-value and statistical significance of the difference between the means of scores of the experimental group and the control group in the pre-test of the conceptual change test and mental motivation scale

Instruments	groups	N	Mean	Standard deviation	t- value	Statistical Significance Level
Conceptual Change Test (CCT)	Experimental	34	5.29	1.47	0.047	0.963
	Control	36	5.28	1.45		
Mental Motivation scale (MMS)	Experimental	34	120.09	36.82	0.785	0.435
	Control	36	126.69	33.59		

It is clear from the previous table that the calculated (t) value is lower than the tabulated (t) value. This indicates that there is no statistically significant difference between the means of scores of the experimental group and the control group in the pre administration of the conceptual change test (CCT) and mental motivation scale (MMS).

Procedures for teaching the experimental and control groups

The physics teacher of the experimental group has been interviewed and trained to apply the proposed TLT-based teaching procedures. The physics teacher of the control group has been instructed to follow the conventional teaching methodology, in which he presents physics concepts, examples related to them, and explains and solves the problems associated with them. The duration of the intervention took four weeks, during which 14 study sessions were implemented.

FINDINGS

First: The Effect of a suggested TLT-based teaching model on inducing a conceptual change in Physics for Secondary school students

The research applied the CCT to the experimental and control groups after experimenting. Students' scores have been calculated by using the "t-test" to identify the difference between the experimental and control groups after conducting the CCT. Table (2) explains it.

Table 2
t-value for the differences between the mean scores of the experimental and control groups in the conceptual change test

Test	Groups	N	Mean	Standard Deviation	t-value	Statistical significance	η2	d	Effect size
Conceptual Change Test (CCT)	Experiment Group	34	20.09	1.94	8.23	0.00	0.26	1.19	Large
	Control Group	36	16.17	2.04					

The results of table (2) indicate that the "t" value is statistically significant. This indicates a statistically significant difference between mean scores obtained by the experimental and the control groups in the CCT favoring the experimental group. To validate the significance of the independent variable (the suggested transformative learning theory-based teaching model) on inducing a conceptual change in physics for Secondary school students), η2 and (d) values have been calculated (Rushdie, 1997). The results of table (2) indicated that the significance of using the suggested TLT-based teaching model in inducing a conceptual change in physics for secondary school students is (d≥0.8). These results generally show how well a TLT-based teaching approach works in causing conceptual changes in first-grade secondary students.

Second: The Effect of a suggested TLT-based teaching model in developing mental motivation in physics for Secondary school students

The research applied the Mental Motivation scale (MMS) to the experimental and control groups after experimenting. Students' scores have been calculated by using the "t-test" to identify the difference between the experimental and control groups after conducting the MMS. Table (3) explains it.

Table3
T-value for the differences between the mean scores of the experimental and control groups in the mental motivation scale

Mental Motivation scale (MMS)	Groups	N	Mean	Standard Deviation	t-value	Statistical significance	η2	d	Effect size
learning orientation	Experiment Group	34	64.62	1.72	5.35	0.000	0.30	1.36	Large
	Control Group	36	62.08	2.19					
creative problem solving	Experiment Group	34	63.68	1.99	5.17	0.000	0.28	1.25	Large
	Control Group	36	60.67	2.79					
mental focus	Experiment Group	34	41.32	1.43	5.38	0.000	0.30	1.31	Large
	Control Group	36	38.39	2.86					
cognitive integrity	Experiment Group	34	74.82	3.73	5.62	0.000	0.32	1.37	Large
	Control Group	36	68.86	5.00					
Mental Motivation scale	Experiment Group	34	244.4	4.41	9.17	0.000	0.55	2.21	Large
	Control Group	36	230.0	8.12					

The results of table (3) indicate that the "t" values are statistically significant. This indicates a statistically significant difference between mean scores obtained by the experimental and the control groups in the MMS favoring the experimental group. To validate the significance of the independent variable (the suggested transformative learning theory-based teaching model) on the development of Mental Motivation for Secondary school students, η2 and (d) values have been calculated (Rushdie, 1997). It is clear from the previous table that the significance of using the suggested TLT-based teaching model in developing mental motivation for first-grade secondary students is (d≥0.8). The previous results generally indicate the effectiveness of using a TLT- based teaching model in developing mental motivation.

Third: The nature of the correlation between the development of mental motivation and the inducing of a conceptual change in physics for secondary school students:

Correlation coefficients were calculated between the scores of each of the experimental and control groups in the conceptual change test and their scores on the mental motivation scale. Table (4) shows correlation coefficients.

