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ADDRESSING PRE-SERVICE TEACHERS' MISCONCEPTIONS AND PROMOTING CONCEPTUAL UNDERSTANDING THROUGH THE CONCEPTUAL CHANGE MODEL

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Abstract

Teaching science concepts for conceptual understanding has its challenges. Bringing about conceptual change in the science classroom can be difficult because most concepts are complicated and often counter-intuitive in the teaching and learning of science concepts. A review of the literature indicates that the conceptual change model, CCM can be an effective teaching technique in addressing misconceptions and improving conceptual understanding when it comes to science instruction. The aim of this research was to find out the effect of the conceptual change model on pre-service teachers' conceptual understanding regarding the topic of forces and motion. Using data from tests and questionnaires, the research questions were answered by quantitatively analyzing the collected data. The analysis revealed that there is a statistically significant correlation between the conceptual change model and the conceptual understanding of the pre-service teacher participants. Overall, the results provide evidence in support of the effectiveness of the conceptual change model, CCM in addressing misconceptions and promoting conceptual understanding of forces and motion among the pre-service teacher participants that volunteered for this research. The results also indicate that the CCM is a teaching model which must be considered by science educators and teachers as they seek to address issues related to misconceptions and conceptual understanding in the teaching of science topics.
Keywords: *conceptual change, conceptual change model, conceptual understanding, misconceptions, pre-service teachers, science education*

Introduction

The authors hold the view that one of the major objectives of science education is to teach students in a way that enables them to organize facts and ideas meaningfully so that they can challenge the erroneous conceptions that hinder their deep understanding of science concepts. Science teaching and learning are often framed as building educational environments that permit students to create knowledge through active scientific investigation and evaluation of experimental evidence (Decristan et al., 2015). However, teaching science concepts effectively has its challenges, such as how to address students' misconceptions as well as stimulate students' interest in learning science (Mansor et al., 2010). Bringing about conceptual change in the science classroom can be difficult because most concepts are complicated and often counterintuitive. Nonetheless, conceptual change is central to science teaching and learning, hence science educators and researchers must endeavor to use educational models that would help promote conceptual change (Nadelson et al., 2018).

The quest to address students' misconceptions and promote their understanding of science has seen the United States educational system undergo a series of unending reforms in the past decades. Transnational assessments such as the Trends in International Mathematics and Science Study (TIMSS) persistently place U.S. students' achievement behind that of students in other technologically developed peer-nations notwithstanding the numerous initiatives undertaken at the K-12 level of American education (Laverty, 2015). It is worth noting that TIMSS and other national assessment programs such as the National Assessment of Educational Progress (NAEP), mostly provide analysis of students' correct responses but do not report on the inaccurate ideas or misconceptions students exhibit in their test answers. Hence, these assessments make it difficult to diagnose students' misconceptions about the science topics they were tested on.

The American Association for the Advancement of Science (AAAS) in its quest to fill the gap referred to earlier, developed an extensive list of assessment items to assess the ideas of middle and high school students across the United States on a wide range of science topics. The test questions provide a picture of what students know and the misconceptions they have about specific science concepts (AAAS Project 2061, 2011). The information from the multiple-choice items included on the AAAS Science Assessment provides teachers the opportunity to diagnose students' misconceptions about the science concepts taught in a classroom.

Addressing misconceptions and building conceptual understanding is vital in science education in terms of promoting scientific literacy. Misconceptions about scientific concepts are due to intuitive thinking, everyday life experiences, and ineffective science teaching (Nadelson et al., 2018). Thus, telling students that their understandings are inaccurate will not lead to conceptual change. Teaching for conceptual understanding requires a constructivist approach whereby students take an active role in the construction of knowledge (Boshuizen et al., 2020).

What can be done to increase students' understanding of science concepts, promote their scientific literacy and improve achievement in national and international assessments? Amid all these reform efforts, the teacher has been identified as a fundamental factor affecting student learning. The benchmarks for teacher certification and pre-service training have all been incorporated into reform models that seek to improve the achievement of students in the United States as far as international assessments are concerned (Laverty, 2015). The above statement gives further credence to the widely held notion that teachers are a major deciding factor in student achievement; therefore, what educational techniques would lead to students' conceptual understanding of scientific concepts? Conceptual understanding is a critical intention when learning abstract concepts and is primarily relevant in science education because it is required in making sense of phenomena. It's the opposite; conceptual misunderstanding involves conceptions that are "wrong and flawed" (Phanphech et al., 2019), which emanate from misconceptions.

