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THE EFFECT OF PEDAGOGICAL HYPERMEDIA ON ACQUISITION OF SCIENTIFIC CONCEPTS AMONG PRIMARY SCHOOL STUDENTS

Aseel O. Ajlouni[1+]
Suhair A. Jaradat[2]

[1,2]*Department of Curriculum and Instruction, Faculty of Educational Sciences, The University of Jordan, Jordan.*
[1]*Email: a.ajlouni@ju.edu.jo*
[2]*Email: s.jaradat@ju.edu.jo*

(+ Corresponding author)

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ABSTRACT

This study examined the effect of a Pedagogical Hypermedia Environment in the Science Discipline (PHFSD) on the acquisition of scientific concepts among fifth-graders during the 2019–2020 school years. The study adopted a quasi-experimental method with 50 fifth-grade students from a private school in Amman, Jordan, divided into two groups of 25 each. Students were randomly assigned to either a control group that was taught using traditional methods or an experimental group that was taught using PHFSD. A scientific concept test was conducted before and after the Motion and Force unit was taught. The data gathered was analyzed using ANCOVA. The results revealed a statistically significant difference at the $\alpha=0.05$ level between the mean scores of the two groups on the scientific concepts test. Most of the variation (70%) in the fifth-grade students' posttest scores was attributed to the effects of the teaching method. Such positive results affirm that this pedagogical hypermedia environment had a positive impact on the fifth-graders. These findings support the use of a pedagogical hypermedia environment to enhance the acquisition of scientific concepts among fifth-graders in Jordan. The ministry of education and teachers can use these findings to enhance teaching and learning scientific concepts.

Contribution/Originality: This study is one of very few studies that have investigated the effect of a pedagogical hypermedia environment on acquisition of scientific concept among fifth-graders in science discipline. This study fills the gap in the literature and provides evidence for the effectiveness of pedagogical hypermedia in the acquisition of scientific concepts.

1. INTRODUCTION

Educational technology is central to the teaching and learning process. The potential of information and communication technologies to improve education quality in several disciplines has been emphasized by previous researchers (Ajlouni, Seitan, & Aljarrah, 2018; Albalawi, 2018; Aşıksoy, 2018; Sangrà & Mercedes, 2010; Seitan, Ajlouni, & Al-Shra'h, 2020). Researchers have paid extra attention to science education, as this area is recognized by governments as conducive to modern economic progress (Luu & Freeman, 2011). The business community has initiated serious requirements to reform science education to prepare the 21st century labor force (Bybee & Fuchs, 2006). Moreover, students' poor results in national and international science assessments reveal a critical need to improve science education (Kubat & Dedebali, 2018; Martin, Mullis, Foy, & Hooper, 2016; Murray et al., 2009; Winarni & Purwandari, 2019). To achieve this, researchers have utilized different pedagogical methods, such as augmented reality, multimedia, and hypermedia (Murray et al., 2009; Unahalekhaka, Radu, & Schneider, 2019).

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Literature on the conceptual understanding of physics provides evidence that interactive, computer-based modalities could improve student learning (Aksit & Wiebe, 2020). Studies also revealed that learning technologies embedded in curricula are able to foster in-depth learning and help students understand scientific concepts and processes; hypermedia technology is one of these (Yang & Baldwin, 2020). However, for these technology tools to be effective in the teaching and learning process, they must be integrated well.

Hypermedia is a mix of hypertext and multimedia technologies (audio, images, and animation) to produce a web-based learning environment that is rich in media (Chambers, 2020; Tahmasebi, Fotouhi, & Esmaeili, 2019). Hypermedia allows students to access different representations of the content with nonlinear navigation. In this way, they can skip or investigate a topic based on their ability. Hypermedia in a learning environment which must overcome any type of challenges during its design, a few of which are summarized by Ajlouni (2020) as : disorientation in hypermedia space, cognitive overhead, variation in cognitive learning style, and learners' prior knowledge. Researchers have investigated the positive effects of pedagogical hypermedia among students in many educational fields, including mathematics and English education (Agudo, Rico, & Sánchez, 2016; Cueli, González-Castro, Krawec, Núñez, & González-Pienda, 2016). In science education, there is an emphasis on the scientific concepts that assist students' understanding of phenomena (Reif, 1987). Many students find it challenging to comprehend concepts; it is especially difficult to comprehend abstract concepts for students who are in their concrete operational phases, since abstract subjects cannot be experienced directly (Ghazi, Ullah, & Jan, 2016; Unahalekhaka et al., 2019). Previous studies have demonstrated that students from primary school to college age had several mistaken beliefs about physical concepts (Aksit & Wiebe, 2020). The results of international science assessments, such as the *Trends in International Mathematics and Science Study* (*TIMSS*), revealed lacking performance in several countries, including Jordan. The TIMSS results of Jordan in 1999, 2003, and 2007 showed improvement among Jordanian students in science, but in 2011, they revealed a decline (Abanikannda, 2016). Studies have shown that most students in science struggle to acquire scientific concepts as a result of their prior knowledge (Chi, 2013). Studies have found science courses to be inaccessible to several students due to conceptual difficulty, theoretical complexity, and misalignment with students' personal interests or practical concerns (Deboer, 2006). Despite hypermedia's potential in an educational context, the present literature lacks research that investigates its impact on students' acquisition of scientific concepts. The majority of existing studies have scope limited to the effect of pedagogical hypermedia on skills and performance. This research was therefore designed to foster the acquisition of scientific concepts among primary school students in Jordan and examine the effects of a pedagogical hypermedia environment on the acquisition of scientific concepts. This study fills the gap in the literature and provides evidence for the effectiveness of pedagogical hypermedia in the acquisition of scientific concepts. This study seeks to address the following question:

