The Relative Effectiveness of Technology-Based Laboratory Real-Time Graphing on Seventh Grade Students' Graph Interpretation Ability

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ABSTRACT

This comparative study provides insight into the Technology-based laboratory (TBL) regarding the ability of 7th grade students (N = 161) to read and interpret graphs. The study was conducted in a government school in Kuwait during the academic year of 2011. The experimental group of ninety (90) students used TBL with real time graphing aids and the other group of 71 students were given conventional lab instruction (control group). A graph test consisting of 30 multiple-choice questions was constructed to measure students ability in reading and interpreting graphs. Pre-test to post-test design was then applied. A statistical analysis of the results showed that using TBL improved students graph reading and interpretation. In addition, TBL group scores showed students ability in transferring their graphing skills to a different context. The research findings were then discussed.

Introduction

Graph construction, reading, interpretation, and prediction skills are important for the development of scientifically literate individuals. Students are continually involved with representing data and drawing relationships between variables and attempting to quantify these relationships.

The effective use of representations in mathematics and science education has gained more importance as the National Council of Teachers of Mathematics state that representation is a means of acquisition and application using content knowledge (NCTM, 2000). Despite students being exposed to adequate amounts of graphing during their school life, several studies asserted that students of all ages had difficulty comprehending these visual representations (Ouzgan, 2001; Kuwait Ministry of Education Report, 2011; Palaninic, Millin - Sipus, Katic % Ivanick 2012). They indicate that a lack of graphing skills is a limiting factor in grasping scientific concepts.

Researchers,(Adams, & Shrum, 1990; Laughbaum, 2000; Nicolaou, Nicolaou, Zachazia & Constantionou, 2007; Araujo, Araujo, Veit & Moreira, 2008; Ozgun-Koca, 2009; and Planinic et al., 2012), also mention that literacy in graphing does not develop spontaneously and research is needed to determine effective methods of teaching and learning in this area. Educational technology in a supportive learning environment for students appears to engage them in cognitive effort within new learning situations, allowing them to take control of their own learning, reflect on their thinking, make decisions and take associated action.

A computer-based laboratory (CBL) will offer the opportunity to study scientific concepts in different ways. For example, data logging instruments provide user-friendly tools for collecting synchronous and asynchronous data, and to construct graphs for different scientific concepts. Computer software, which effectively integrates numerical and graphical data as quickly as probes attached to the computer can record it, often require technology skills beyond novice level (Martinl, Seytom & Gerlouich, 2001). Real-time graphing may be one of the key elements in assisting students to construct scientific concepts and graphing skills because it provides opportunities for students to connect the production of the graph with the physical manipulation of the materials, and they have control over variables under investigation.

However, in practice, it is not about being able to benefit from the latest instructional technology: numerous factors affect student learning, understanding and achievement. The sources of these factors are embedded in: curriculum and content, instruction and pedagogy, students intrinsic and extrinsic motivation, learning style, students cognitive load, and prior experience with technology and learning environments. Nevertheless, there could be other contributory factors that should be investigated. In general, knowledge about the conditions which affect students learning is far harder to grasp, and a lot more problematic to control. The combination and interaction of scientific concepts, pedagogy and technology have to be considered, and if we know the boundaries between conditions under which one factor should be preferred over the other, we can design instructions more effectively.

Problem of the study

Findings (Brasell, 1987; Mokros & Tinker, 1987; Svec, 1995; Laughbaum, 2000; Nicolaidou et al., 2007, Dori& Sasson, 2008; Ozgun-Koca, 2009; Palaninic et al., 2012) suggested that the use of computational activities could improve the students ability to read and understand graphs. An important aspect was that the students presented more willingness to learn because during the interactions with the computational models they realized the relevance of some mathematical relations and physics concepts, and the concepts that had previously seemed abstract became more familiar and concrete. These results encouraged us to carry out the present research. However; it is essential to consider the science education culture of the research population and subjects. The introduction of TBLs into classrooms started in 1980s in American schools, yet only recently into Kuwaiti school laboratories. The subjects of this research, were being introduced to such technologies for the first time. On the other hand, Kuwaiti students are generally familiar with computer and mobile technology as almost all students have access to it and incorporate it into their lifestyle. However, TBLs, data loggers and related software typically require more than beginner-level computer skills. This encourages us to investigate how CBL real-time graphing enables 7th grade students to read and interpret graphs through activities and techniques that provide opportunities for learning. The research context brings us to two research hypotheses.