Table 4
Correlation Coefficients between the Scores of the Students of the experimental and control groups in the mental motivation scale and the conceptual change test in physics

Variables	Research Group	N.	Correlation coefficients	Statistical significance (2-tailed)
Mental Motivation	Experimental	34	0.358	Sig. (0.003)
Conceptual Change	Control	36	0.224	Non-sig. (0.072)

The results of table (4) indicate to the correlative relationship between the development of mental Motivation and a conceptual change in students of the experimental group.

DISCUSSION

First: The Effect of a suggested TLT-based teaching model on inducing a conceptual change in Physics for Secondary school students

The results in table (2) confirm that the TLT-based teaching model encourages students to adjust their conceptual thinking by investigating and locating alternative "centralized" conceptions. Exercising critical self-reflection, examining alternative preconceptions, and rejecting the preexisting opinion and viewpoints in favor of the new viewpoints, also aids the students in recognizing the preexisting belief and re-examining its value, accuracy, and balance in the light of new knowledge. Additionally, it encourages students to seek out new information, change frames of reference or alternative conceptions, and choose to rebuild conceptions before going on to create meaning through new knowledge and experiences (Maiese, 2017; White and Gunstone, 1989).

It also agrees with the viewpoint of Tolba (2023) in that the conceptual change sharpens through using teaching models and strategies that make the students' thinking compatible with the concepts of physics, as well as a change in conventional thinking patterns, a shift to a deeper understanding, and a transition from incorrect to correct concepts.

The high scores of the experimental group in the conceptual change can be explained by the fact that the TLT-based teaching model supported the idea of a conceptual exchange between the old and the new concepts and transforming alternative perspectives into accurate concepts. A change in perspective is what consciously and carefully guides students through the learning process allowing them to correctly integrate the new concepts and experiences into their cognitive construction (Pedigo et al., 2023; Rojo et al., 2023;Liu and Nesbitt, 2018; Hewson, 1992).

The students' prior knowledge or alternative knowledge can be used to determine their conceptual environment . Supporting the TLT-based teaching model during critical self-reflection and self-examination of alternative conceptions as a requirement for creating students' a belief about the insignificance of this concept in dealing with the problem is another way to perceive it. It can also be observed by choosing real-world situations that call for the application of the incorrect concept in order to demonstrate its failure to solve the problem and to consider the incapacity of substitute concepts to do so. It can be demonstrated if the new perception is acceptable or not, as well as creating a belief among students about the logic and validity of the new concept and making students ready to accept the contradictory evidence obtained (Al Sharifi & Sahib, 2022; Kokkos, 2022; Fleming, 2022; Liu and Nesbit, 2018; Maiese, 2017).

These results support the importance of using teaching models that support conceptual change. These results are consistent with Meziro (2009) who stressed the importance of changing the educational pattern and how students deal with knowledge (e.g., using TLT-based teaching models), testing them, and critically reflecting on them to make a clear decision to transform and change them (conceptual change). One prerequisite for that is that the transformation process must follow scientific stages based on evidence and the teaching model (exploring perceptions, identifying alternative perspectives, practicing critical self-thinking, examining alternative perceptions, seeking new knowledge, changing frames of reference or alternative perceptions, and building meanings from the new experience) (Al Sharifi & Sahib, 2022; Kokkos, 2022; Fleming, 2022) . TLT-based teaching model led to changing beliefs and knowledge (replacing misconceptions and bringing about conceptual change) (Fleming, 2022; Maiese, 2017).

The results can generally be explained by the fact that the suggested TLT-based teaching model has assisted students in engaging in transformative thinking by reviewing interpretations of physical phenomena, practicing the self-reflection process, using mental habits and meaningful concepts and experiences (Fleming , 2018; Martins and Strawer, 2017; Mezirow, 2009; Taylor, 2007). Therefore, transformative learning theory is an effective model for shifting ways of thinking, as it emphasizes the importance of exposing students to complex situations that allow them to question their beliefs, ideas, and concepts and change their point of view (Rojo et al., 2023)

The control group's low performance in the CCT may be attributable to the fact that alternative or false concepts are still ingrained in their daily experiences and cognitive framework and are challenging to change as a result of the use of traditional education. Lakatos (1994), Park and Kim (1998), Jiang et al., (2018) also stated that. They said that traditional education is insufficient to bring about a conceptual change in students' thinking and cognitive structure or to cause a essential change in their previous perceptions or experiences.