Are there significant (α=0.05) statistical differences in the acquisition of scientific concepts among fifth-grade students based on the teaching method (traditional vs. hypermedia)?

2. LITERATURE REVIEW

Scientific concepts have a vital role in the foundation of scientific knowledge. "Concept" refers to an abstract idea generalized from a particular instance (Spitzer, 1975) scientific concepts aid students in interpreting and predicting phenomena. Understanding of scientific processes is one of the most important aims of teaching science (Al-Doulat, 2017). Present literature on learning concepts concentrates on a two-phase theory: the formation of conceptual knowledge and the development of procedural knowledge (Tennyson & Cocchiarella, 1986). Merrill & Tennyson stated five ways to teach concepts: definitions, expository presentations, attribute isolation, inquisitory practice presentations, and tests. Students may make three types of classification errors if they do not understand a concept well: under generalizations, overgeneralizations, and misconceptions (McKinney, Larkins, Burts, & Davis, 1982). Sufficient acquisition of scientific concepts is an essential condition for solving scientific problems, but

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numerous students have difficulty acquiring them (Chandrasekaran, Silamboli, Gunasekaran, & Sujathamalini, 2020; Gungor & Ozkan, 2017). Study findings have demonstrated that students have difficulty understanding basic concepts of physics, such as the concepts of force and displacement (Erfan & Ratu, 2018). Some concepts of physics are connected to others, as with the interconnections among the concept of motion and the concepts of force and energy, which cause motion (Erfan & Ratu, 2018; Mufit, 2019). This makes physics concepts even more difficult to comprehend. Primary students can solve problems related to concrete things when they are in the concrete operational phase—from 7 to 11 years, according to Piaget's cognitive development theory (Ghazi et al., 2016). Abstract concepts are difficult to conceive at this phase; therefore, Kommers (2004) recommends using groups of metaphors. Erfan and Ratu (2018) stated that the difficulties of acquisition and comprehending physics concepts can be overcome through several methods and strategies in the classroom. As the instruction of scientific concepts has a vital role in the mental development of children and science teaching depends on visual instruction (Chandrasekaran et al., 2020; Lantolf, Poehner, & Swain, 2018) consequently, researchers must integrate technological tools to enhance the acquisition of scientific concepts.

Hypermedia can provide metaphors and simulations (among other examples) to represent content through nonlinear navigation of text, graphics, images, sound, and video (Vin-Mbah, 2018). These multiple representations of the learning material create opportunities for students to experience flexible, realistic views of a topic. Visual representations permit students to investigate spatial perspectives to help them develop a better understanding of physical objects (Schoenmaker & Stanchev, 1994).

Abanikannda (2019) stated that hypermedia is the best media for students and efficient in improving student understanding, especially on abstract concepts. Lu, Wan, and Liu (1999) summarized the significance of hypermedia in education, namely: it is convenient for storing and using information; it is a tool for open thinking; and it permits individuality. Others opine that hypermedia is used in education as an empowering infrastructure for instruments that support learning (Jacobson, 2008) as it is a promising approach for knowledge transfer (De Vries, 2001). It provides opportunities to employ video examples instead of traditional examples based on text and illustration (Lehrer, Petrosino, Koehler, Bransford, & McClain, 1999). Hypermedia helps students understand and recall concepts (Alduwairi, 2018). It develops case-based and problem-centered learning to achieve significant learning outcomes, including deep conceptual understanding (Jacobson & Archodidou, 2000). As proven by the meta-analysis, hypermedia instruction had positive effects compared to the effects of traditional instruction (Yuen-kuang, 1998). Studies have been conducted to develop hypermedia learning environments; such as "Hipatia: A hypermedia learning environment in mathematics" (Cueli et al., 2016), "*Assistência de Enfermagem aos Períodos Clínicos do Parto: A hypermedia learning environment in nursing* (Oliveira et al., 2019) "Alien Rescue: A hypermedia learning environment for science focus on astronomy and space travel (Pedersen & Liu, 2002) and "PHFSD: A pedagogical hypermedia environment for science focused on motion and force (Ajlouni & Jaradat, 2020). On the other hand, Del Río, Sanz, and Búcari (2019) demonstrate the positive impact of hypermedia material on students' mathematics learning, while the research of Liu (2005) found that hypermedia improved science-related knowledge among sixth-graders. Studies in physics revealed that hypermedia enhanced students' problem-solving skills and scientific processing skills (Amin, Haris, & Swandi, 2017; Bunga, Haris, & Swandi, 2019). Studies in chemistry have proven that students exposed to hypermedia instruction performed significantly better and had better academic performance than those receiving traditional education (Abanikannda, 2016; Abanikannda, 2019). Studies in biochemistry found that hypermedia consistently improved biochemistry learning and students' performance (Bayas-Morejón, 2017; Peñafiel, Arrieta, Bayas-Morejón, & Peñafiel, 2017). Thus, literature reveals the positive influences of hypermedia on learning mathematics and sciences. Despite this, there is a lack of research examining the influence of hypermedia on the acquisition of scientific concepts.