The subject of Physics was one of the first areas in which students' prior educational conceptions were studied (Aretz et al., 2016)the Big Bang, being an important subdomain in cosmology, marks the very beginning of space and time. Therefore, it has formed the modern scientific worldview. Transferring this to students through science teaching is a frequent request in science literacy discussion (e.g., American Association for the Advancement of Science, 1993; Schecker et al., 2004. If the instruction does not consider students' pre-educational conceptions, it will be almost ineffective (Anggoro et al., 2019; Bigozzi et al., 2018). Regarding the topic of force and motion, previous studies have established that common-sense explanations for Newtonian concepts are prevalent among students, hence the advocacy for radical instruction aim at reducing such misconceptions and building conceptual understanding (Bigozzi et al., 2018).

In their research that examined student misconceptions about forces and motion, Liu and Fang (2016) found out that although these misconceptions were termed differently in different

papers, there were some common features. With regards to force, the misconceptions were related to a lack of comprehension of Newton's laws of motion and student learning difficulties in grasping the properties of force itself. Some studies have also indicated that several high school physics teachers are unable to identify the passive force exerted on an object placed on a table (Liu & Fang, 2016). In some instances, students erroneously claim that a moving object has a continuous force acting upon it, despite instruction on Newton's First Law of Motion, informing them of the contrary; a classic case of students' inability to apply what has been learned in the classroom to real-world situations due to misconceptions (Chen & Techawitthayachinda, 2021; Demirbas, 2014).

Research shows that the conceptual change model can be an effective teaching model in addressing misconceptions and improving conceptual understanding when it comes to science instruction (Duit & Treagust, 2012; Potvin et al, 2020; Stepans, 2008; Vosniadou, 2013). Two recent studies on student misconceptions and conceptual understanding made a positive case for the conceptual change model as being amongst the most suitable educational techniques for helping students experience conceptual change during science instruction (Kural & Kocakülah, 2016; Nadelson et al., 2018).

Conceptual understanding entails equipping students with the requisite skills to enable them to develop the ability to deeply understand and transfer knowledge gained in a topic, build on it and become creative with knowledge in a relevant way (Tan et al., 2020). Conceptual understanding of science concepts is the ability of students to apply learned scientific concepts to phenomena in an everyday life and how the change in conception is influenced by individuals' real-life experiences (Schwortz & Burrows, 2021). This comprises students' aptitude to recognize new information, build explanations and draw linkages between what they learn and relevant phenomena (Widiyatmoko & Shimizu, 2018).

Research Problem

In this research, the six-phase teaching model referred to as Conceptual Change Model (CCM) was used in teaching a cohort of pre-service elementary school (from kindergarten, grade K to grade 5) teachers. The research was based on a series of teaching and learning activities designed to teach pre-service teachers the topic of forces and motion. This research examined the effect the conceptual change model had on pre-service teachers' conceptual understanding of forces and motion.

In their article on 'Students Conceptions and Conceptual Change' published in the 'Handbook on Science Education, Volume II', Amin et al. pointed out that, the process of conceptual change consists of processes that are "internal to individual learners' minds and interactions with more knowledgeable individuals and peers". They proposed that future research should undertake the task of "improving our understanding" regarding the intricacy of stimulating conceptual change in the teaching and learning environment (Lederman & Abell, 2014, p. 77). It is this gap, that influenced the undertaking of this research.

Research Aim and Research Questions

The purpose of this research was to ascertain the effect of the conceptual change model on pre-service teachers' conceptual understanding of forces and motion. In addition, this research sought to improve the understanding of the science education community on how the various phases of the conceptual change model contribute to the conceptual change process. The questions that guided this research are:

1. What is the effect of the conceptual change model on pre-service teachers' conceptual understanding of forces and motion?

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2. In what ways did the conceptual change model address pre-service teachers' misconceptions about forces and motion?
3. How do the various phases of the conceptual change model affect pre-service teachers' conceptual change?

The first research question addressed the effect of CCM on pre-service teachers' "conceptual understanding" of the scientific concept of forces and motion. Question one was answered using analyzed pre and post-test data as well as items from the questionnaires.

The second research question focused on how the CCM tackled misconceptions about forces and motion. Data from Likert scale items were used to answer this question. The third research dealt with the relevance of the various phases employed in the CCM to participants' conceptual understanding.

Research Methodology

General Background

Data collection for this research was done using pre-and post-questionnaires, pre- and post-tests about misconceptions on forces and motion, and a Likert scale questionnaire to measure the linkage between the conceptual change model, CCM, and their conceptual understanding. The 5-point on the Likert scale on pre-and post-questionnaire was designed to elicit participants' conceptions of forces and motion. The conductors of this research used quantitative methodology to answer all the research questions. The participants in this research had similar educational and socio-economic backgrounds, having comparable educational backgrounds, it can be posited that they had almost similar experiences in the learning of forces and motion. The CCM was the foundational teaching technique employed in the elementary physical science course used for this research. The theoretical framework of constructivism was the underlying theory in the conduction of this research and also in the engagement with the pre-service teacher participants during the teaching and learning of forces and motion. Thus, the participants had the liberty to explore the concepts and construct their particular understanding of the topic through personal discoveries (Deliberto, 2014). This research was conducted in the Fall of 2021, it wanted to find out the effect teaching forces and motion using the CCM will have on participants' conceptual understanding, and also contribute to the literature on science teaching and conceptual understanding.