Hypotheses of the study

- There is no significant differences between the experimental and control groups pretest mean score in students' graphing ability ($P < 0.05$).

- There is no significant differences between the experimental and control groups posttest mean score in students' graphing ability ($P < 0.05$).

- There is no significant differences between the experimental and control groups in posttest mean score in students' graph reading and interpreting skills ($P < 0.05$).
- There is no significant differences between the experimental and control groups in posttest mean score in students' graph ability within the subject context "heat and temperature" ($P < 0.05$).

Importance of the study

This study is important in that it was conducted at a time when education was taking a quantum leap in terms of new trends in educational methods and practices, aiming at keeping pace with quantitative and qualitative changes in knowledge. In the domain of e-learning, educators are constantly looking for the best theories and methods to help improve the effectiveness and outcomes of education by the following means:

- Verification of the effectiveness of using TBLs in reading and interpreting graphs.
- Drawing the attention of educational process supervisors to the importance of getting students accustomed to using computerized learning skills.
- Shedding light on the combination and interaction of scientific concepts, pedagogy, and technology for more effective design instructions.

Theoretical Framework

All types of representations are being encouraged in teaching and learning, especially in the information and communication era. Graphs can effectively summarize very complex information or relationships. Although graphs are explicitly taught in mathematics classrooms as an end in themselves, many subject areas, such as science or social studies, utilize graphs to represent and interpret relationships. Therefore, being able to construct and interpret graphical representations is a fundamental skill for all students and not just in science and mathematics classes.

The capability of TBL to immediately transform data from each experiment into a graph, or set of graphs, can be considered as one of the most powerful forms of information presentation. Real-time graphing may be one of the key elements in helping students construct scientific concepts and graphing skills and it provides opportunities for students to connect the production of the graph with the physical manipulation of the materials. In addition, real-time graphing provides opportunity for students to modify initiator experimental conditions and variables and immediately see the effect of their modification on the resulting graph.

However, graphs, charts, etc. are meaningless as representations without meditation or analysis. They must be brought into the discussion through the interpretive lens of the student (Kelly & Crawford, 1996). Graphical images of abstract relationships support reflective thinking when they enable users to compose new knowledge by adding new representations, modify old ones and compare the two (Gordon, 1996).

Theoretically, manipulating experiment variables using a relevant sensor, while watching the graph of a scientific concept appear in real-time on the computer screen is assumed to engage a cognitive process. The student's practices are concrete, and appeal to the kinesthetic sense, while the graph is abstract, and appeals to logical thinking. The kinesthetic experience of using the movement or changes in variables as data is linked with the visual experience of seeing graphs of these movements on the screen. By linking the concrete and the abstract, TBL may provide a bridge that facilitates the development of formal operational thinking.

Several researchers (Brasell, 1987; Laughbaum, 2000; Mokros & Tinker, 1987; Nicolaidou et al., 2007) have speculated that experiencing the action of using sensors while watching a graph appear helps the student form a link between the two, and thus transfers the event-graph unit into their long-term memory as a single entity. Immediate abstraction is the result of the process where the student bridges the gap between concrete and formal operations (Adams & Shrum, 1990). Students observing the progress of the experiment can also view the development of the graphical relationship between the variables. Potentially, this provides students with an extremely powerful learning experience, as well as a genuine scientific experience.

Pedagogically, the National Research Council (NRC, 2007) makes several suggestions for how laboratory activities can be changed to improve students scientific skills and understanding: first, laboratory activities need to be more inquiry-based so students can develop practical skills and an understanding of ambiguity and complexity as associated with empirical work in science. Second, students need opportunities to read, write, and engage in critical discussions as they work. Finally, it is important to encourage students to construct or critique arguments and to embed diagnostic, formative, or educative assessment into the instruction sequence. The vast majority (95%) of science teachers believe that computers help students understand physics concepts (Beichner, 1995). Utilizing meta-cognition and constructivism when employing TBL activities very much parallels scientific methods. Most educators assert that inquiry-based and facilitated learning lend themselves to constructivism in the science and mathematics classroom. TBLs employing science teachers have the opportunity to apply theoretical views of learning and develop design models to investigate and demonstrate these theoretical views (Gordon, 1996).

