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The Effectiveness of a Guided Inquiry-based, Teachers' Professional Development Programme on Saudi Students' Understanding of Density

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ABSTRACT: Despite a general consensus on the educational effectiveness of inquiry-based instruction, the enacted type of inquiry in science classrooms remains debatable in many countries including Saudi Arabia. This study compared guided-inquiry based teachers' professional development to teacher-directed approach in supporting Saudi students to understand the topic of density. One hundred and seven, sixth-grade, Saudi students in six classes were randomly assigned, by school, to one of two conditions (guided or teacher-directed condition) while they studied the same unit on density in their science curriculum. The three teachers in the guided condition attended an intervention on using guided-inquiry activities to teaching a unit on density. The three teachers in the teacher-directed condition used their regular approach to teaching the same unit. Pre- and post-tests of the students' understanding and explanation of density was adopted for the study. A one-way analysis of variance (ANOVA) and repeated analyses were performed to assess the students' understanding and explanation of density. In comparison to the teacher-directed condition, the students in the guided-inquiry condition demonstrated significant improvements in both conceptual understanding and their levels of explaining the concept of density.

KEY WORDS: Guided inquiry, Teacher-directed, Pedagogical content knowledge, Density

INTRODUCTION

Although learning through inquiry is often encouraged in the literature as an effective approach for science teaching, enacting inquiry as a teaching approach in the science classrooms is, however, problematic. Anderson (2002) suggested the word "dilemma" in addition to the word "barrier" to describe different challenges to teaching science inquiry. While he thought that the word barrier implies external difficulty, the word dilemma is helpful placing emphases on the internal difficulty for science teachers. This difficulty includes beliefs and values related to students, teaching, and the purposes of education.

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Research has emphasised the strong relationship between internal teachers' beliefs and values of science and their enactment of inquiry based teaching. For example, Lotter, Harwood, and Bonner (2007) found that teachers' conceptions of science are varied ranging from viewing science as a set body of facts that can be memorised to more inquiry as practice with an emphasis on science process skills. Lotter et al. (2007) suggested that teachers' different conceptions of science, and other factors such as the purpose of education, students, and effective teaching practices were also found to influence teachers' receptivity to inquiry-based teaching.

External factors also play a key role on the teachers' implementation of science based inquiry instruction. Teachers often have difficulties in distinguishing between their roles and their students' roles in science based, inquiry classes, possibly because of a lack of understanding about how much instruction should be provided to students during the inquiry process (Bell, Smetana, & Binns, 2005; Blanchard et al., 2010; Colburn, 2000). A lack of professional development support for teachers learning about inquiry can thus result in confusion in its implementation in science classrooms.

Given this literature, it is crucial to support teachers' learning through authentic classroom practice, science content knowledge and the use of the inquiry activities. Learning about authentic practice of inquiry includes helping teachers to learn how to teach constructively, to strengthen their assessment competencies in a way that suits the inquiry method and to enhance their skills in engaging the students (Anderson, 2002).

With a centralized, educational system, the in-service, teacher-training programmes and activities in Saudi Arabia have been designed nationally without taking into account the teachers' experiences in their science classes. It can be described as a 'pre-packaged', top-down approach, with a 'one size fits all' model (Alharbi, 2011.p.3). This model has previously been found to be ineffective for it imposes professional-development on teachers without first identifying their needs for activities that are related to their classroom practice (Colbert, Brown, Choi, & Thomas, 2008). Programmes that adopt this model are often lacking in a strategic plan to develop the teachers' knowledge and skills (Almazro, 2006; et al., 2008).

Another way of supporting the teachers in their inquiry-learning practices is to improve their knowledge of the science curriculum's content and associated teaching activities. In-service education "must not only address practical matters, it should also attend to those practical activities, which teachers are actually using in their own classes" (Anderson, 2002, p. 9). These more effective professional-development activities should focus on enhancing the teachers' knowledge of particular, subject matter and should support them as they learn how to teach this content to their students (Fennema et al., 1996; Kahle, Meece, & Scantlebury, 2000; Keys & Bryan, 2001).

This study was developed to engage Saudi teachers in professional learning sessions that supported and gave them practice in the guided inquiry learning. Using the context of density related activities, the sessions were based on the 5E's instructional model (Bybee, 2009) .The sessions actively explored the requirements of each of the guided-inquiry phases: engage, explore, explain, elaborate, and evaluate .The function of these phases is to provide teachers with coherent instructions, which embed opportunities for the students to learn scientific concepts and to develop inquiry skills and, thus, to help them to achieve a deeper understanding of the nature of science (Bybee, 2009). This guided-approach encouraged the students to take primary responsibility for their own learning via their participation in practical experiments in which the teacher had only a guiding and a supportive role. The teacher-directed condition emphasised the dominant role of teachers in facilitating the students' learning, whereby students were first presented with the concept and then observed an experiment to verify the ideas behind it.