Sample

The sample for this research consisted of 52 pre-service teacher participants enrolled in the elementary physical science course, 42 females and 10 males. The first author led the data collection and invited the participants to volunteer for the research. Participants were told that their participation was voluntary, and they permitted all research instruments and written work to be used for research and writing purposes. All the participating pre-service teachers were undergraduates (mostly sophomores and juniors) and the majority were non-science majors. Everyone in the course was invited to participate, but the sampling approach was purposive; this required that the participants met certain criteria to be able to partake in the research (Huck, 2012). The inclusion criteria were that a potential participant must be a pre-service teacher enrolled in the elementary physical science course, and all enrolled students qualified to volunteer for this research. However, since participation was voluntary some potential participants decided against participation, and they were within their rights to decline. The authors obtained the institution's IRB approval. Informed consent was obtained from all participants whose data was used for this research. The data collection was based on a 3 weeks' course module on the topic of forces and motion.

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Instrument and Procedures

The collection of data was done using a one-group 10 questions pre- and post-test (see Appendix A) on participants' forces and motion knowledge. 5-point Likert scale questionnaire (from strongly disagree to strongly agree) to measure participants' linkage between the CCM and their conceptual understanding (see Appendix B). Also, included in the data collection instruments is a questionnaire on the effects of the phases of CCM on conceptual change (see Appendix C) in addition to a pre- and post-questionnaire on participants' conceptions of forces and motion (see Appendix D), both questionnaires are based on a 5-point Likert scale (from strongly disagree to strongly agree).

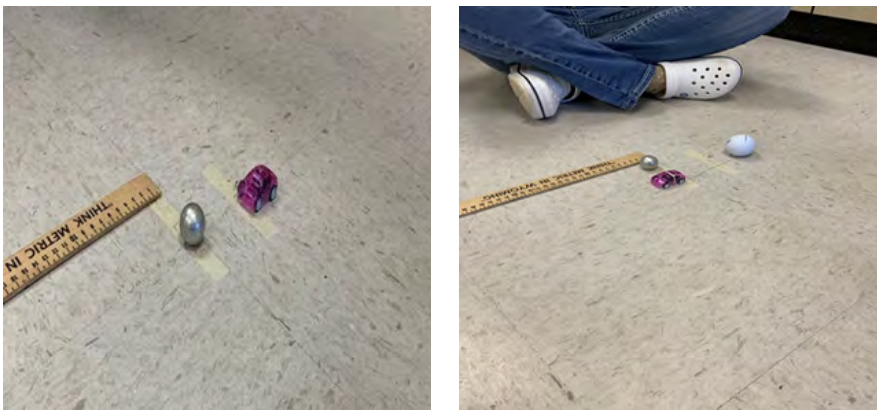
Before the commencement of the 3-week module on the topic of forces and motion, the participants were given a pre-test that consisted of 10 questions to measure their knowledge of forces and motion. The pre- and post-test questions are designed using the AAAS project 2061 Science Assessment website test questions to test students' ideas about forces and motion. The test questions were intended to help participants demonstrate accurate knowledge of forces and motion, and analyze the reasons why a scientific claim might be true or not. The questions on the test and items in the questionnaire also include well-known misconceptions such as wrong answer choices so that they can be used for analysis and data interpretation. Using this approach had the advantage of directing students' attention to the particular misconceptions that needed to be addressed.

The educational session that was used for data collection commenced with a phenomenon-based learning approach where a "phenomenon," (air-blowing ping-pong activity) was used to hook students into the lesson. At the end of the air-blowing ping-pong activity, participants came up with an investigative activity to find out the effect a constant force would have on the velocity and acceleration of four different types of balls (rubber ball, styrofoam ball, steel ball, and golf ball). The constant force was provided by a pull-back toy car. Participants wrote down their initial predictions and explanations per the CCM teaching phases. Students held group discussions about their predictions and explanation before, during, and after the activity.

The class on forces and motion was a process of looping back and forth with the CCM's six phases. The process was when the instructor as participants came with new questions that they would like to seek an answer to beyond the scope of the current lesson.