Reviews of the literature have shown that TBL provides opportunities for science. These opportunities include: improved effectiveness, saving student time, immediate abstraction and conclusions, simplifying data analysis, making experimental results more meaningful by allowing students to perceive relationships between independent and dependent variables as the experiment is completed, allowing students to more effectively comprehended abstract concepts, and providing opportunities for developing problem-solving skills (Dori& Sasson, 2008; Ozgun-Koca, 2009; Svec, 1995). It also supports many learning styles, and provides real world experience (Horton, Storm & Leonard, 2004).

The greatest assets of TBLs appear to include real-time graphing, data manipulation, ease of use and accuracy. Implementation is seen as the key to the effective use of a TBL. Techniques for classroom use have included: small groups in rotation, whole class problem solving, and demonstration. Those techniques that most directly involve students using TBLs appear to have the greatest potential for effectiveness. However, Russell, Lucas & McRobbie (1999) state that it is possible that teachers' failure to utilize TBL activities more widely is a result of not recognizing their capacity to bring laboratory activities more in line with contemporary constructivist theories of learning.

There could subsequently be other contributory factors that should be investigated. In general, knowledge of the conditions that impact students learning is currently remote, and learning is therefore difficult to control. If we can identify the parameters of various learning styles and environments, we will consequently be better able to design appropriate and effective frameworks and processes. The reading and interpretation of graphs have become essential skills for students to master in the knowledge era and researchers continue to find grounds and windows for exploration.

Review of literature

Several researchers advocate the use of computers, calculators, TBLs or Calculator-Based Laboratories in improving students' graphing skills. Mokros & Tinker (1987) have studied the effects of computer-based laboratory (CBLs) on students' understanding of graphing. The use of a CBL allows students to collect real-time physical data, such as temperature, motion, light, or sound. The above authors conclude that, in a three-month longitudinal study of CBLs, students showed a significant gain in understanding, although the instruction was targeted towards science topics, rather than graphing skills. They add that CBL may also help children develop graphing skills because it eliminates the drudgery of graph production.

Brasell (1987) hypothesizes that the real-time nature of the graphs produced by CBL equipment was critical to the success of this instruction. She studied the effects of one hour of instruction on four groups of high school students. Brasell found that the standard CBL treatment group significantly out-performed all other groups. She estimates that the real-time feature accounted for about 90% of the improvement that CBL offered over pencil-and-paper instruction. She stated that the appearance of these differences after such a brief treatment (one class period) suggests there is a fundamental difference in the information processing generated by immediate display.

Moreover, Svec (1995) studied students who were enrolled in two physics courses. One class used TBL equipment with motion sensors, while the other used traditional motion laboratories. The study showed that the TBL treatment group students learned more about graphing interpretation, more about motion graphs and gained a greater conceptual understanding of motion, than did the traditional group.

In order to enhance students' understanding of functional and graphical relationships, Sivasubramaniam (2004) compared students' graphing skills in a learning experiment, both with and without the use of computers. The paper concludes that the computer group improved significantly more than the paper group in their graphing skills from pre-test to post-test, while Adams & Shrum (1990) add that CBL activities which present graphs to students in real-time result in educationally significant achievements in graph-interpretation tasks. Hollar & Norwood (1999) used graphing calculators to teach algebra within a graphing approach curriculum focused on real-world situations. They concluded that the students in the graphing approach curriculum showed better understanding of functions than did traditional students.

In the same vein, Ates & Stevens (2003) explored two ways of teaching line graphs and compared the line-graphing skills of tenth-grade students. Two chemistry classes participating in the study lasted three weeks; one group completed a line-graphing unit with computer-supported activities, while the other group completed a line-graphing unit without computer-supported activities. It was determined that there were no statistically significant differences in the mean scores for graphing between the groups. Furthermore, the data collected indicated that there were no statistically significant effects of interaction between treatments and scientific reasoning levels.

Dori & Sasson (2008) conducted a study in a case-based computerized laboratory (CCL) to create a chemistry learning environment that integrated computerized experiments with an emphasis on scientific inquiry and the comprehension of case studies. The research objective was to investigate the understanding of chemistry and graphing skills of high school honors students via bi-directional visual and textual representations in the CCL learning environment. The CCL contribution was most noticeable for those students involved in the experiment who had relatively low academic levels. These appeared to benefit the most from the combination of visual and textual representations. Their findings emphasized the educational value of combining the case-based method with computerized laboratories to enhance students' understanding of chemistry and graphing skills, and to develop their ability in bi-directionally transferring information from textual and visual representations.