INQUIRY IN SCIENCE CLASSROOMS

There is no doubt that further research is needed to understand which and how different types of inquiry can be implemented in science classrooms (Bunterm et al., 2014). While research seems to concur on the effectiveness of both open and guided inquiry-learning approaches, the more appropriate type for teaching and learning remains controversial (Sadeh & Zion, 2009). Proponents of open-inquiry learning claim that it enhances the students' levels of inquiry and their logical thinking skills (Berg, Bergendahl, Lundberg, & Tibell, 2003; Germann, Haskins, & Auls, 1996). By contrast, those who are in favour of a guided inquiry-approach laud the efficiency of this method in preventing a waste of time and in reducing student frustrations at unexpected results (Trautmann, MaKinster, & Avery, 2004).

Although there is an extensive empirical literature comparing inquiry approaches against non-inquiry-based approaches, there are only a few studies that focused on studying the effectiveness of guided inquiry based professional development approach. Blanchard et al. (2010) found that the guided inquiry-approach is more effective than the traditional verification approach in enhancing both the science content-knowledge and the process skills of the students. In this study, Blanchard et al. (2010) compared the pre, post, and delayed post-tests results of high and middle-school students who were taught using traditional-verification or guided-inquiry approaches. The professional-development instruction for both groups included a week-long, laboratory-based, forensics unit and the treatment group were taught by teachers who had accomplished six weeks of these professional development sessions. This program was designed to support the teachers' understanding and their implementation of the inquiry-based, instructional approach. These results generally indicated that students, who were taught using the guided-inquiry approach and particularly in high school, produced better results and stronger growth in their understanding than did the students in the traditional group. Blanchard et al. (2010) also suggested that long-term intervention is not always required to see results in their study, with only six weeks of intervention, the guided inquiry-approach, outperformed students in the more traditional, laboratory groups.

Guided inquiry also showed its efficacy in other developing countries such as Thailand. Bunterm et al. (2014) studied the effects of guided versus structured inquiry on 239 secondary students in three schools in Thailand. The dependent measures in this study were content knowledge, and process skills of science, scientific attitudes, and self-perceived stress. Although the results showed variations between the three schools in the scientific attitudes and stress levels, there were greater improvements for students in the guided inquiry condition in both science content knowledge and science process skills measures.

There is also evidence suggesting that a guided inquiry-learning approach is the "ideal" form of inquiry when teachers are inexperienced in conducting an open inquiry-lesson (Bybee, 2010; NRC, 1996). An analysis of the students' results of Organisation for Economic Co-operation and Development (OECD) in many countries has indicated that students who had experience in guided inquiry learning demonstrated higher, scientific literacy than those who had experienced open-ended or the teacher-directed learning-approaches.

Inquiry for teaching density

The concept of density provides a challenge for primary teachers because it requires students' dealing with proportional reasoning. Research indicates that density is a complex concept and is thus difficult for the students to master (Dawkins, Dickerson, McKinney, & Butler, 2008; Smith, Maclin, Grosslight, & Davis, 1997; Smith, Snir, & Grosslight, 1992). This difficulty can be associated with the abstract nature of density since it is must be understood by working with ratios or proportions. It cannot be directly observed as a clear property of matter but, rather, must be calculated by first finding the object's mass and volume and then by dividing the mass by the volume. It is thus defined as a ratio between an object's mass and its volume or its mass per unit volume.

In the traditional modes of instruction, however, density, mass and volume are taught via related equations and formulas and by providing instruction on how to apply these to solve problems related to density. Smith et al. (1997) indicated that in such traditional model, the students are rarely encouraged to interact with each other or to reason about the phenomena, which often leads to a lack of conceptual understanding and scientific explanations of density. If, however, the students are to change their conceptions, both quantitative and qualitative explanations of density are required for more effective teaching

Teachers need to consider the nature and organization of student concepts about matter and density prior to instruction. Student conceptions of matter and density can be placed on one of two theories (Smith et al., 1997). In a first, common-sense theory 1, students believe in observable matter that can be seen, touched, and felt. They also believe that matter is impenetrable, and bodies cannot occupy the same space at the same time. When pieces of matter are too tiny to be observed, students cannot conceptually conceive of their masses and will often conflate a material and its property in one concept on the basis of how much of this material can be observed. This does not encourage the students to differentiate between the mass, the size and the density of an object. Alternatively, in a second common-sense theory 2, students conceive of a more abstract definition of matter, which can be divided into smaller units with each of them having a definite mass and volume, and with both having observable and non-observable units of matter to preserve their properties. Thus, students can differentiate between weight, volume and density and their interrelationship, which may enhance their understanding of density (Smith et al., 1997).

The teacher's role is the key to scaffolding student explanations when the teaching approach is carefully implemented. Teachers' pedagogical practices are considered to be an effective tool for enhancing the quality of the students' explanations of science (Osborne, Erduran, & Simon, 2004). In science-based inquiry-practices, the teacher's role is essential in supporting the students' constructions of evidence-based, scientific explanations (Duschl & Osborne, 2002; McNeill & Krajcik, 2008). Embedding reasons behind the scientific explanations as a part of the teachers' instructional practices may support stronger, student understandings of these explanations and may encourage the students to provide stronger, scientific explanations (McNeill & Krajcik, 2008).