The post-test and post-questionnaire on the connections between the CCM and conceptual understanding were administered. Also, another questionnaire was completed on the effect of the various phases of CCM on participants' conceptual change

Figure 1
Pull-back Car Being Used to Apply Force to Steel and Golf Balls



Data Analysis

The data from the pre- and post-tests as well as the questionnaires were coded in an Excel Spreadsheet and imported into the SPSS statistical software for quantitative analysis. The pre -and post-tests were graded by the author out of a total score of 10. The test scores were analyzed using a paired-samples *t*-test statistical model to check if there was a statistically significant difference between the means of the pre and post-tests. The data from the questionnaire was also analyzed using a Pearson bivariate correlation in SPSS to find out if there was a relationship between participants' conceptual understanding forces and motion and the conceptual change model (CCM) In addition, another paired-samples *t*-test was conducted on the pre and post questionnaire data.

Research Results

A bivariate (Pearson) correlation (Field, 2018) was run in SPSS to see if there is a significant correlation between the conceptual change model (CCM) and conceptual understanding of the topic of forces and motion. The results showed that the significant value (*p*-value), $p < .001$ is below the standard criterion of .05, indicating that there is a statistically significant positive linear correlation between CCM and building conceptual understanding. Table 1 summarizes the bivariate correlation between the two variables. The CCM moderately correlated with building conceptual understanding; Pearson's $r = 0.646$, this correlation is significant at the .01 level.

Table 1
Correlation Results for Conceptual Change Model and Conceptual Understanding

Variables		Conceptual Change Model	Conceptual Understanding
Conceptual Change Model	Pearson's *r*	1	0.646**
	p-value	-	< .001
	N	52	52
Conceptual Understanding	Pearson's *r*	0.646**	1
	p-value	< .001	-
	N	52	52

**Correlation is significant at the .01 level (2-tailed)

A paired-sample *t*-test (Field, 2018) was conducted to compare pretest and posttest scores (n=52) on pre-service teachers' understanding of some concepts on forces and motion. Results point to a statistically significant difference between pretest scores (M = 5.75, SD = 1.118) and posttest scores (M = 9.06, SD = .873); $t(51) = -19.93$, $p < .001$. Effect size (d) was calculated to examine the magnitude of difference between the average score of both tests. Cohen's d effect size was 1.197.

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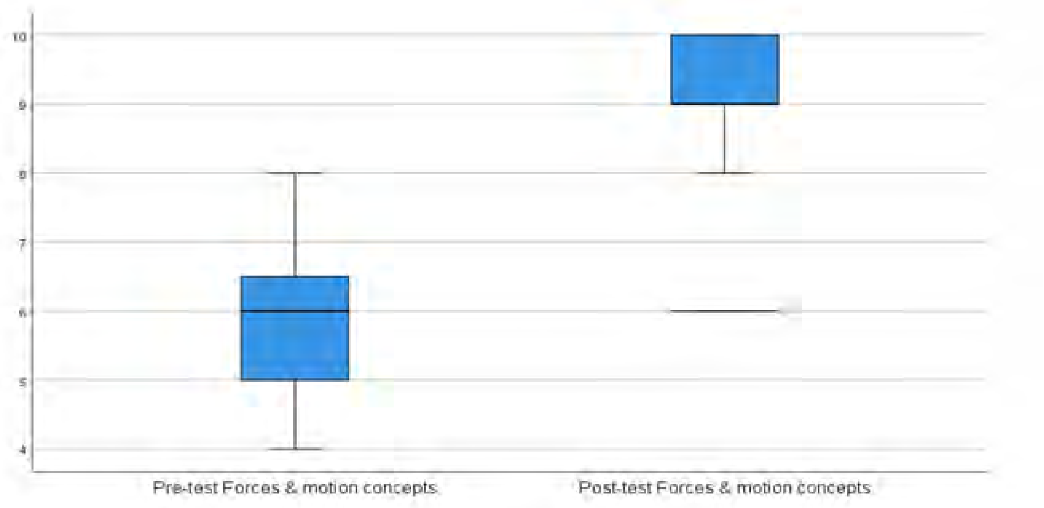
Figure 2

Boxplot Showing the Means of the Conceptual Change Model and Conceptual Understanding