Similarly, Araujo et al. (2008) investigated students performance while exposed to complementary computational modeling activities for the improvement of physics learning. The interpretation of kinematics graphs was the physics topic chosen for investigation. The results of this work show that there was significant improvement in the performance of students from the experimental group. Students perception with respect to concepts and mathematical relationships, as well as a motivation to learn originated by the activities, played a fundamental role in these findings.

In fact, Palaninic et al. (2012) state that, in order for learning and knowledge transfer to succeed, both physics and mathematics should focus more on the meaning (interpretation) of graphs. Students need to make sense of graphs during instruction; to discover and discuss their meaning through collaboration with their peers, and if possible, connect graphs with real examples of motion. Linn, Layman & Nachmias (1987) found that TBL instruction in chemistry and the study of temperature, focused on improving graphing skills, and also improved students' ability to interpret graphs representing motion, although motion was not included in the instruction. Apparently, the students' graphical interpretation abilities had improved in ways that were not dependent on the context of the instruction.

Many researchers who have started with more of an interest in applied areas of instruction in graphical interpretation find that TBLs work well, and speculate that there may be cognitive benefits which extend beyond developing an ability to interpret the graphs used in the instruction. In Lehman & Campbell (1991) the use of TBLs in science classrooms was examined through the triangulation of several data sources. Data collected include classroom observations of the use of TBLs, and student graphing performance. On the other hand, quantitative results from one classroom studied show no evidence of the impact of using a TBL on student graphing skills.

Procedures

Design and sample: This research was conducted at a Kuwaiti state sector school. Within the school, participating students were randomly selected from classes. The subjects included 161 7th grade students, divided into 4 classes (90 students) to form the experimental group, and 3 classes (71 students) as the control group. In fact, Kuwait is a small country, with a population size of around one million. The role of the Ministry of Education is to finance and supervise education in the country using the national curriculum in state sector schools. Students are almost completely homogenous in economic, social, culturaland geographic terms. In this case, a semi-experimental method with pre-test and post-test investigation was applied for both groups.

Within each of the experimental classrooms, five groups were formed, and five students per group worked together, each group with a temperature sensor attached to a laptop computer. Computer software created a graph of the temperature change over a period of time. The graph was displayed in real-time and could be stored and displayed on demand. Classroom teachers had the same equipment and could demonstrate the experiment using the sensor while students watched the graph simultaneously being displayed on the classrooms big screen, via a data show projector. Temperature and heat units comprised the curriculum content. The control group received the same instructions and content, without CBLsupport, using a thermometer and pencil with graded paper. The treatment lasted for three weeks. Seventh grade classroom teachers were trained in the use of the hardware and software, integrating a data logger and temperature probes into the science curriculum and lesson plan.

To reduce technical obstacles that could take students attention away from instructional goals, several steps were taken: 1) laptops were kept on standby mode, 2) the data logger icon appeared on screen, 3) a plug and play mode was set as default, 4) a simple graph presented at pre-test was used to figure out the relationship between variables.

Instructional model: For this research, we adapted the model recommended by NRC (2007) to help teachers meet the goals outlined, by providing opportunities for students to design their own investigations, gather and construct related graphs, analyze and interpret data and communicate their ideas to others during structured and interactive discussion sessions. They also wrote investigation reports to share and document their work and engage in reflection during a laboratory investigation.

Instrument: For data collection, a test consisting of 30 multiple choice questions and one correct answer in each instance was administered (1 point for each correct answer). Sixteen of the test items emphasized graph reading ability and fourteen of the test items emphasized graph interpretation skills. Fifteen of the test items were on general content knowledge rather than on temperature and heat. The content validity of the test was checked by three science and mathematics education faculties at Kuwait University, two science teachers, and one science supervisor. The internal consistency of the test was determined by Spearman-Browns method of dividing tests into two halves ($\alpha = 0{,}70$).

Statistical method: Descriptive and analytical statistics were used via statistic package, Spss, v.19 for windows, to provide information regarding the ability of 7th grade students to read and interpret graphs; t-Test was used to research hypothesis and examine means differences.