Studies indicated that students' understanding of abstract concepts such as density, mass and volume can be enhanced when they engaged in inquiry based learning experiences. For example, Austin (2005) indicated that conceptual understanding of science can be combined with the 5E model to create authentic inquiry learning instruction. During the learning stages, students are challenged to approach a scientific concept, which results in more engaging and realistic science instruction. Smith et al. (1997) found that the modified curriculum used to teach density that addressed students' initial conceptions, resolved incompatible views and engaged students to reason and restructure new learning concepts. This helps students to have opportunities to discuss different abstract concepts (density, mass, and volume) and thus they will be encouraged to foster integration between mathematical and qualitative reasoning.

During the inquiry phases, the learners' roles should be distinguished from the teachers' roles and, thus, more opportunities for students should be provided for them to reason about evidence, to modify their ideas in the light of this evidence and to develop 'bigger' ideas from 'smaller' ones (Skamp & Peers, 2012). Bybee (2014) identified the teacher role as a guide of students' learning in the five phases of guided inquiry. At the beginning of teaching, the engage phase provides opportunities for teachers to elicit students' prior knowledge, which in turn can be used to review and resolve inconsistent views in second phase (explore). The teacher's role in the explore phase after initiating the activity and providing background and materials, is to listen, observe, and guide students as they clarify their understanding. In the explain phase, the teacher establishes linkages and relationships between students' prior knowledge and new learning experiences leading them to construct evidence-based explanation. Students in the elaborate phase are challenged with a new situation to apply the learned concept and encouraged to interact with each other and with other resources. Finally, "in the evaluate phase, the teacher should involve students in experiences that are understandable and consistent with those of prior phases and congruent with the explanations" (Bybee, 2014, p. 11). In so doing, teachers learn about students' conceptual understanding, and can provide effective teaching, creating more opportunities for student-centred learning.

Purpose of the Study

The purpose of this study is to compare the effectiveness of a guided inquiry professional development program with the existing teacher directed approach in improving Saudi students' understanding and explanation of science. The specific research question investigated is "What is the effect of a guided inquiry-based professional development program for teachers on Saudi students understanding and explanation of density?"

METHODOLOGY

The study design

This study compared the effectiveness of embedding specific activities into a science-based, inquiry unit where students were taught in one of two different conditions; the guided-inquiry condition and the teacher-directed condition. Before the beginning of the study, the guided-inquiry group of teachers participated in workshops in which they explored activities to strengthen students' conceptual understanding of density. There was a specific emphasis on developing their guided inquiry strategies and skills in their practice of this unit. These activities were developed by Hackett, Moyer, and Everett (2007) and involved modelling the 5Es approach to inquiry learning.

The teacher-directed condition taught the density lessons in the manner prescribed by the Saudi Arabian science-curriculum. According to the Saudi National Assessment of Educational Progress (SNAEP, 2010), the school system in the kingdom still retains a traditionalist-teaching methodology, and a traditional curriculum that is dependent on the textbook as the cornerstone of the process of education, with insufficient standard of professionalism amongst teachers to manage curricula, assessment and data gathering.

The two conditions

Six male teachers participated in this study and were randomly divided into one of the two conditions - the guided inquiry and the teacher-directed. Guided inquiry group of three teachers participated in inquiry-science workshops activities using the 5E's model and teacher-directed group participated in the regular traditional training.

The teachers in the guided condition received specific training sessions in how to implement a guided, inquiry-based, density unit in their science classrooms. Although the teachers in the teacher-directed condition did not receive training in the practice of teaching guided inquiry lesson, they also spent a similar amount of time in discussing the teacher-directed approach as prescribed by the Saudi science-curriculum.

The guided-inquiry condition

The workshop sessions were followed by seven weeks of monitoring sessions for teachers in this condition. In the workshop sessions teachers were given the opportunity to explain and share their views about their own understanding of the 5E's guided-inquiry model (Bybee, 2009). An important part of the professional development involved the engagement of the teachers in a discussion about the use of questions which initiate and continue the inquiry process. They learnt strategies that support the use of non-evaluative questions that ask for students' prior knowledge and support more opportunities for student investigations (Oliveira, 2010; Ruiz-Primo & Furtak, 2006). This included the process of eliciting, interpreting, and using student responses to enhance assessment based guided inquiry environment. This ability to make students ideas explicit requires teachers to be prepared "not only to identify correct or incorrect answers but also to recognize the range of ideas that lie in between" (Furtak, 2012, p. 1184). The teachers also investigated and designed probing questions that were based on different density activities; these questions were practiced throughout these sessions. Probing questions included questions which were asked after receiving initial responses from students from asking them to reflect on their prior learning by giving meaning and clarifications. These questions also encouraged further inquiry by, for example, asking for comparing and contrasting different views and explanations. These sessions also highlighted the respective roles of the teachers and of the students during a guided-inquiry lesson.