On participants' conceptions of the concept of forces and motion, there was a statistically significant difference between the pre- and post-questionnaire responses on all items. Tables 2 and 3 below provide a summary of the descriptive statistics and paired sample *t*-test results. The results indicate that using the CCM for teaching the topic had a positive effect on pre-service teachers' misconceptions about forces and motion. Participants' response for the item, "*The constant motion of a pull-back car requires a constant push or pull*", $t(51) = 20.935$, $p < .001$, M (difference) = 1.94 between the pre- and post- responses, with a Cohen's $d = .669$, suggesting a moderate to high effect size. On the second questionnaire item, "*If a ping-pong ball is not moving then there is no force acting on it*", $t(51) = 15.803$, $p < 0.001$, M (difference) = 1.83 with a Cohen's $d = 0.834$, suggesting a high effect size and practical significance. The results for the third questionnaire item, "*A golf ball stops moving because the applied force is finished*", $t(51) = 17.062$, $p < 0.001$, M (difference) = 1.92 with a Cohen's $d = 0.813$, suggesting a high practical significance. Regarding the item, "*An object can only move at constant speed if a force is pushing or pulling it*", $t(51) = 21.974$, $p < 0.001$, M (difference) = 2.08 with a Cohen's $d = 0.682$, suggesting a moderate to high effect size.

Table 2

Descriptive Statistics of Pre- and Post-Tests on Conceptions of Forces and Motion

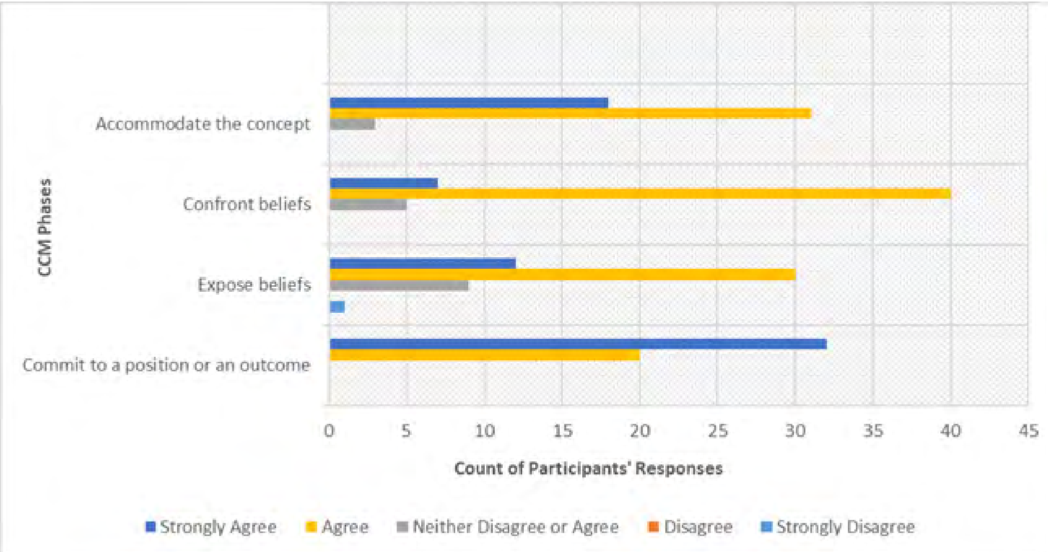
		Pre-Test		Post-Test	
	N	*M*	*SD*	*M*	*SD*
The constant motion of a pull-back car requires a constant push or pull.	52	3.71	.536	1.77	.546
If a ping-pong ball is not moving, then there is no force acting on it	52	3.52	.828	1.69	.466
A golf ball stops moving because the applied force is finished	52	3.67	.474	1.75	.556
An object can only move at constant speed if a force is pushing or pulling it	52	3.77	.546	1.69	.065

Table 3
Paired Samples Statistics of Items on Conceptions of Forces and Motion

	t-test	*df*	*p*	Cohen's *d*
The constant motion of a pull-back car requires a constant push or pull.	20.935	51	<.001	0.669
If a ping-pong ball is not moving, then there is no force acting on it	15.803	51	<.001	0.834
A golf ball stops moving because the applied force is finished	17.062	51	<.001	0.813
An object can only move at constant speed if a force is pushing or pulling it	21.974	51	<.001	0.682

The descriptive statistics carried out on participants' responses to how the various phases of the conceptual change model affected their conceptual change showed that the pre-service teachers perceived the *"Confront beliefs"* and *"Accommodate the concept"* phases to have had the most positive effect on their conceptual change. The mean values for the *"Commit to a position or an outcome"* and *"Expose beliefs"* phases are 3.08 and 3.13 respectively, indicating that participants believe that they had no significant effect on their conceptual change. However, the mean values for the *"Confront beliefs"* and *"Accommodate the concept"* phases are 4.31 and 4.48 respectively. The bar graph shown in figure 4 provides the graphical interpretation of their responses.