Results

Before applying the research treatment, a pre-test was applied to all students to examine the equality of the sample groups. The results summarized in Table 1 indicate no significant difference between the control and experimental groups.

Table 1

Table 1: pre-test mean, SD, and the t-Test of significant differences between the experimental and control groups in terms of students' graphing ability

Source	Group	N	Mean	SD	Sig. (2-tailed)
TBL	Experimental	99	10.48	2.82	.097
	Control	71	11.23	2.93	

The experiment was carried out for three weeks, whereby a post-test was applied and data collected and analyzed, in addition to the conduction of a t-Test, to examine the second hypothesis.The results of the analysis are provided in Table 2. The data shows the differences between the two groups with regard to the impact of TBL aids on students graphing ability.

Table 2
Table 2: post-test mean, SD, and t-Test on the significance of differences between the experimental and control groups in terms of students' graphing ability

Source	Group	N	Mean	SD	Sig. (2-tailed)
TBL	Experimental	99	25.5	4.2	.00
	Control	71	22.3	4.45	

According to the data, the mean score of the TBL groups was 25.5 out of 30, and the control groups mean score was 22.3. The t-Test revealed that there was a significant difference in students mean scores, thus indicating the effects of TBL real-time graphing on students graphing skills.

The third hypothesis of the research was that real-time graphic representation would improve students' ability to read and interpret graphs.

Table 3
Table 3: post-test mean, SD, and t-Test for significant differences between the experimental and control groups in terms of students' graph reading and interpreting skills

Source	Group	N	Mean	SD	Sig. (2-tailed)
Graph reading skill	Experimental	99	14.8	2.4	.022
	Control	71	12.2	2.9	
Graph interpretation skill	Experiment	99	12.5	2.1	.035
	Control	71	11.2	2,5	

Findings revealed that amongst the experimental groups (applying TBL), the mean score for graph reading skills displayed a reading of 14.8 out of 16 and the mean score for the control group, was 12.2 out of 16. For graphic interpretation skills, the mean for the TBL groups was 12.5 out of 14, whereas the control group produced a mean score of 11.2 out of 14. The data gathered from the t-Test analysis showed a significant difference between the two student groups regarding reading and interpreting graphing skills and this could support the effect of TBL aids, as indicated in Table 3.

The fourth research hypothesis was that TBL's real-time graphic representation improved students' graphing ability within a context. In this investigation, the graphs related to temperature and heat- the curriculum content.

Table 4

Table 4: mean, SD, and t-Test on significant differences in students' graphing ability within the subject context

Source	Group	N	Mean	SD	Sig. (2-tailed)
Temperature and heat content knowledge	Experimental	99	11.9	2.7	.614
	Control	71	11.4	2,8	
General issues content knowledge	Experimental	99	13.9	2.3	.001
	Control	71	12.1	2.6	

For the experimental group (applying TBL) the mean score was 11.9 out of 15 points, whereas the traditional groups mean score was 11.4, with no significant difference (see Table 4). For graphs that represent general issues, outside the curriculum content topic, the TBL groups scored 13.9 and the control group scored 12.1. Table 4 shows that the mean difference is significant.

According to these results, we can say that TBLs using real-time aids have impact on students learning graphing within the context of curriculum content knowledge. It seems that there were kind of drawbacks arising as a result of shifting to new tools that would impact on students attention to content knowledge " heat and temperature" which consisted several ‘‘declaration knowledge’’ in which working memory and long-term memory are involved in memorizing and retrieving such kind knowledge. This is supported by Russell et al. (1999). We can also say that the students in the experimental groups were focused on the task and learning activities that addressed content knowledge " heat and temperature" and may be were overexcited by the CBL instruments. The equipment eventually had a neutral effect on their approach and hence, did not draw their attention away from the main learning issues, graphing abilities to be used in real context. This interpretation maintained by the TBL groups (experimental) score 13.9 and the control group score 12.1 for outside the curriculum content topics, which mean less loud on working memory and it is contentsfree.

The results of this study tally with findings from Mokros & Tinker (1987), as well as with work by Brasell (1987), Svec (1995), Dori, Yehudit, Sasson & Irit (2008), Linn, et al. (1987), and Palaninic et al. (2012).