These inquiry activities as used by Hackett et al. (2007) were then modified to teach the underlying density concepts in such a way that actively encouraged the students' conceptual understanding of mass and volume before dealing with density as a proportional concept. Each activity was used to support the students' engagement in a discussion about the features of each concept; this discussion also included the importance of eliciting their thoughts in the first stage (engage). In this phase, teachers planned for questions that elicit information about the students' prior knowledge of things that float by asking an inquiry question (for example, "Which of the popped and un-popped popcorn will sink?"), and then following this by having students provide reasons for their predictions ("What do you think might cause different objects to float?"). The most important information about students' thinking could inform the teachers' actions and help them to decide the next step for interactions (Furtak, 2012).

In the explore phase, the discussion focused on the significance of challenging the students' current understandings and their presently-held concepts by asking questions and by providing opportunities for the students to carry out the experiments; this thus allowed them to observe the changes as they happened. The teachers learnt how to ask questions and how to respond to the students by using questions to encourage further investigations without answering the original inquiry-question. They intentionally planned for elicitation questions that could encourage the students to observe the changes "What observations/elements cause these changes?", and to provide time for group discussions which could utilize cooperative learning strategies. They also followed up on student thinking by asking questions which connected with previous learning and understanding, collected explanations from different groups to challenge and compare these responses through the data collection process.

This, in turn, encouraged the students to present modified explanations in the third stage of the inquiry lesson (these explanations were constructed after dealing with the exploration process). The teachers also learned to decrease their guiding questions so as to involve the students in a decision-making process in relation to their collected data and, so, to encourage them to draw their own conclusions. Teachers guided their students' thinking with appropriate probes via the use of open-ended questions, after they have collected their data. They could ask the students to explain changes that are based on evidence from their data, as well as by asking them to provide a rational justification ("How do you explain the flotation of the popped popcorn? What evidence supports your explanation?").

The teachers could also use strategies that might encourage the students to compare the density variables such as;

- "How could the mass and volume of the popped and un-popped popcorn be compared?"
- "If the masses of both were almost the same, what do you think was the cause of the flotation of the popped corn?"
- "Students could be asked to write down their hypotheses to explain the relationship between flotation and density."

In the elaborate phase, the teachers discussed those alternative activities, which would best support the students' understanding of a particular scientific-concept. Teachers were introduced to a relevant concept-application (e.g. the party balloons activity, the coke activity).

The evaluation stage of the guided inquiry-activity discussed the need to design tests that would appropriately assess the students' understanding, their skills and their abilities to effectively communicate their solutions. Teachers discussed whether any quizzes and exams items involved the application of thinking skills and the derivation of conceptual understanding.

Enhancing the teachers' content-knowledge of a particular unit of science was a significant part of these workshops and this was achieved by encouraging authentic practice in an inquiry-learning environment (Crawford, 2000; Smith et al., 1997). The key guiding-principle of this unit was to encourage the teachers to help the students to make connections between the mathematical and the conceptual understanding of density. These sessions started by investigating the students' misconceptions about density and these were then followed by a discussion of the ways in which the teachers could address the common student misconceptions when teaching it. Such misconceptions included confusion between mass and volume, mass and density, volume and weight or their alternative concepts of volume.

The approach was to separate the component concepts of mass and volume and to independently develop their relationships with density. Table 1 provides the teaching-guideline for these activities.

The teacher-directed condition

The three participant teachers in this condition attended the Education Department's training programs and taught the same, density activities as outlined in their science text-books.

The teacher-directed model emphasises the teacher's authority and minimizes the students' cognitive engagement in which the teacher serves as the source of knowledge. Teaching is very detailed and the teacher provides the oral and written explanations. Teachers are responsible for every stage during the process of demonstrating objects, solving equations and performing calculations (Aizikovitsh-Udi & Star, 2011). "The channel of communication in this teacher's classroom tended to be one-way, because he asked the students who were required to listen and to respond, often reiterating information provided earlier by the teacher" (Gillies, Nichols, Burgh, & Haynes, 2012, p. 94).

Table 1 The workshop activities (Hackett et al. 2007)

Activities	Teaching focus	Student misconceptions	Teachers' guided role
1. Popped and not popped popcorn	Changing volume causes density change	Conflating volume and weight in one concept	Focus students' reasoning on the volume changes when an object is heated
2. Dancing raisins	Attached bubbles affect the raisins' volume and decreases its density	Gas bubbles inside the raisins	Direct a discussion that compares the density of the raisins when placed in a glass of water or of soda
3. Blocks of different materials with constant volumes	Changing the mass affects the blocks' densities	Hard materials are heavier	Provide chances for the learners to explore the mass of cubes of constant volume
4. Different balls with changing masses and volumes	Dealing with the density as a ratio	More volume means more weight	Compare the different balls and observe the density changes.

In this approach, understanding the relationships between different scientific concepts may occur after students have memorised a critical mass of facts (Lemberger, Hewson, & Park, 1999; Tobin & Gallagher, 1987). Encouraging this rote memorisation of factual information did not support meaningful learning of science in which students should be involved to develop conceptual understanding by themselves on the basis of their prior knowledge (Yip, 2004).