Figure 3
Phases of the CCM and their Effect on Pre-Service Teachers' Conceptual Change



Discussion

The results are discussed in relation to this research and other research in the literature, as well as its implications for science education, are pointed out, and possible areas for future research are proposed. Misconceptions and lack of conceptual understanding are major

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obstacles to teaching science and improving scientific literacy across the educational spectrum. Therefore, the teaching and learning of science concepts for concrete understanding and minimization of misconceptions require a conceptual change model to make the educational process more meaningful. This research set out to investigate the effect of the CCM on pre-service teacher participants' conceptual understanding and misconceptions about forces and motion. Generally, the results showed that the pre-service teacher participants in this research experienced conceptual change and gained conceptual understanding as well as minimized their misconceptions concerning the topic of forces and motion. The educational process which involved an investigative activity to find out the effect of a push and pull force on the motion of different types of balls was carried out using the conceptual change model, addressed pre-service teachers' conceptual understanding, and reduced their misconceptions about the concept of forces and motion.

Results in this research not only confirm what is generally known about the positive effect of the conceptual change model in addressing misconceptions and improving conceptual understanding but also advance our understanding of the importance of the conceptual change model (CCM) for conceptual change. The six CCM steps referred to in earlier sections of this write-up illustrate the model as a student-centered learning method. This technique appreciates students' independence to construct their own knowledge (Aydin, 2015; Ayaz, 2015). This self-directed learning approach provides students the openness and confidence to share their ideas with peers and teachers, thus encouraging them to take responsibility for their learning. Such impetus creates the opportunity for conception change when the evidence shows that their views are misconceptions. This approach complemented by peer discussions nurtures students' self-reliance in accepting a scientifically accurate conception as opposed to holding on to pre-teaching misconceptions (Madu & Orji, 2015).

In answering the first research question, the analysis indicated that there was a positive correlation between pre-service teachers' conceptual understanding of forces and motion and the conceptual change model of teaching. Congruent with other results in the literature (Nadelson et al., 2018; Potvin et al., 2020), the results of this research also showed that teaching with the conceptual change model increased conceptual understanding and minimized misconceptions (Akbaş & Gençtürk, 2011; Heddy et al., 2018). However, most of the research available in the literature has been done with students in kindergarten to high school settings (Amponsah & Ochonogor, 2018; Ekon & Edem, 2018; Gates, 2010; McLure et. al., 2020; Santyasa et al., 2018) or on students enrolled in science-major programs at the university (Arthurs, 2019; Arthurs et. al., 2021). Our research results extend the literature by reporting on pre-service teachers' learning force and motion through the conceptual change model. This research is different from the work of Anggoro et al., (2019), though their results showed that the teaching model had improved the conception of the pre-service teacher participants after instruction they used the multimedia visual reflective conceptual change model (RCCM). Although they reported improvements in participants' conceptual knowledge of force and motion, their sub-topic was on free fall whiles this research was based on pushes and pull. Also, the results of this research were based solely on quantitative data whiles Anggoro et al., (2019) conducted their research by using a mixed-methods design.

In connection with research question two, the differences in pre- and post-test scores may be attributed to several reasons. To begin with, the low mean score on the pre-test could be due to the participants' lack of exposure to the science concept knowledge being tested. Though almost all the participants had studied forces and motion at various levels of their education, their understanding of forces and motion concepts had not been tested in such a manner. Furthermore, the method used in teaching the lesson by the instructor placed the pre-service teacher participants in an environment that emboldened them to question their conceptions and work toward resolution and conceptual change just as Koponen, (2014) had surmised in their

paper. The resultant effect is the comparatively high post-test mean score. The results on the effect of the various phases of the CCM process that facilitated the most conceptual change amongst participants showed peer-to-peer discussions and sharing of ideas provided the most opportunities for students to develop conceptual understanding.

In the pre- and post-questionnaire responses on participants' conceptions about the concept of forces and motion, there was a statistically significant difference between pre- and post-responses on all items. All the items on the questionnaire were designed to test pre-service teachers' misconceptions about forces and motion. The descriptive statistics carried out to help answer research question three showed that the pre-service teachers believed the "Confront beliefs" and "Accommodate the concept" phases to have had the most positive effect on their conceptual change. The four items in the questionnaire on the effects of the phases of CCM on conceptual change produced different responses as can be seen in figure 4. This is indicative that the different phases of the CCM had an unequal effect on preservice teacher participants' conceptual change. This result is in agreement with proponents of using multi-phase educational approaches to prop up conceptual understanding in the teaching and learning of science (Duit & Treagust, 2012; McLure et al., 2020). In agreement with other results in the literature (Duit & Treagust, 2012; Santyasa et al., 2018), the results of our research also showed that using the conceptual change model in teaching science concepts promotes conceptual understanding and minimizes faulty prior conceptions.

Overall, this research in addition to confirming the importance of the conceptual change model, CCM in promoting conceptual understanding, conceptual change, and reducing misconceptions in learning science concepts; also discovered that the six phases of the Conceptual Change Model have different effects on conceptual change.

