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The effectiveness of Driver's model in teaching mathematics for developing intermediate school students conceptual understanding

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Abstract

This study aims to investigate the effectiveness of Driver's model (DM) in developing the conceptual understanding (CU) of first-class intermediate students in geometry and polygons via quasi-experimental design, for a random sample of 62 female-students divided into two groups, the experimental group with 31 students who were taught the module by DM, and the control group with 31 students were taught the module by the traditional teaching method. The study found significant statistical variances regarding scores means between the two groups at the three levels of explanation, interpretation, and application for the experimental group with a high impact reached at0.31 along with a high impact, too, regarding the mean of the total score of CU test for the same group, which reached at 0.43. Thus, the study recommends using DM in mathematics teaching.

Keywords: Driver's model, conceptual understanding, mathematics, geometric

INTRODUCTION

Al-Kubaisi and Abdullah (2015) mentioned that mathematics is not just routine operations that are separate from each other, but rather contains tight structures and systems that are closely related to each other. These structures are considered the main components for mathematical knowledge, and as Saidi and Al-Balushi (2009) observed, such concepts are the cornerstones on which mathematical knowledge is built. Also, learning mathematics is considered a cumulative structural process that depends on linkage between new information and previous information resulting into a new and meaningful knowledge for the acquired concept (Hassan, 2019b). The main goal of achieving the objectives of mathematics learning represents in achieving a deep understanding of mathematical concepts by learners, so that they can integrate mathematical knowledge into their knowledge structure (Abu Khatero, 2018).

In this context, the National Research Council (NRC) in the United States (NRC) emphasizes that teaching mathematics requires knowledge with how-to-teach the conceptual understanding (CU) along with teaching practices needed (Kilpatrick et al., 2001). It stressed that CU better enables learners to understand facts, mathematical ideas, and other contexts. CU is also expected to be more effective in enabling learners to link new knowledge and ideas to the ones acquired previously, in addition to retaining knowledge for longer time (Kilpatrick et al., 2001).

As one of the essential pedagogical concepts, the significance of CU in learning mathematics has been highlighted by the current trends in the field of education (Al-Khuzaim, 2019b). Wiggins and Mctighe (2005) presented indicators of deep understanding such as explanation, interpretation, application, emotional participation, and self-knowledge as being more comprehensive and accurate indicators of judging learners' deep understanding along with consolidating meaning-based learning.

The importance of CU in teaching various stages of mathematics has been recommended by many studies such as Abu Al-Rayyat and Khattab (2020), Abu Khatero (2018), Al-Janabi (2019), Al-Shamrani and Al-Maliki (2021), and Andamon and Tan (2018). All these studies aimed to develop CU in mathematics as well as searched methods to improve performance and deep understanding of mathematical concepts to retain their impact on the learners.

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Contribution to the literature

- This study takes different accounts of essential facts that tend to combine the relation of mathematics teaching and learning with CU techniques.
- It can prove as a contribution for upcoming researchers to design a framework that could highlight genuine relation of mathematics teaching and its learning based on CU techniques.
- It can be considered as a source to demonstrate the beliefs of mathematics teachers and students that utilize their CU techniques in classroom.

Development of CU resulted in establishing many teaching strategies and models that are concerned with proper acquiring of concept and correcting wrong or misleading concepts. In this regard, Abu Shaweesh (2021) emphasized that one of the priorities of teaching and learning process, is concerned with employing different teaching models that assist in activating the learners' minds and stimulate their motivation towards investigation and discovery. This can be accomplished by providing opportunities for learners to reflect on the situations, obstacles and problems they face, and to think about generating ideas that enable them to overcome such problems whilst developing their experiences and knowledge-structures by linking the new knowledge with the one they acquired previously.

Among that strategies and models is Driver's model (DM), which is designed and used to correct concepts, to facilitate and enable conceptual-change, and to modify misconceptions based on the learners' interpretations of educational situations and their awareness per previous experiences (Al-Khuzaim, 2019b). Therefore, this research seeks to investigate the effectiveness of DM in developing CU for a sample among intermediate stage female-students.

Significance of the Study

This study represents a scientific material contains the basics of CU in field of mathematics teaching at the stage of intermediate schools as well as presenting an understanding for the relation between the structure theory and DM basics. It also explains the basics of teaching mathematics by DM and how-to-use DM for developing levels of CU.

THEORETICAL FRAMEWORK OF THE STUDY

Driver's Model

The application of the conceptual change approach to mathematics teaching and learning is rather new, although there were research studies during the seventies and eighties. However, mathematics education community has been reluctant to embrace the method of conceptual change that has been developed and used in the context of physics primarily, because mathematics has been traditionally seen as limited (Vosniadou, 2008).

In the eighties, five developments appeared in science-education research at schools: the emergence of alternative concepts among students in the 1980s, the concept of "curriculum focus" (1982-1988), emotional responses by students to specific scientific content (1981-1987), and beyond processes-correlation between the conceptual and practical content in 1987, and the recognition of a general weakness in the content of cognitive sciences for many science teachers in 1986. Roslind Driver and Jack Easley's "Pup as scientist" study in 1983 was one of the studies that inspired the most striking shift of research interest among science teachers for student alternative concepts in the 1980s (Fensham, 2001). Driver became interested in the constructivist movement focused on science education in the 1980s and 1990s (Osborne et al., 1998).