Teachers in this condition taught density by first explaining the concepts and then by using the inquiry activities to verify the discussed ideas. They controlled the discussion by asking questions and by explaining the different, scientific concepts. The textbook encouraged the teachers to teach the concept of density via a demonstration of the buoyancy of different objects and then compared with the density of water. If an object floats, then its density must be less than the density of water (1g/cm3) and, if it sinks, its density must be more than the density of water. The students' quantitative understanding of density was thus emphasised by narrowing the students' thinking so that they only compared the density of an object with the density of water. The students were then required to apply the known density formula to find the density and mass or volume of different objects. The teachers' foci were to find the quantity of density, mass, and volume but without engaging with the students' in constructing scientific explanations or in helping them to clarify these abstract concepts.

The teachers and the schools

Six, male, primary teachers from six schools were selected to participate in the study on the basis of one the following criteria:

- The school district's science-coordinator considered the selected participants to be seeking or to be receptive to effective science-teaching strategies;
- The selected teachers had participated in previous training-programs;
- The selected participants had taught science for grade six students; and,
- They had volunteered.

The teachers were randomly allocated by school to one of the two conditions - the guided inquiry or the teacher-directed approaches. All the participant teachers had taught for more than ten years.

The six, selected, primary schools had a similar socio-demographic profile. These schools are supervised and evaluated by the Ministry of Education and have regular visits by the supervisory teams in their district. The supervisory team considered that these schools were the best schools to participate in this study on the basis of the teachers' teaching practices, on the students' achievements.

The Students

For religious and cultural reasons, the Saudi educational-system separates schools according to gender and prohibits males from having access to girls' schools. Thus, this study included one hundred and eighteen male students from the above teachers' classrooms participated in one of the two conditions - the guided-inquiry or teacher-directed science units, which were taught as part of their regular curriculum. All students were from similar middle-class, socio-economic, Saudi backgrounds. One hundred and seven students completed pre- and post- density tests, fifty-five were in the experimental, teachers' classes (the guided-inquiry), whilst there were fifty-two students in the comparative (teacher-directed) classes.

The density achievement test

Pre- and post-tests of the students' understanding of density were given to both groups. Each test consisted of two sections of 14 multiple-choice and two open-ended questions (See Appendix A). These covered the important, conceptual ideas about density in the grade 6 curriculum. A teaching-objectives matrix was developed, in consultation with the teachers, to verify that each objective was assessed in these tests (see table 2).

Table 2 The distribution of the test items amongst the learning objectives of the density unit

Teaching objectives	Number of related questions
Understanding volume and comparing the volumes of different shapes	1,4,9
The relationship between the density and the volume	4, 8,11, 16
Understanding mass and the relationship between the density and the mass	2,8,12,15
Calculating density and comparing the density of different objects	7,10, 5,13,14
Density as a property of a material	11

The tests were designed to assess the range of the students', appropriate, problem-solving skills for the grade 6, density unit. Different questions were designed to examine the students' understanding of mass, volume (for regular and irregular shapes) and of the ratio of mass per unit volume. Some test items also focused on the students' abilities to compare the densities of different objects or to analyse changes in the volume of the same object.

Each item in the multiple-choice section consisted of four alternatives. Each of the distractors was designed to provide an appropriate level of difficulty. The design of the distractors specifically tested the students' abilities to use the density concept in a range of contexts.

The scoring of the two questions (a total of six) focused on the four levels of the students' explanations of density. These questions emphasised students' abilities to explain floating and sinking of an object, based on their understanding of the relationship between density and mass, density and volume, and their ability to explain density as a ratio of mass/volume (see the two open questions in appendix A).

The researchers corrected students' explanations by developing a scale based on research by Smith et al. (1997). See Table 3 for the open-ended questions scoring rubric.

Table 3 The rubric for the students' various levels of explanations (Smith et al. (1997))

Level of Understanding	Description: Students' explanation focused on…
0	Explanation shows little understanding of the concept with no mention of density, mass or volume.
1	Explanation focuses on one variable (mass, volume or density only) and shows little understanding of the main variable that causes the density to change.
2	Explanation accurately identifies the main variable (mass, volume) that causes the density to change in a linear relationship.
3	Explanation identifies the main variable that causes the density to change and includes the effect of this change on this object's density (dealing with density as proportionality).

Both parts of the test gave a total score of twenty. There was one mark for each correct answer in the multiple-choice questions and three marks for each of the two open-ended questions, which were based on the rubric scoring in Table 3.

Four science education experts evaluated the tests and agreed as to their validity. Two were lecturers from the School of Education at Albaha University; each had many years of experience of science teaching and of supervising pre-service, science teachers. The other two were science teachers with Masters' degrees in science education and had taught physics and chemistry for more than ten years.

RESULTS

The Statistical analysis

A one-way analysis of variance (ANOVA) and repeated analysis of variance design were performed to determine if there were significant differences between the students' learning-gains in the guided-inquiry condition and in the teacher-directed condition. The students' scores on both the multiple choice and on the open questions were analysed separately, for both the pre- and post-tests. The homogeneity of the variances for the students' pre-tests in both the multiple-choice and in the open, qualitative questions was examined before conducting the ANOVAs to ensure the homogeneity of the variances in both the experimental and in the comparison group. Levene's test of homogeneity of variances was not significant ($p > .05$) for these scores and so the ANOVAs could proceed. The effect sizes were reported by using partial eta squared (η2) values.