Second: The Effect of a suggested TLT-based teaching model in developing mental motivation in physics for Secondary school students

The results of table (3) indicate the effectiveness of using a TLT- based teaching model in developing mental motivation. The interpretation of this effect is that the TLT- based teaching model plays a role in building self-confidence, awareness of ability, desire to continue performing, and developing the ability to solve problems and make decisions, working on developing, expanding, and enriching the learner's cognitive structures with many experiences, and a willingness to use these cognitive structures; these are vital components of mental motivation (Shenhav et al., 2021; Abdul-Ameer et al., 2020; Heilat & Seifert, 2019; Ames, 1992). TLT- based teaching model promote mindfulness, subjective well-being, self-motivation, self-efficacy, and the intention to engage in learning tasks to achieve maximum performance (Sujarwanto et al., 2022).

This result is consistent with the results of studies that indicated the importance of using strategies and teaching models that support autonomy and self-efficacy, motivate students and participate effectively in the learning process, practice self-regulated learning, and prefer challenge and curiosity motivation (Siacor et al., 2024; Nur et al., 2023; Krishan & Al-rsa'I, 2023; Munawaroh et al., 2022; Pambudi, 2022; In'am & Sutrisno, 2021). All of these components help develop students' mental Motivation.

The superiority of the experimental group students in mental motivation can be attributed to the fact that the phases of the suggested teaching model have enhanced the students' practice of the components of mental motivation, which allow them to move, activate, and direct behavior and maintain its sustainability and thinking independently. In the phase of exploring and identifying alternative concepts and perspectives, the components of orientation toward learning and mental focus are reinforced, and they work together to provoke cognitive construction and raise a set of open questions about conceptual perceptions and identify these perceptions (Martin & Strawser, 2017). In the phase of critical self-reflection of alternative perceptions: students are allowed to use logical and reflective methods to discover science structure (knowledge, concepts, relations, Laws, theories) and to enter into a process of autonomous thinking, and thinking in the sciences process through the use of problem-solving strategies (Mezirow, 2009; Hatcher, 2004), and thus enhances the creative problem-solving component, in addition to the mental focus component; which allows to organize and focus in performance (Siacor et al., 2024; Nur et al., 2023; Krishan & Al-rsa'I, 2023; Herlambang et al., 2021; Heilat & Seifert, 2019; Earle et al., 2015). While in the phase of searching for new knowledge and changing frames of reference or alternative conceptual, Experiences and knowledge is sought and reconstructed, discovering correct physical concepts and building evidence that confirms the validity of the discovery (Maiese, 2017). Here, the cognitive integrity component is developed as one of the dimensions of mental motivation components, which allows the learner to build options, adopt divergent viewpoints, acquire new information, feel the ability to challenge and face problems, as well as feel happy when finding solutions to them (Munawaroh et al., 2022; Pambudi, 2022; Giancarlo et al.,2004). Finally, in the phase of building meaning from a new experience, which requires the learner to give a new meaning and a new perspective to the previous experience, build a new interpretation or a revised meaning of the experience, and expand the physical concepts by giving additional examples that demonstrate the possibility of applying these concepts in new situations (Mezirow,1997; 2009; Maiese, 2017).

It stimulates the components of mental motivation (mental focus and cognitive integrity); In which the learner strives towards perfection, organization and intellectual clarity when confronting new concepts, focusing on new experiences and giving meaning to them, and finding integration between new and previous experiences (McInerney & Etten, 2001).

Third: The nature of the correlation between the development of mental motivation and the inducing of a conceptual change in physics for secondary school students

In the table (4), The correlative relationship between the development of mental motivation and a conceptual change in students of the experimental group can be explained because the suggested TLT-based teaching model has helped in stimulating directed learning in the learner and creating a desire to acquire new knowledge, nourishing his mental curiosity through effective search and discovering of the correct knowledge base, learning from experiences, continually seeking new knowledge to support his correct physical concepts, showing interest in engaging in challenging situations of cognitive conflict, appreciating and evaluating the value of discovered physical knowledge.

Also TLT-based teaching model reinforced the tendencies learner to think of an alternative concept and generate a strong sense of self-confidence in his ability to solve difficult problems when he has creative perspectives (Innovative problem solving). The TLT-based model of teaching aims to enhance an individual's ability to focus on previous physical experiences and knowledge, subject it to conscious examination and critical reflection, make a sound decision about transformation and change, and continue to perform the task without feeling bored until it reaches the formation of new physical concepts (Mental focus).