Driver worked on a project focusing on conceptual change that can be achieved through the active construction of meaning by the learner, the development of scientific ideas and concepts by starting with students' own ideas and providing opportunities for modification and construction accordingly (Driver, 1986).

DM, like other models, relies on a constructivist philosophy that is based on learners' interpretations for phenomena, and their understanding of these phenomena per past experiences. Driver pointed out that it is difficult to change in the alternative perceptions that exist among learners using traditional teaching methods (Shehabi, 2020). Driver took seriously the responsibility to improve learners' comprehension at the time it was seen as coherent knowledge of ideas based on past experiences, rather than misunderstandings during the construction of previous ideas. Accordingly, employing DM to encourage learners for changing their ideas and building scientific ideas for themselves. Thus, sequential stages of the model have been developed aiming to promote conceptual change in the classroom (Osborne et al., 1998).

Driver explained the concept of the model as stimulating students about a particular topic, and then discussing their different opinions and testing the possibility of using and applying their opinions (Driver, 1986). According to Driver (1986), it is necessary and useful to develop a model of a constructivist learning sequence. Her model provided a basis for the development of detailed learning plans of a variety of topics. This sequence itself takes various forms while it

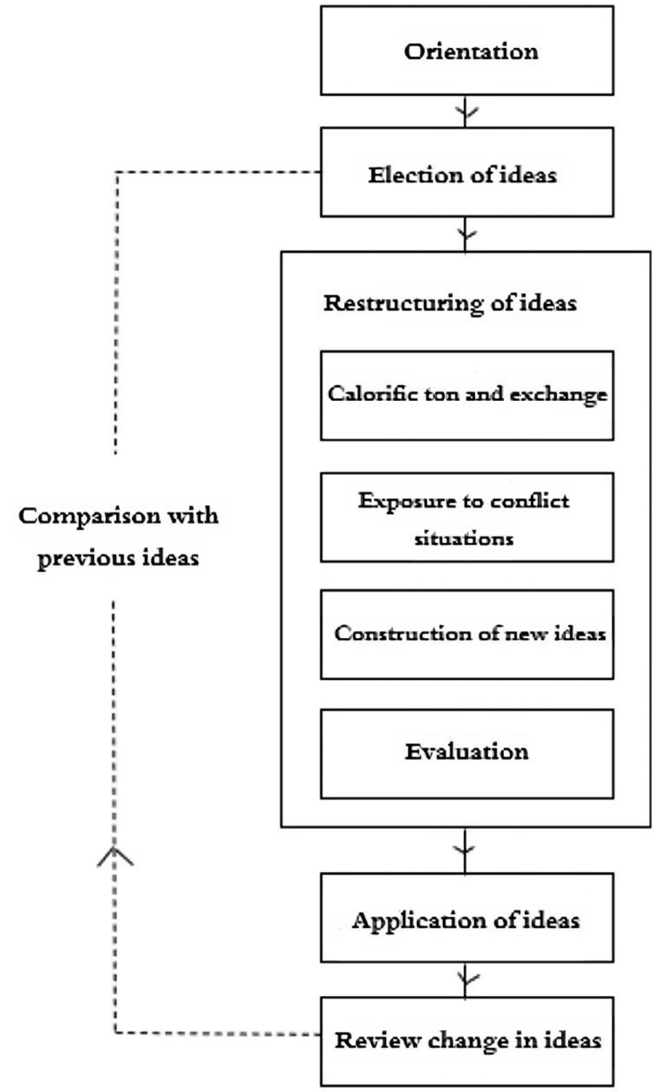

Figure 1. Sequence of phases of DM (Adapted from Driver, 1986, p. 119)

intends to encourage active construction of meaning by starting from the students' own ideas, providing opportunities to build upon, and modifying them towards scientific theory. These forms could be displayed, as follows:

1. Orientation: This stage is designed to give students the opportunity to sense a purpose and develop motivation towards learning the subject of the lesson.
2. Elicitation of ideas: At this stage, students answer questions of their ideas to be presented, they show conceptual errors, then their thoughts move to conscious awareness, i.e., diagnosed, then their thoughts can be checked during a group discussion.
3. Restructuring of ideas: This stage includes several aspects; when the pupils' ideas appear "openly", the opinions are clarified and exchanged through discussion of the questions that were asked to the cooperative groups, and thus the students have the ideas that they use in comparison to alternative views or conflicting ones. This provide them with the opportunity to develop their knowledge, where many ideas to explain or describe the same concept is possible in this case.
4. Application of ideas: At this stage, learners obtain new ideas and are provided the opportunity to use their new ideas in a variety of familiar and new activities. This contributes to unify and enhance new concepts.
5. Review of ideas: Here, questions will be directed to learners allowing them rethink once again about the method of changing their ideas through comparing their answers before and after the lesson.

Figure 1 shows the sequence of phases of DM (Driver, 1986, p. 119). **Appendix A** shows an example of a lesson.