The implications of this research for science education are numerous. Regarding the theoretical implication, the theory of conceptual change in science education must be developed and propagated to ensure that it doesn't remain the preserve of psychology or cognitive science research. The methodological implication is that the CCM technique of instruction should be employed in more science classrooms across the K-20 educational spectrum to improve its visibility in science education research. The practical implication is that peer-peer collaborative discussions should be promoted and encouraged in the science classroom. As evident from the results, conceptual change and understanding of science concepts are most successful in student-centered collaborative learning environments. The current practice of top-down, teacher-centered, and question-answer approaches to science learning should be discouraged. In its place should be leveraging the advantages of group discussions and student-student collaborations (Kilinc et al., 2017). In the context of real-world application, this research banks on a strong groundwork of teaching concepts while developing enhanced learning experiences for K-12 students, investigates the challenge of student engagement and content learning in STEM coursework (Burrows et al., 2013).

Since data collection and analysis were based on a quantitative approach, we couldn't elicit participants' responses in terms of how their conceptual change was influenced by the *"Confront beliefs"* and *"Accommodate the concept"* phases. Future research should use a mixed-methods approach to explore participants' thoughts about these phases affecting their conceptual change and understanding of forces and motion. Research that is qualitatively designed or includes qualitative components would give more information about the role the various phases play in participants' conceptual change process during classroom instruction. These activities would be beneficial for teachers, educators, and curriculum designers in terms of how CCM instruction can be developed for use in science classrooms. In addition, the merit of the conceptual change model for conceptual change and understanding should be investigated and researched across multiple science topics and concepts with the wide-ranging perspective of promoting lifelong science learning and literacy. The results of this research, also contribute to

the literature on effective educational practices that can inform the design and implementation of conceptual change teaching practices within teacher education programs. This research has a couple of limitations. To begin with, the limited number of participants. Even though the participants developed deep knowledge about the topic of forces and motion, increasing the number of participants can reinforce the generalization of the results. The other limitation is the deficiency of in-depth interviews of participants to get their views on the specific effects of the phases of the CCM and how they would implement it in their future classrooms. Hence, future research that explores a mixed-methods approach should be done.

Conclusions

This research provides evidence in support of the effect of the CCM in promoting conceptual understanding of forces and motion among pre-service teachers enrolled in the elementary physical science course. The results showed that the CCM is a teaching model which must be considered by science educators and teachers when dealing with issues related to misconceptions and conceptual understanding of science topics. The theoretical value of the conceptual change model in terms of facilitating conceptual change and minimizing misconceptions was empirically tested in this research. Furthermore, the results of this research help connect theory and practice and offer empirical support for the knowledge assimilation perspective of conceptual change by showing that participants developed more conceptual understanding when their misconceptions and alternative ideas were engaged during instruction. The result of this research makes a good case for why it is essential for science teachers and educators must use the CCM in science teaching and learning.

This research submits that using the conceptual change model is a favorable approach to developing pre-service teachers' conceptual understanding and knowledge of science content, particularly when incorporated with the teaching of pedagogy. The evidence further suggests that the conceptual change model or phases of it has applicability and utility in teaching science topics related to the forces and motion sub-topic of pushes and pulls. The question then is, why does this research matter? This takes us to the essence of this research, the desire for science educators and teachers to create an educational experience for students that causes them to change their wrong prior notions based on the experience of teaching and classroom interaction with peers. The experiences of students in the teaching and learning process influence their understanding, and this is a tenet into which the conceptual change model taps to develop conceptual understanding. This research shows that pre-service teachers can change their wrong ideas about science concepts when they learn under the experiential conditions that the conceptual model creates. The objective going forward is to conduct research on the concrete processes that facilitate conceptual change by interviewing participants who experience the phenomenon of learning using the conceptual change model.

Declaration of Interest

The authors declare no competing interest.

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Appendix A: Pre and Post-Test on Forces and Motion

This test is being administered to pre-service teachers enrolled in the Elementary School Physical Sciences Course, EDEL 1440. The primary objective of this test is to assess pre-service teachers' knowledge of

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forces and motion required for teaching elementary grade physical science curricula at schools. Please, know that you are under **no** obligation to complete this survey. You can decide to **not** complete it and it would **no**t affect you in any way as far as the EDEL 1440 Course is concerned.
Modified questions from the AAAS Project 2061

Kindly answer the following questions to the best of your understanding.

1. Is it possible for an object to move at constant speed without a force pulling or pushing it?
   A. No, a constant force is needed to keep an object moving at constant speed.
   B. No, a force is needed to keep an object moving at constant speed, but it doesn't have to be a constant force.
   C. Yes, an object will move at constant speed unless a force acts to change its motion.
   D. Yes, an object will move at constant speed as long as the force inside the object doesn't run out.