In the TLT-based teaching model, the learner seeks truth and openness to new physical concepts, evaluates alternative viewpoints, uses neutral thinking skills, confronts alternative concepts, and works on self-correcting these concepts (cognitive integrity) (Pedigo et al., 2023; Al Sharifi & Sahib, 2022; Romano et al., 2022; Giancarlo et al.,2004). This finding indicates that learner engagement in transformative learning is a strong predictor of intrinsic motivation, openness to experience, self-exploration, contemplation of new perspectives, meaningful dialogue with self, and mindfulness (Pedigo et al., 2023).

It can also be explained in light that the TLT-based teaching model has stimulated the students' cognitive structure (Mental Motivation) and extracted their most significant conceptual perceptions of the scientific concepts under study during exploring and identifying the alternative conceptions and perspectives phase, i.e "the central experience." It has produced a type of confrontation or conflict with their prior knowledge and experience, which has led to uncertainty, confusion, and unease. The model could have disrupted the alternative perceptions, re-examined the knowledge and assumptions, and forced the use of rational, reflective, and dialogue methods to find and evaluate alternative knowledge, as well as the concepts during the phase of practicing critical self-reflection and examination of alternative perceptions (Pedigo et al., 2023; Rojo et al., 2023; Martins and Strawer, 2017; Taylor, 2007;Mezirow, 1990; 2009).

Besides, the TLT-based teaching model has helped students in resolving conflicts, arriving at the right scientific concept, and exploring the right physical concepts during the phase of seeking out new information and shifting frames of reference or alternate perspectives (learning orientation and creative problem solving). At this phase, the old and new concepts are conceptually exchanged to pave the way for creating new concepts (White and Gunstone, 1989).

Finally, in the phase of building the meaning from the new experience, building the learning experience and the personalization of knowledge can be done by creating a new interpretation or revised meaning of one's experience in order to prepare and expand multiple interpretations related to accurate physical concepts (cognitive integrity) (Fleming , 2018; Mezirow,2009).

The TLT-based teaching model only introduces modifications to the students' cognitive structure and adjustments to their thought processes (Liu and Nesbit, 2018; Hewson, 1992). These transformations in the thinking process and the strengthening of the cognitive structure of students require a high level of mental motivation to motivate the learners to resolve the conflict between correct physical concepts and alternative perception (i.e. oriented towards learning). It also requires a high level of attention and interest in resolving this conflict (i.e. mental focus), and has the desire to practice active behavior and engaging in activities (i.e. creative problem solving) that demonstrate their cognitive abilities and their skills in arriving at the correct physical concepts (i.e. cognitive integrity) (Stevens-Long, et al., 2012; Henderson, 2012).

It is also evident from the table (4) that there is a positive relationship between the development of mental motivation and making a conceptual change for the students of the control group, but it is not statistically significant, and this is because the Conventional method of teaching does not enhance the components of mental motivation in the learner to make him active and active in the research about new knowledge, nor does it offer him activities that challenge his cognitive structure, and enhance cognitive curiosity that allows him to discover, analyze and evaluate arguments (evidence), reveal assumptions about physical concepts, all of these elements are necessary and lead to conceptual change.

CONCLUSIONS & RECOMMENDATIONS

The results showed firstly, There are statistically significant differences between the mean scores of the students in the two groups: experimental and control in the conceptual change test favoring the experimental group. Secondly, There are statistically significant differences between the mean scores of the students in the two groups: experimental and control in the mental motivation scale favoring the experimental group. Thirdly, There is a positive correlation between the scores of the experimental group in the mental motivation scale, and their scores in the conceptual change test . According to these results, it is obvious that using the transformative learning theory in the teaching physics is effective in inducing a conceptual change and developing mental motivation in Physics for Secondary school students.

In light of the research results, it can be concluded that TLT has important educational implications in teaching physics because it emphasizes the value of students’ previous experiences, perceptions, and knowledge, as well as testing and thinking critically about them to make an informed decision about changing them. TLT also helps students engage in logical discussion to convey their ideas after thinking about them. It provides arguments and explanations that motivate the learner to modify or change his previous perceptions, ideas, and beliefs. TLT-based teaching models emphasize the importance of developing mental motivation (learning orientation, creative problem-solving, mental focus, and cognitive integrity) as a prerequisite for exploring and defining somatic concepts and practicing critical self-examination.

The current research presents some suggestions for further research, represented in conducting many research in physics teaching and learning, Such as Investigating the effectiveness of using TLT-based teaching in developing high school students' physical concepts and other variables such as critical self-reflection skills, creative thinking, solving physical problems, the ability to make decisions, and emotional thinking. In addition to Investigating the effectiveness of using TLT-based teaching in constructing mental representations of physical phenomena and developing high school students' scientific and engineering practices and 21st century skills in physics.

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