The students' learning gains

A one-way ANOVA was performed to determine if there were significance differences between the two conditions at pre-test on the multiple-choice and on the open-ended questions. No significant differences were found in the pre-test, multiple-choice, mean scores, (F (1,105) =1.923, p = 0.169, p > 0.05) or for the pre-test open-question scores, (F (1,105) = 2.262, p = 0.136, p > 0.05) of the students who were taught using the guided-inquiry approach and of those who were taught using the direct-teacher approach (see Table 4).

Table 4 The means, standard deviations and the p-values for two parts of the pre-test

Variable	Group	*M*	*N*	*SD*	*F*	*p*
Pre-test MCQs	Teacher-directed	5.02	52	.960	1.923	.196
	Guided	4.75	55	1.075		
Pre-test Open questions	Teacher-directed	.83	52	8.41	2.262	.136
	Guided	1.05	55	8.96		

Key: MCQs= multiple choice test; Maximum score for the multiple choice test = 14 & Maximum score for the open question test = 6

A second one-way ANOVA of the students', gain scores (where gain = post-test – pre-test scores) for both parts of the tests revealed a significance difference in favour of the guided- condition in both the multiple choice test - (F (1,104) = 9.896, p = 0.002, p< 0.05) and in the open-question tasks (F (1,104) =21.422, p = .000, p > 0.05). The significant difference in the means for both multiple choice and open questions are demonstrated in Table 5.

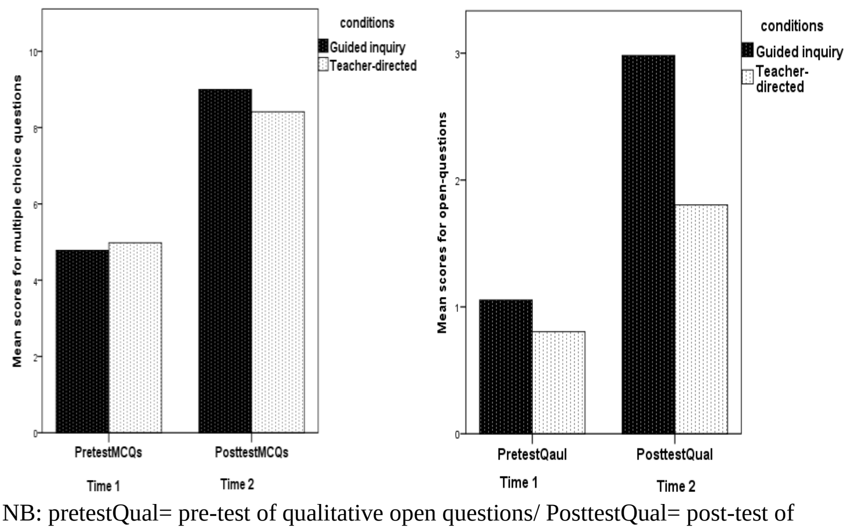
The repeated measure analysis of variance was performed to compare the effect of the intervention from time 1 to time 2. The students understanding and explanation of density measures were affected by an interaction effect involving time of test and the two conditions (p = 0.005, p < 0.05) (See figure 1).

Table 5 **Tests of between subject effects for two difference scores (post-test minus pre-test)**

Dependent Variable		*Ss*	*df*	*M*	*F*	*p*
Change MCQs	Between Groups	20.386	1	20.386	9.896	.002
	Within Groups	214.255	104	2.060		
Change Open questions	Between Groups	23.654	1	23.654	21.422	.000
	Within Groups	114.836	104	1.104		

NB: MCQ = multiple choice questions

Multivariate test of time effect showed a significance improvement from time 1 to time 2 in favour of the guided-condition in the multiple-choice mean scores (Wilks' λ= 0.118, (p< 0.05), partial $\eta2$= 0.88), and in the open questions (Wilks' λ= 0.334, (p< 0.05), partial $\eta2$= 0.66).



NB: pretestQual= pre-test of qualitative open questions/ PosttestQual= post-test of qualitative open questions

Figure 1 **Differences between the pre-test and post-test score of students based pedagogical condition in the multiple choices (left panel) and the open-questions (right panel)**

Interestingly, Multivariate tests test of (time-condition) interaction showed that the guided condition improvement in the open questions

(Wilks' λ = .883, partial η2= 0.167) was larger than that was found in the multiple choice questions (Wilks' λ = .927, partial η2= 0.073).

DISCUSSION

The current study investigated the effectiveness of training teachers to incorporate guided-inquiry strategies and content-knowledge into their science lessons in order to improve the students' understanding and explanations of science. It has specifically sought to determine how the teachers' knowledge of guided inquiry practices and of their science content-knowledge can contribute to enhancing the students' content-knowledge of density. It has also investigated whether this training course can elevate the students' levels of scientific explanations.

This study demonstrated that the students who were exposed to a guided form of inquiry showed a better conceptual understanding of density in comparison to their peers who had been taught using a teacher-directed approach. The students in the guided-condition had significantly greater success in both the multiple-choice and in the open-question tasks. However, the mean difference of the means was larger in the open-ended tasks (partial η2= 0.167) than in the multiple questions (partial η2= 0.073).