2. What will happen to an object that is moving forward if a force pushing it backward is greater than the force pushing it forward?
   A. The object will move at constant speed for a while and then slow down and stop.
   B. The object will slow down for a while and then move at a slower constant speed.
   C. The object will slow down, stop, and then begin to move faster and faster in the opposite direction.
   D. The object will slow down, stop, and then begin to move at a constant speed in the opposite direction.

3. What is the net force on a 200g ball when it hits a wall with an acceleration of 10 m/s^2?
   A. 4 N
   B. 3 N
   C. 2 N
   D. 1 N

4. A flying Frisbee stops because it has run out of force. True/false. Explain. ………………………
   ………………………………………………………………..

5. While you're slowly lifting a book straight upwards at a constant speed, the upward push of your hand on the book is:
   A. greater than the downward pull of gravity on the book.
   B. equal to the downward pull of gravity on the book.
   C. smaller than the downward pull of gravity on the book.
   D. equal to the sum of the book's weight and the pull of gravity on the book.
   E. the only push or pull on the book.

6. Your friend pushes a sofa with a constant horizontal force, so that it moves down your school hallway at a constant speed. The force that she applies is:
   A. the same as the weight of the sofa.
   B. greater than the weight of the sofa.
   C. the same as the total friction forces that resist the sofa's motion.
   D. greater than the weight of the sofa plus total friction forces that resist the sofa's motion.
   E. greater than the total friction forces that resist the sofa's motion

7. If you apply a net force of 3 N on a 100g box, what is the acceleration of the box
   A. 10 m/s^2
   B. 30 m/s^2
   C. 20 m/s^2
   D. 5 m/s^2

8. A person pushes a box across the floor. There are two horizontal forces on the box: the force of the push, and the force of friction. The force of friction is in the opposite direction to the box's motion. The speed of the box is increasing. Which of these statements *must* be true?

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A. The force of the push is stronger than the force of friction.
B. The force of the push is the same strength as the force of friction.
C. The force of the push is strong.
D. The force of friction is weak.

9. Is force required to keep an object moving? Explain your answer. ……………………………
………………………………………………………..

10. A moving golf ball has a force within it that keeps it moving.
A. True because it has a force acting on it to push or pull it in motion.
B. False because a force acts on an object to keep it moving, the force is not within it.
C. Neither true nor false.
D. Partially true.

Appendix B: Questionnaire on CCM and Conceptual Understanding of Forces and motion

Conceptual Change Model

Item	**Strongly Disagree**	**Disagree**	**Neither Disagree or Agree**	**Agree**	**Strongly Agree**
The teaching approach helped me understand the concept of forces and motion.	O	O	O	O	O
Recording the reasons for my ideas dispelled some misconceptions I had.	O	O	O	O	O
The peer-to-peer group discussions convinced me to abandon some preconceptions I had.	O	O	O	O	O
I was able to see applications of the concept of forces and motion beyond the lesson for the day	O	O	O	O	O

Please, indicate how strongly you agree or disagree with the following statements

Conceptual Understanding

Item	**Strongly Disagree**	**Disagree**	**Neither Disagree or Agree**	**Agree**	**Strongly Agree**
Force is required to keep an object moving.	O	O	O	O	O
Constant motion requires a constant push or pull.	O	O	O	O	O
A stationary object has no force acting on it.	O	O	O	O	O
A moving object will stop when it runs out of force.	O	O	O	O	O

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Appendix C: Questionnaire on the Effects of the Phases of CCM on Conceptual Change

Please, indicate how strongly you agree or disagree with the following statements

Item	**Strongly Disagree**	**Disagree**	**Neither Disagree or Agree**	**Agree**	**Strongly Agree**
Writing down my predictions and explanations helped build my understanding of forces and motion.	O	O	O	O	O
Conducting the investigative activity and working with measured data helped me change my initial ideas	O	O	O	O	O
The discussions, debates and arguments using collected data had a positive effect on my understanding of the concept of forces and motion	O	O	O	O	O
Sharing my ideas, predictions and explanations with group members enhanced my understanding of forces and motion.	O	O	O	O	O

Appendix D: Pre and Post Questionnaire on Conceptions of Forces and motion

Item	**Strongly Disagree**	**Disagree**	**Neither Disagree or Agree**	**Agree**	**Strongly Agree**
The constant motion of a pull-back car requires a constant push or pull.	O	O	O	O	O
If a ping-pong ball is not moving, then there is no force acting on it.	O	O	O	O	O
A golf ball stops moving because the applied force is finished.	O	O	O	O	O
An object can only move at constant speed if a force is pushing or pulling it	O	O	O	O	O

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