Studies such as of Al-Khuzaim (2019a), Hassan (2019a), Koparan et al. (2010), Omar and Shana'a (2020), and Skane and Graeber (1993) have all confirmed the effectiveness of DM in modifying alternative perceptions in multiple mathematical topics in various places and at different ages.

Conceptual Understanding

National Research Council (NRC) defines this term as an understanding of mathematical concepts, processes, and relationships (Kilpatrick et al., 2001). Syukriani et al. (2017) define CU as the learner's ability to use concepts, rebuild understanding of concepts, and apply them to solve mathematical problems in the classroom and in everyday life. However, Dahlan and Wibisono (2021) define CU as the ability to understand mathematical concepts, processes, and relationships to solve problems, and mathematical problems in everyday life.

It is worth noting that teaching CU is a way to instill a deeper and long-term understanding for mathematical concepts, and thus it is clear that it plays an important role in mathematics concepts learning. Despite the prevalence of CU in the educational literature, defining it and discussing its concept accurately are still a field of study and research, where the main idea is the deeper understanding of learning the concept. There is no clear consensus on a specific definition for this term or the best ways to measure it. The term of CU refers to a wide variety of definitions, but all definitions in consensus that CU is:

- a mental process,
- integrated conception for mathematical ideas,
- acquaintance with the relationships between concepts through their explanation, interpretation, and application,
- solving of mathematical problems, and

- linking previous knowledge with new knowledge.

Accordingly, we can define CU as a mental process that enables the learner to perceive concepts or relationships, and integrate them with the previous cognitive structure, evident from the learner's ability to explain, interpret and apply concepts in different situations.

The above mentioned brings us to the levels of CU, where Wiggins and McTighe (2005) mentioned that there are sequential manifestations that are different indicators for deep understanding levels, which can be measured through:

1. Explanation: The learner's ability to clarify and explain the concept in his/her own way.
2. Interpretation: Where the learner could provide related explanations about the topic and can identify the reasons lead to the desired results.
3. Application: Where the learner could link past experiences and use them in new situations.
4. Perspective: Where the learner could present opinions and form views about the topic based on a correct background knowledge.
5. Empathy: Where the learner could express about others' opinions and could put himself in the place of others, to feel the same feelings and thinking, and to judge the subject per his personal view.
6. Self-knowledge: Where the individual reaches the level of wisdom by knowing himself and his mental habits, so he is aware of his abilities, flaws, and biases in understanding or interpreting any subject.

These levels were also confirmed by Blythe (1998) in addition to many studies that have examined the development of levels of CU at different ages and in various mathematical topics and places, such as the study of Abu Al-Rayyat and Khattab (2020), Al-Janabi (2019), Abu Khatero (2018), Al-Shamrani and Al-Maliki (2021), Andamon and Tan (2018), and Kusumah et al. (2016).

The current study is distinguished by selecting a model based on the modification of mathematical concepts, which is DM, and its impact on development of CU in the module of geometry: polygons at the first three levels (explanation-interpretation-application) for first-grade intermediate pupils in Saudi Arabia through answering the following questions:

1. What is the effectiveness of using DM in teaching mathematics for developing CU at the level of explanation for first-intermediate-class pupils?
2. What is the effectiveness of using DM in teaching mathematics for developing CU at the level of interpretation for first-intermediate-class pupils?
3. What is the effectiveness of using DM in teaching mathematics for developing CU at the level of application for first-intermediate-class pupils?

Study Hypotheses

1. There is no statistically significant variance at the level ($\alpha \leq 0.05$) between the scores mean for the experimental group (students were taught by DM), and the control group (students who taught by the traditional way) in post-application test of CU at the explanation level.
2. There is no statistically significant variance at the level ($\alpha \leq 0.05$) between the scores mean for the experimental group (students were taught by DM), and the control group (students who taught by the traditional way) in post-application test of CU at the interpretation level.
3. There is no statistically significant variance at the level ($\alpha \leq 0.05$) between the scores mean for the experimental group (students were taught by DM), and the control group (students who taught by the traditional way) in post-application test of CU at the application level.
4. There is no statistically significant variance at the level ($\alpha \leq 0.05$) between the scores mean for the experimental group (students were taught by DM), and the control group (students who taught by the traditional way) in post-application test of CU totally.

Study Limitations

This study focuses on polygons module of geometry from mathematics book of the first-intermediate-class. It was applied during the second semester of the year 1441-1442H. In Al-Khobar Governorate of the Kingdom of Saudi Arabia. In the second school in Al-Thuqbah area, the age group of the pupils ranged between (13-14) years old. Both groups, experimental and control groups, were chosen in a simple random manner from the same school, to ensure that the economic, cultural, and social conditions are equal for the pupils of the two groups as much as possible.

METHODOLOGY

The study methodology was an experimental method, where a quasi-experimental design based on the two groups was applied to be suitable for the objectives of this study. The sample was chosen by a simple random method through two groups; one is experimental and the other is control group. The experimental group was taught per DM, and the control group was taught according to the traditional teaching method.