The greater improvement for students in the guided- condition could be attributed to the teachers' skills to teach guided-inquiry after their participation in the professional development. In the context of this study, teachers were able to teach the 5 E's instructional model in away the encourage students' engagement in the process of learning by placing themselves in the role of a moderator between the students and the instructional materials for the lesson. It was clear that the guided-inquiry approach was an effective, transition method; this is important since Saudi students are more familiar with the more traditional, science-teaching approaches. The guided approach was quite efficient in challenging the students' prior knowledge, in providing them with appropriate activities to examine their previous knowledge and in connecting them with the new, learning experiences. It also promoted the students' collection of their own data, which supported them in the construction of their ideas before providing their own explanations. When teaching density, it is important to adjust the instruction from an exclusively, teacher-directed and quantitative, mathematical calculation using the density formula to the guided-inquiry instruction, which encourages students' conceptual changes and helps them to develop more abstract thinking (Smith et al., 1997).

Despite the students' levels of scientific explanations in the guided-condition were significantly higher than were those of the students in the teacher-directed condition, the mean scores did not, however, reach the highest level of the scientific explanations scale (the students only included the linear relationship between mass or volume with density). This meant that, even in the guided-inquiry condition, the students did not all achieve the level where density was integrated with mass or with volume in a proportional relationship. The majority of students in the guided-condition recorded an average level (2) score, where they clearly identified the main cause for changing the density of an object in a linear relationship.

By contrast, the students in the teacher-directed condition scored mainly at level (1) where they showed little understanding of mass, volume, and density, and without identifying the main variable for changing an object density. The overall comparison between the multiple-choice items and the open questions indicated that the students in both groups improved their quantitative understandings of density better than they did for the conceptual reasoning. These findings are similar to the findings of Smith et al. (1997).

There are a number of factors that may have contributed to these results. Shayer and Adey (1981) observed that most students' cognitive levels in the last year of an average primary school are at the early or mid-concrete stage of operational thinking so that students' understandings of density are still only partly conceptualized at this stage with many experiencing difficulties in differentiating between the weight and the volume relationship. The students from both groups in this study had difficulty in incorporating the relationship between the mass and the volume when explaining or when comparing changing densities so that it was difficult for them to provide a full and accurate scientific explanation. Conceptual understanding at this stage "is not exclusively verbally mediated but involves restructuring of well-established, long-held physical intuitions" (Smith et al., 1997, p. 386).

These findings point to the effectiveness of supporting teachers during the implementation of the guided-inquiry learning approach. This level of inquiry has been shown to be an efficient, transition-method for Saudi teachers who are more familiar with the more traditional, science-teaching approaches. This supports the argument that a guided inquiry-learning approach is the 'ideal' form of inquiry for teachers who are inexperienced in conducting an open inquiry-lesson, as previously suggested by previous researchers such as Bybee (2010) and Trundle et al (2005).

Other studies in different scientific and cultural contexts have also validated the efficiency of this guided-inquiry approach (Blanchard et al., 2010; Nwagbo, 2006; Sadeh & Zion, 2009; Trundle, Atwood, Christopher, & Sackes, 2010). Nwagbo (2006) related the efficacy of guided inquiry to its learning environment where students are encouraged to control their own learning with the guidance provided by the teacher. In such a learning approach, the students become more aware of any contradiction between their pre-knowledge and the newly-learned concept via their own scientific explanations, which are derived from the analysis of their own data (Trundle et al., 2010). Despite the fact that the questions are supplied by the teacher in a guided-inquiry activity, the students are the leaders of the inquiry-process and are engaging themselves in motivational thinking; this then enables them to reach self-conceived conclusions (Sadeh & Zion, 2009).

The teachers' professional development that integrates pedagogical and content authentic practices may also contribute to the enhancement of the students' learning-gains. Promoting a guided inquiry-based practice was achieved in this study by engaging the teachers in learning how to guide the students' thinking through appropriate questions, which assessed both mathematical and conceptual understandings of density, mass, and volume. The careful design of these activities may support the development of understanding of the density concept by teaching its linear relationship with mass and volume independently, before studying it as a ratio of mass per unit volume. This supports previous findings that "programs that focus on subject-matter knowledge and on students' learning of a particular subject-matter are likely to have larger positive effects on student learning than are programs that focus mainly on teaching behaviours" (Kennedy, 1998, p. 17). This finding is particularly relevant for primary teachers where they have strong, content knowledge about some topics but have limited content knowledge about other topics (Smith & Neale, 1989).

CONCLUSION

This study shows that training teachers to integrate guided-inquiry with science content in authentic practices is critically important. It enhances the teachers' ability to promote students' understanding and explanation of density.

Students in the guided-condition achieved significantly higher scores when compared with their peers in the teacher-directed condition. The results showed significant, scoring differences in the answers to the questions in the multiple-choice section in favour of the guided-condition.

In the open-ended questions, the students' explanations of density in the guided-condition were significantly improved in comparison with the students' explanations in the teacher-directed condition although these explanations did not always link the interaction between mass and volume.