Discussion

First of all, it is essential to consider the science education culture of the research population and subjects. Looking into the theoretical framework and the review of the literature, three issues must be taken into account. To begin with, the introduction of CBLs into classrooms started in 1980s in American schools, yet only recently into Kuwaiti school laboratories. However, Alshaya’s (2003) walk around the issue and explore teachers ’and students attitudes towards microcomputer-based laboratories in Saudi Arabia. Secondly, 7th grade students, the subjects of this research, have been introduced to such technologies for the first time. On the other hand, Kuwaiti students are generally familiar with computer and mobile technology as almost all students have access to it and incorporate it into their lifestyle. However, CBLs, data loggers and related software typically require more than beginner-level computer skills. Thirdly, none of the previous research was carried out in the Kuwaiti context.

The result of this study indicates a significant improvement in students graphing abilities in general and specifically in their graph reading and interpretation skills. Moreover, TBL instruction improved students graphing abilities in topics beyond the curriculum content knowledge under study, namely Temperature and Heat. This means that learning environments and CBL help students to transfer their graphing knowledge and skills from one situation to another and link them with a new situation and different context, which is also supported by Potgieter, Harding &Engelbrecht (2008).

Learning environments help students to make sense of graphs during instruction; to discover and discuss their meaning through collaboration with their peers, and if possible, connect graphs with real examples. Otherwise having students engaged in operating and using hardware and software properly would have become an aim in it self.

Cognitively, through neutralizing some factors in the way TBL was introduced, put into use and integrated with instructional technique, most students made substantial links between the concrete and the abstract. It was an appropriate framework and tool for transferring concepts from the topics being explored, to different contexts. It seems that students attention was on graph variables (time and temperature), and they were involved in interpretation, as well as sharing their thoughts within the group, even within the entire classroom.Woolnough (2000) also offers the same explanation while studying how students learn to apply their mathematical knowledge to interpret graphs in physics.

Experiencing the action of using sensors while watching graph displays helps students form a link between the two, and thus transfer the event-graph unit into their long-term memory as a single entity (Brasell, 1987; Laughbaum, 2000; Mokros & Tinker, 1987; Nicolaou et al., 2007). Furthermore, we can say it is beneficial to work with students over a period of time so they can gain experience of CBL and thus develop skills. This would have the side-effect of helping them overcome their excitement at encountering new technology and so enable them to focus their attention on learning concepts and skills.

Recommendations: As students are given more opportunities to apply technology in their regular classroom and laboratory activities, they become more proficient in various computer tools through practice and advance to another level of technology application;

TBL can put information and data readily at hand that not be available in static environment, but we don't want the learning to be overwhelmed by TTL "device" or gadget. This could accrue when teachers carefully merge TTL with effective pedagogy for more student's engagement; Student who are engaged retain more information and able to utilize that information in more sophisticated ways and contexts

Future Research: In-depth investigation using qualitative and quantitative research methods to explore teachers pedagogy, technology, and science content knowledge and skills is needed to establish a science learning environment for the 21st century.

أثر استخدام تكنولوجيا اظهار الرسومات البيانية بصورة آنية في قدرة طلبة الصف السابع على قراءة الرسومات البيانية وتفسيرها

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الملخص

تأتي هذه الدراسة لزيادة فهم أثر دمج تكنولوجيا المختبر في قدرة طلاب الصف السابع على قراءة وتفسير الرسومات البيانية. أجريت الدراسة في إحدى مدارس التعليم العام بدولة الكويت خلال العام الدراسي ٢٠١٠/٢٠١١. استخدمت المجموعة التجريبية (ن = ٩٠) تكنولوجيا تظهر الرسومات البيانية بصورة مباشر مع الوقت الحقيقي، ومجموعة أخرى من الطلاب (ن = ٧١) استخدمت المختبر التقليدية المجموعة الضابطة. تم بناء اختبار الرسم بياني ويتألف من ٣٠ سؤال لقياس قدرة الطلاب على قراءة وتفسير الرسومات البيانية. تم تطبيق الاختبار القبلي، وبعد التدخل التجريبي على المجموعة التجريبية تم تطبيق الاختبار البعدي. وأظهرت نتائج التحليل الإحصائي أن استخدام تكنولوجيا اظهار الرسومات البيانية الآنية ساعد على تحسن أداء الطلبة على قراءة وتفسير الرسومات البيانية، بالإضافة إلى زيادة قدرة الطلبة على نقل الفهم إلى سياقات مختلفة.

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