Table 1. Pre-test results

Level	Group	n	Mean	SD	df	Levene's test		"T" value	*
						test value	*		
Explanation	Experiment	31	5.32	2.64	60	0.216	0.6440 NS	0.390	0.698 NS
	Control	31	5.03	3.20					
Interpretation	Experiment	31	3.84	1.70	60	0.101	0.752 NS	1.011	0.316 NS
	Control	31	4.26	1.57					
Application	Experiment	31	4.19	2.70	60	2.057	0.157 NS	1.934	0.058 NS
	Control	31	5.68	3.31					
Total	Experiment	31	13.35	5.46	60	2.658	0.108 NS	0.983	0.329 NS
	Control	31	14.97	7.32					

Study Community

Obeidat et al. (2015) define the research community as "all individuals, people or things who are the subject of the research problem" (p. 109). The current research community consisted of all female students in the first-intermediate-class in a governmental school, in Al-Khobar, during the second semester of the year 1442 AH/1443H, 2,883 students, according to the statistics of Information and Statistics Unit in the Planning and Development Department subordinates to Education Department of the Eastern Region**.**

Study Sample

The study sample is a group chosen by the researcher from the study community relevant to the research (Creswell, 2019). The study sample consists of 62 female-students from the first-intermediate-class at the 2nd school in Al-Thuqbah. The school was chosen by a simple randomly by Education Office in the Eastern region, Saudi Arabia. The total sample number of female pupils was distributed randomly, as follows: (two semesters), where the class (first-2) was chosen to be the experimental group (31 students studying according to DM), and the class (first-3) in the same school to be the control group (31 students study according to the traditional method).

After dividing the research sample into two groups, a pre-test for CU was applied before conducting the procedure of teaching according to DM for the module of polygons of geometry subject aiming to control the variance of the pre-test for the two groups. After the experiment, a post-test was performed to investigate the variance of the two groups performance at the levels of CU (explanation-interpretation-application).

Setting of Variables

It is necessary to adjust the internal variables that may interfere with the independent variable and cause the variance that was measured and appeared from the results of the experiment, Creswell (2019). Such variables are, as follows:

1. **Chronological age of sample members**: the age-group of the female-students in both the control and the experimental groups ranged from (13-14) years old.
2. **Previous experiences**: The researcher investigated whether the factor of previous experiences among the pupils of the two groups was neutralized for parity between the two groups. It was found that all pupils are new, none of them is a repeat pupil.
3. **The nature of the study subject**: The content was the same. Only the difference was in the method of teaching, where the control group studied per the traditional method, and the experimental group per DM.
4. **Research application period**: The study application period was equal for both groups, and the study period for the topics (geometry module: polygons) was four weeks, with six periods per week (six sessions).
5. **Teaching processing:** The subject teacher taught the experimental group (using DM) and taught the control group according to the traditional method, to prevent bias for both groups, and to avoid variables that may affect the results.
6. **The economic and social level:** The two groups were selected in a simple random manner from the first-intermediate-class students at the same school, to ensure that the economic, cultural, and social conditions are equal for the students of the two groups as much as possible.
7. **Verification of parity between the two groups**: CU test was pre-applied to the control and experimental groups, then the arithmetic means, standard deviations and t-test values of the independent samples were calculated, and homogeneity was measured by Levene's test, to identify the significance of the variance between the mean scores of the experimental group and the control group in the pre-application of CU test.

   The results were as in **Table 1**. **Table 1** shows no statistically significant variance at the significance level (0.05≥α) between the mean scores of the two groups per the pre-test at all levels of CU, and at the total score of the test, too , because the values of the significance level (sig.) are greater than 0.05,

Table 2. Results of "T" test & Levene's test in pre-application of conceptual understanding test

Level	Group	n	Mean	SD	df	Levene's test		"T" value	*
						Test value	*		
Explanation	Experimental	31	5.32	2.64	60	0.216	0.644	0.39	0.698
	Control	31	5.03	3.2			NS		NS
Interpretation	Experimental	31	3.84	1.7	60	0.101	0.752	1.011	0.316
	Control	31	4.26	1.57			NS		NS
Application	Experimental	31	4.19	2.7	60	2.057	0.157	1.934	0.058
	Control	31	5.68	3.31			NS		NS
Total	Experimental	31	13.35	5.46	60	2.658	0.108	0.983	0.329
	Control	31	14.97	7.32			NS		NS

which indicates to equivalence between the two groups and their homogeneity before starting the application of teaching according to DM. Accordingly, any change in the post-test can be attributed to the effect of the program, not to the differences of the two-groups abilities.

8. **Verification of equivalence between the two groups:** CU pre-test was applied on the control and experimental groups, then the arithmetic means, standard deviations and T-test values for the independent samples were calculated, and homogeneity was measured by Levene's test, to identify the significant variance between the mean scores of the students of both groups in the pre-application of CU test, and the results were as shown in **Table 2**.