These improvements in favour of students in the guided-condition may have occurred because of the students' better opportunities to provide more explanations and reasons. When teaching the guided-inquiry, the teachers used more appropriate questioning strategies to support the students' accommodation of newly-learned conceptions into their existing, conceptual frameworks.

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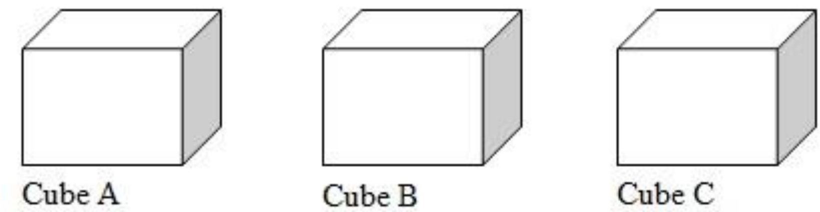
APPENDICES

Appendix 1 Pre and post density achievement tests

1. Which of the following has the greatest volume?
    a. A rock that displaces 25 ml of water
    b. A cube that has a length of 4 cm
    c. Two balls that each displaces 15 ml of water
    d. All of the objects have the same volume

2. The three following cubes have the same volume but different densities. They have a different density because of:



    a. Different length, width, and height
    b. Same volume
    c. Different masses
    d. Same masses

3. Which of above cubes (A, B, C) has the greatest density?
    a. Cube A
    b. Cube B
    c. Cube C
    d. Not enough information given

4. A popped popcorn floats mainly because of a :
    a. Big increase in its mass
    b. Big decrease in its density
    c. Big decrease in its volume
    d. Big increase in its volume

5 . In the following image, there is a piece of sunken wood and a floating rock. What makes the wood sink?

    a. The volume of the rock is greater than the volume of the wood
    b. The mass of the wood is less than that of the rock
    c. The mass and volume are the same
    d. The density of the wood must be greater than that of the rock

6. Which of the objects listed in the table below has the greatest mass?

Objects	density	Volume
A	10 g/cm^3	5 cm^3
B	6 g/cm^3	2 cm^3
C	6 g/cm^3	W=2 cm L=3 cm H= 2 cm
D	5 g/cm^3	5 cm^3

a. Object A
b. Object B
c. Object C
d. Object D

7. The mass of a substance is 6 g. What is the density of the substance, which occupies $3cm^3$?

a. 0.2 g
b. 0.02 g
c. 2 g
d. 4g

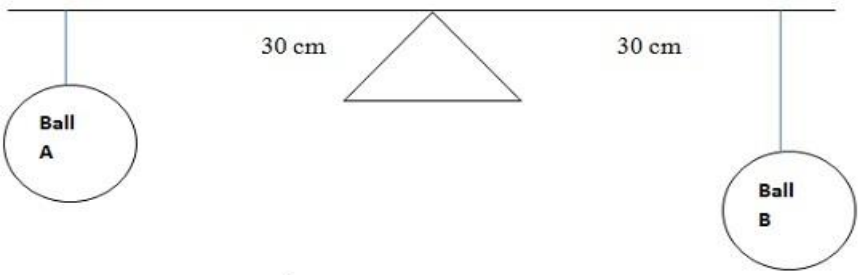
8. A rock dropped in a graduated cylinder raises the level of water from 20 to 35 ml. The volume of this rock is?

a. 20 ml
b. 25 ml
c. 35 ml
d. 15 ml

9. If the same rock in question 8 has a mass of 30 g. its density will be:

a. $2g/cm^3$
b. $3g/cm^3$
c. $5g/cm^3$
d. $3.5g/cm^3$

10. Two balls, which have the same volume, are placed at an equal distance from the centre of an equal-arm scale. Use the diagram below to compare the density of balls A and B:



a. Ball A has greater density than ball B
b. Ball B has greater density than ball A
c. They have the same density
d. More information is required

11. A solid, rubber ball sinks when placed in water. What will happen if the ball is cut in half and one of the smaller pieces is placed underwater?
    a. The smaller piece will rise
    b. The smaller piece will sink
    c. The smaller piece will stay motionless
    d. The smaller piece will dissolve
    e. There is no way to predict what will happen
12. By adding more copper to a copper block, you:
    a. Increase its density
    b. Increase its mass
    c. Decrease its density
    d. Decrease its mass
13. A pebble is dropped into a cup of water and sinks to the bottom of the cup. A solid metal bead of exactly the same size is dropped into the same cup and sinks to the bottom of the cup. How do the pebble and the metal bead compare?
    a. The metal bead and the pebble have the same density
    b. The metal bead and the pebble are the same mass
    c. The metal bead and the pebble are denser than water
    d. The metal bead and the pebble contain the same materials
14. If the density of a block of wood = 0.6 g/ cm^3, its density will be:
    a. Less than water
    b. More than water
    c. Same as water
    d. More information is required
15. Why do the balloons, which you blow up with your mouth, not float up in the air as do the same-sized party balloons?
16. Refer to the following image and explain the difference:

Density of Coke

What is the difference?
Both cans are in water.