The results in **Table 2** show the followings:

1. For the explanation level: The value of the arithmetic mean for the experimental group was 5.32 with a standard deviation of 2.64, while the arithmetic mean for the control group was 5.03 with a standard deviation of 3.20, which indicates a close convergence in the level of explanation between the two groups, and to find out the statistical variances between both groups, , the condition of homogeneity between the two groups of the study was priorly verified by Levene's test, which value amounted to 0.216, at a level that is not statistically significant (0.466), and that indicates an existence of homogeneity between the two groups, then the "T" test was used for the independent sample, where "t" value reached at 0.390 with a non-statistically significant level (0.698), which indicates that there are no statistically significant variances between the two groups, and also confirms the equivalence between the control group and the experimental group at explanation level of CU test.
2. For interpretation level: The arithmetic mean of the control group was 4.26 higher than that of the experimental group (3.84), while the standard deviation of the level of interpretation in the control group was 1.57 and in contrast (1.70) for the experimental group. A "t" test was made for independent samples, which had a value of 1.011, and a non-statistically significant level (0.316), after verifying the homogeneity of the data using the Levene's test, which confirmed the existence of homogeneity between the two study groups with a value of 0.101, and a non-statistically significant level of 0.752, these results show that there are no statistically significant variances between the two groups, which confirms the convergence and equivalence between the control and experimental groups at the level of interpretation of CU test.
3. For application level: The value of the arithmetic mean for the control group was 5.68, with a standard deviation of 3.31, which is a higher value than that of the experimental group (4.19) with a standard deviation of 2.70. The homogeneity between the two groups was verified by Levene's test with a value of 2.057, and at a level that is not statistically significant (0.157), which confirms the homogeneity between the two groups. Then, a "t" test was made for the independent samples, to compare between the two groups, and its "t" value was 1.934, and the level was not statistically significant (0.058). This result indicates that there are no statistically significant variances between the two groups at level of application, which confirms the equivalence between them at this level of CU test.
4. When comparing the total score of CU test as a whole between the two study groups, the arithmetic mean of all the two groups was very convergent with a tiny preference for the control group that has an arithmetic mean of 14.97 and a standard deviation of 7.32, against an arithmetic mean of 13.35 and a standard deviation of 5.46 for the experimental group. And to verify the existence of the condition of homogeneity between the two groups, Levene's test was used, which had a value of 2.658, at a level that was not statistically significant (0.108) indicating that the condition of homogeneity was met between the two groups of the study. And to find out the statistical variances, and to compare between the two groups, a test was used too "T" for the

Table 3. Values of correlation coefficients between score of each question & total score of test

Explanation		Interpretation		Application	
Question	CC	Question	CC	Question	CC
1	0.451*	2	0.560**	3	0.817**
4	0.625**	5	0.696**	6	0.758**
7	0.854**	8	0.669**	9	0.545**
10	0.863**	11	0.687**	12	0.480**
15	0.783**	13	0.555**	14	0.443**
18	0.771**	16	0.514**	17	0.735**
-	-	19	0.569**	20	0.698**

Note. *Statistically significant at significance level 0.05≥α & **Statistically significant at significance level 0.01≥α

independent samples, which showed that there were no statistical variances between the two groups, as the value of "T" was 0.983, and the level of significance was 0.329, which is a non-statistical level confirms no variances between the two groups, and also confirms a degree of convergence and equivalence between the two groups at the total score of CU test.

Study Tools

The current research requires to investigate the effectiveness of DM in teaching mathematics for developing CU among intermediate school female-students, so the researcher built the research tool (**testing of CU)** and then applied it following three steps:

1. Analysis of the module content of the research by identifying mathematical concepts, and skills included in the content, per stated by Saadeh and Ibrahim (2011), as the mathematical concept is a group of things or symbols that were collected according to the common characteristics or features that can be expressed by code or specific name such as rectangle, triangle, regular polygon. Mathematical generalization is verbal phrases or relationships that link two or more concepts, and it clarifies the relationships that link concepts such as the sum of the internal angles of the triangle, greater than. Skills are the learner's ability to do work quickly, accurately, and perfectly such as drawing a geometric shape and proof of mathematical rules.
2. Defining the behavioral objectives to be measured by specific phrases for obtaining learning outcomes along with defining the relative weights of the objectives.
3. Preparing and applying CU pre-test for the control and experimental groups to verify the equivalence of the two groups. Then, the post-test to compare the performance of the two groups, for finding out the effect of the independent variable (DM) through which the experimental group was taught to reach CU at the three levels (explanation, interpretation, and application) of the geometry module of "polygons" from the mathematics course for the first-intermediate-class in the second semester.

Table 4. Values of correlation coefficients between score of each level & total score of test

#	Level	CC
1	Explanation	0.928**
2	Interpretation	0.919**
3	Application	0.936**

Note. **Statistically significant at significance level 0.01≥α

Table 5. Coefficient of reliability of test

n	Mean	SD	S^2	Coefficient of reliability
30	19.96	9.35	87.42	0.95

Test Validity Calculation

Obeidat et al. (2015) mentioned that internal validity can be calculated by correlation coefficient between each item and the whole test. To calculate the internal consistency validity, the researcher applied the test on the survey sample to find Pearson correlation between the items of the test and the total score for the level, as well as between the score of each level and the total score of the test as demonstrated in **Table 3** and **Table 4**.

Table 3 and **Table 4** show that the correlation coefficient between the items of the test and the total score of the level, as well as between the score of each level and the total score of the test is statistically significant at the level of significance (0.01), and this indicates that the test has a high degree of consistency and applicable to the research sample.

Achievement Test Reliability

Al-Khalili (2012) mentioned that test reliability is "the degree of accuracy in which the test measures what it is intended to measure" (p. 301). For calculating the reliability coefficient of CU test the researcher adopted the Cottr-Richardson equation (KR-21) (Al-Said. 2006, p. 535); the reliability of the test was calculated by the following equation:

$$Coefficient\ of\ reliability\ of\ test = \frac{n-S^2-(n-\bar{X})}{(n-1)S^2},$$

where $\bar{X}$ is the arithmetic mean of the students' scores in the test, S^2 is the square of the standard deviations of the students' scores in the test (variance), and n is the number of test items.

Table 5 shows coefficient of reliability of test. **Table 5** shows that the value of the reliability coefficient of CU test for the mathematics course is 0.95, and this indicates that the test has an appropriate degree of stability and homogeneity, which means that the obtained reliability coefficient gives the minimum test reliability coefficient as indicated by Al-Said (2006).

And after completing the taking of the arbitrators opinions, monitoring the results of the exploratory

Table 6. Results of post-test for two groups related to explanation level

Application & level	n	Experimental group		Control group		"T" value	df	*	η^2
		Mean	SD	Mean	SD				
Explanation level	31	9.52	1.671	6.10	3.259	5.198	44.747	.000	.310

Table 7. Results of post-test for two groups related to interpretation level

Application & level	n	Experimental group		Control group		"T" value	df	*	η^2
		Mean	SD	Mean	SD				
Interpretation level	31	5.94	0.929	4.65	1.762	3.608	45.478	.001	.178

Table 8. Results of post-test for two groups related to application level

Application & level	n	Experimental group		Control group		"T" value	df	*	η^2
		Mean	SD	Mean	SD				
Application level	31	9.58	2.248	5.55	2.706	6.382	60	.000	.404

experiment of the test, ensuring the validity and reliability of the test, and analyzing the items statistically, which confirmed that the test is acceptable in terms of easiness, difficulty and discrimination, the test became ready for application in its final form.

FINDINGS

This part deals with the results concluded by the study through data statistical processes for the study tool post-application, followed by a discussion according to the theoretical framework and previous studies. Below are the results per each hypothesis.

First Hypothesis Results

To verify the validity of this hypothesis, the arithmetic means, and standard deviations were calculated, and the "T" test was used for two independent samples, in order to identify the variances between the mean scores of the students of the experimental group that were taught by DM and the students of the control group that were taught in the traditional method for the post-measurement related to the level of explanation, as illustrated by **Table 6**.

Table 6 shows statistically significant variances at the level (0.01) between the mean scores of the experimental group and the control group in the post-measurement level of explanation, and the variances were in favor of the experimental group with a mean of 9.52, where t=5.198, df=44.747, p=0.000 while η^2=.310.

Second Hypothesis Results

To verify the validity of this hypothesis, the arithmetic means, and standard deviations were calculated, and the "T" test was used for two independent samples, in order to identify the variances between the mean scores of the students of the experimental group that were taught by DM and the students of the control group that were taught in the traditional method for the post-measurement related to the level of interpretation, as illustrated by **Table 7.**

Table 7 shows statistically significant variances at the level (0.01) between the mean scores of the experimental group and the control group in the post-measurement level of interpretation, and the variances were in favor of the experimental group with a mean of 5.94, where t=3.608, df=45.478, p=0.001, while η^2=0.178.

Third Hypothesis Results

To verify the validity of this hypothesis, the arithmetic means, and standard deviations were calculated, and the "T" test was used for two independent samples, in order to identify the variances between the mean scores of the students of the experimental group that were taught by DM and the students of the control group that were taught in the traditional method for the post-measurement related to the level of application , as illustrated by **Table 8**.

Table 8 shows statistically significant variances at the level (0.01) between the mean scores of the experimental group and the control group in the post-measurement level of application, and the variances were in favor of the experimental group with a mean of 5.94, where t=6.382, df=60, p=0.000, while η^2=0.404.

Fourth Hypothesis Results

To verify the validity of this hypothesis, the arithmetic means, and standard deviations were calculated, and the "T" test was used for two independent samples, in order to identify the variances between the mean scores of the students of the experimental group that were taught by DM and the students of the control group that were taught in the traditional method for the post-measurement related to the total score of CU test , as illustrated by **Table 9**.

Table 9 shows statistically significant variances at the level (0.01) between the mean scores of the experimental group and the control group in the post-measurement total score, and the variances were in favor of the experimental group with a mean of 25.03, where t=6.826, df=45.747, p=0.000, while η^2=0.437.

Table 9. Results of post-test for two groups related to total score

Application & level	n	Experimental group		Control group		"T" value	df	*	η^2
		Mean	SD	Mean	SD				
Test total score	31	25.03	3.351	16.29	6.294	6.826	45.747	.000	0.437

DISCUSSION

The results of this study showed that there were statistically significant variances at the level of 0.01, between the mean scores of the experimental group students who studied by DM, and the control group students who studied via the usual way in the post-measurement for explanation level, and the variances were in favor of the experimental group with a mean of 9.52, where(t=5.198, df=44.747, p=0.00, while the value of practical significance for η^2 was 0.310. The results also showed that there were statistically significant variances at the level of 0.01, between the mean scores of the experimental group students who studied by DM, and the control group students who studied by the usual way in the post-measurement of interpretation level, and the variances were in favor of the experimental group with a mean of 5.94, where t=3.608, df=45.478, p=0.001, while the practical significance value of η^2 was 0.178. It also showed that there were statistically significant differences at the level 0.01 between the means of the experimental group students who studied using DM, and the control group students who studied in the usual way in the post-measurement of application level, and the variances were in favor of the experimental group with a mean of 5.94, where t=6.382, df=60, p=0.000, while the value of practical significance for the η^2 was 0.404.

In general, this study showed that there are statistically significant variances at 0.01 level between the means of the experimental group students who studied via DM, and the control group students who studied via the traditional method in the post-measurement of CU test as a whole, and the variances were in favor of the experimental group with a mean reached at 25.03, where t=6.826, df=45.747, p=0.000, while value of practical significance of the η^2 was 0.437.

All these results are found aligned with the current research regarding the effectiveness of DM in mathematics learning such as Al-Khazim (2019), Hassan (2019a), Hassan et al. (2019b), Kobarana et al. (2010), Omar and Shana (2020), and Skane and Graeber (1993).

This study also comes in line with studies that emphasized the importance of developing CU, such as the study of Abu Al-Rayyat and Khattab (2020), Abu Khatro (2018), Al-Janabi (2019), Al-Shamrani and Al-Maliki (2021), Andamon and Tan (2018), and Kusumah et al. (2016). The previous studies revealed that most learners encounter many problems resulting from their lack of CU in learning environments (Abu Al-Rayyat & Khattab, 2020; Abu-Khatro, 2018; Al-Janabi, 2019; Al-Shamrani & Al-Maliki, 2021; Andamon & Tan, 2018; Kusumah et al., 2016). Thus, learners need interventions that enhance and develop their use of CU in learning effectively through learning strategies or models, and this was the aim of this study, which comes compatible to what stated by Shehabi (2020) about the use of DM assistance to diagnose previous concepts and post perceptions along with consolidating the acquired concepts and knowledge.

The current study revealed that the relationship between the steps of DM and CU, where DM begins with guidance, which is the basic stage for evoking it, directing ideas and recalling information previously acquired and linked to the subject of the lesson in congruency with the study of Omar and Shana (2020) who indicated that the stages of DM support conceptual change and develop a deeper understanding of mathematical concepts and information.

The second stage is based on demonstrating ideas that give learners opportunities to clarify their concepts to the teacher and other students, Lonning (1993), which helps to enhance one of the dimensions of CU (explanation) by introducing concepts and allowing learners to express understanding about that concept in their own way. The third stage comes to reformulate the ideas for giving the learners the opportunity to exchange ideas with their groups and build new ideas along with the ability to evaluation, and this helps to develop an application dimension for the knowledge gained in a range of familiar and new activities. Finally comes the stage of reviewing the change occurred to the ideas, which reflects the learners' performance toward concepts acquiring and ideas improvement. Thus, it can be concluded that the use of DM in the learning process is appropriate and has a positive impact, through linking of the model stages and the dimensions of CU.

The results of the study showed a consistent rise in those three components of CU, which practically supports the integration between mental processes and understanding of mathematical ideas along with knowledge of the relationships between concepts through explanation, interpretation, and application, as well as linking previous knowledge with the newly acquired one. This is due to what was confirmed by Kholid et al. (2021) in their definition of CU, and what is included in definition of Jaber (2003) and Tolba (2009).

One of the important conditions for the successful implementation of the phases of DM and the development of CU is to give the learners sufficient time to share and think about their ideas, then discuss them and interact with the group to try to understand and interpret the solution of the activities, discuss them with the teacher, evaluate them and restructure them. Model phases require teachers' consideration and respect for learners' ideas whilst allowing them to continually build knowledge through activities and observation, and to present concepts in a way that stimulates learning. It requires providing an educational environment that encourages thinking, listening, questioning, and supports mutual respect to allow space to exchange opinions and ideas between both learners and teachers. Such attitude allows to clarify misconceptions and provides opportunities for teacher to help learners build correct concepts in their cognitive structure contrary to traditional dominant role of teacher who is seen as a transmitter of knowledge as stated by Al-Khazim (2019), Al-Shehri and Shamakhi (2021), Chadwick (2009), Driver (1983), and Omar and Shana (2020).

CONCLUSIONS

The purpose of the study is focused on developing CU by showing and addressing erroneous mathematical concepts, and interest in re-acquiring them correctly in the cognitive structure of learners along with forming a coherent knowledge structure that helps learners move from one educational stage to another. Accordingly, the study focused on answering the following main question: What is the effectiveness of using DM for mathematics teaching on developing of CU for first-intermediate-class female-students? The results provide evidence that the use of DM for conceptual change facilitates the learning process, and helps to detect misconceptions and alternatives, and acquire them correctly by reforming them. Thus, the study urges teachers to use DM to overcome many of the challenges facing learners in learning mathematical concepts along with providing a supportive educational environment for all, which contributes to develop thinking and concepts, express ideas, and exchange them within groups, whilst applying experiences gained in new situations through activities consider dimensions of CU.

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Ethical statement: The study was approved by the Department of Curriculum at IAU in KSA. The head of the school for the study informed consents were obtained from the students, and their legal guardians.

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

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

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APPENDIX A

Lesson 2: Complementary and Supplementary Angles

Number of classes periods: 3

Learning outcomes

After the end of the lesson, the student is expected to be able to:

- Distinguish complementary and supplementary angles
- Find the measure of the unknown angle
- Write an algebraic equation that represents the sum of the measures of two angles

Teaching aids

Laptop - Google Forms Links - Activities - Geometric Shapes – Pictures

Lesson timeline

1. **Guidance: Activity (1-2)**

Stimulating students' motivation and preparing their minds for the lesson through the following activity:

I ask the students the following questions:

- What does complementary mean in language? The answer is the complete number
- What does supplementary mean in language? The answer is the fullness of the description, type, or manner
- What is the sum of an angle of 25° and another angle of 65°? 90°, which means that the two angles are complementary.
- What is the sum of an angle of 85° and another angle of 95°? 180° This means that the two angles are called supplementary.
- What do these two words (complementary - complementary) idiomatically mean for angles?

Complementary angles: two angles that complement each other to 90°.

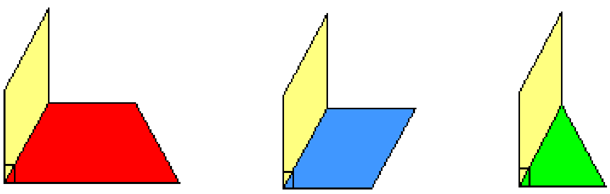
Supplementary angles: two angles that supplement each other to 180°.

2. **Expressing ideas: Activity (2-2)**

Identifying the students’ knowledge background and ensuring its validity by preparing a set of questions about the lesson and asking them to the students, such as the questions shown here or any questions the teacher deems appropriate, and discussing them in a cooperative learning style in the group, where the students are allowed to present their ideas about these questions as in the activity booklet:

Dear student, in cooperation with the members of your group, answer the following questions:

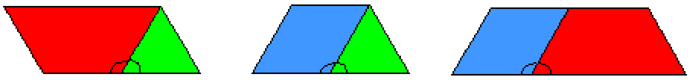
A. What do you notice about the shapes below?



Answer:

- All are 90°.
- Two adjacent sectors of different measure, their summation is 90°.
- The two angles are complementary (the first angle is complementary to the second angle and the second angle is complementary to the first angle).

B. What do you notice about the shapes below?



Answer:

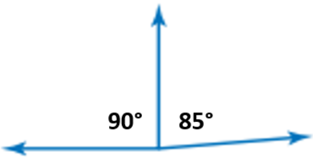
- All are straight angles and 180°.
- Two adjacent sectors of different measures, their summation is 180°.
- The two angles are supplementary (the first angle is complementary to the second angle, or the second angle is complementary to the first angle).

3. Reformulating ideas: Activity (2-3)

The students participate in the collaborative group to clarify the ideas through conducting the activity (3-1) from the activity booklet, which includes the questions that were directed to the students in order answer these questions after correcting their previous idea.

Dear student, in cooperation with members of your group, answer the following:

A. Determine if each of the following pairs of angles is supplementary, complementary, or none:



............none................

...........complementary..............

a. Find s ∠ c if ∠ c and ∠ d are supplementary, and s ∠ d is equal to 115°?

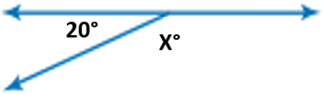
65°-115-180

b. Fill the gaps

We say that the two angles are ..... supplementary ... if the sum of their measures is 180.

We say that two angles are ... complementary... if the sum of their measures is 90°.

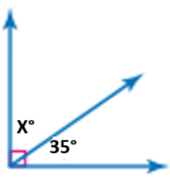
c. Find the value of the unknown angle x in each of the following figures:



Solution: 20°+x= 180°

180-20=x

x= 160°



Solution: 35°+x=90°

90-35=x

x=55°

4. Idea application stage: Activity (2-4)

The student enhances building and formulating new ideas at this stage by using them in new situations. For example, we ask the student to answer the activity (2-4) from the activity booklet in order to make sure that the students apply the new ideas and the ability to employ them in situations and benefit from them.

A. Zaid pitched his tent on flat ground, as shown in the following figure. If the measure of ∠1 = 140°, find the measure of ∠ 2. Explain your answer.

Solution: s∠2=40°, ∠1 and ∠2=180 because they are supplementary angles.

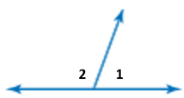
B. Explain the phases of the moon in the picture in front of you when the angle is complementary and when it is supplementary?

When it is Waning Crescent, it is 180° because it is supplementary.

5. Reviewing the change in ideas: Activity (2-5)

Dear student, in cooperation with members of your group:

A. Choose the correct answer using the adjacent figure:



a) ∠ 1 and ∠ 2 are supplementary.
b) ∠ 1 and ∠ 2 are vertically opposite each other.
c) ∠ 1 and ∠ 2 are complementary.
d) ∠ 1 and ∠ 2 are right angle.

B. If angles a and b are supplementary, and s ∠ a = x -10, and s ∠ b = x + 2, what is the measure of each angle?

Solution: s∠a=84°, s∠b=96°.