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3. METHODOLOGY

This study adopted a quasi-experimental method with two groups. A scientific concept test was conducted on each group as a pretest and posttest. The participants of the study were 50 fifth-grade female students enrolled in a private school in Jordan during the 2019–2020 scholastic year. The age of the students was between 10 and 11 years. The school contained three fifth-grade female classes. Two classes were randomly assigned to the experimental group (N=25) taught with hypermedia; the responsibility of the teacher was reduced to assisting the learning process (i.e., inquiring, answering, and providing feedback, as shown in Figure 1. The control group (N=25) was taught by the traditional method. All students were taught the Motion and Force unit by the same science teacher over a period of eight weeks (18 hours). The independent variable in this study was the teaching method, while the dependent variable was the acquisition of scientific concepts. Approval to conduct this study was received from the Ministry of Education in Jordan.

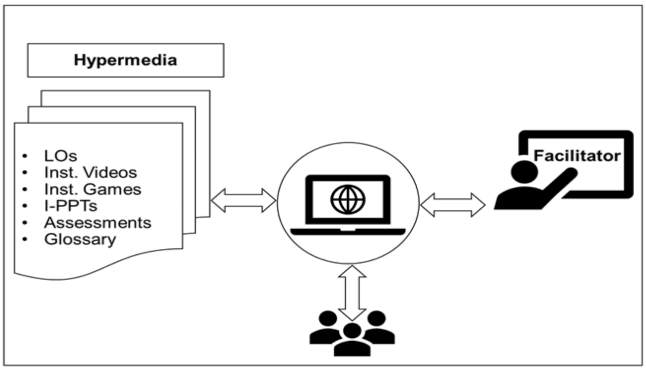

Figure-1. Pedagogical hypermedia environment for the science discipline (PHFSD).

A pedagogical hypermedia environment for the science discipline (PHFSD) was used in this study. This is a tool established to help fifth-grade students acquire scientific concepts. PHFSD has very good quality, is efficient for learning and teaching science, and was evaluated by a panel of experts and a targeted audience (Ajlouni & Jaradat, 2020). It covers the Motion and Force unit with multiple representations that permit nonlinear navigation to accommodate students' learning styles and abilities. It comprises prerequisite, remedial, and enriched material as assessment tools. Each topic includes learning outcomes, instructional videos, instructional games, interactive PowerPoint presentations, assessment tools, and a glossary. PHFSD is hosted at http://www.JSG5a.com and is accessible by the teacher and students at any time, even at home, where students can do quizzes, reflect, and revise material. Inside the classroom, students had access via tablets and Wi-Fi, and they worked collaboratively in groups to complete the activities and worksheets. The Scientific Concepts Test (SCT) developed by Ajlouni and Jaradat (2020) was used to collect the data. It is a reliable and valid tool. The SCT measured students' understanding and acquisition of the scientific concepts contained in the Motion and Force unit. It consisted of 20 true or false questions with test scores from 0 to 20. The Cronbach's alpha coefficient for the SCT was 0.82, the Pearson correlation coefficient was 0.96, and the discrimination index values for the SCT questions were positive and above 0.20. As such, the tool was judged good for the purpose for which it was developed. The SCT was administered to both groups before and after the selected unit.

Descriptive and inferential data analyses were conducted. SPSS software was used to investigate the effect of pedagogical hypermedia on the acquisition of scientific concepts among primary school students in Jordan.

4. FINDINGS AND DISCUSSION

The mean (M) and standard deviations (SD) of the students' scores in the experimental group and the control group were calculated for both pretest and posttest, as shown in Table 1. The mean of the hypermedia instruction

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was higher, as demonstrated by the mean posttest scores; the experimental group's mean score was 15.80, while the control group's was 12.92.

Table-1. Means and standard deviations of fifth-grade students' pretest and posttest SCT scores.

Group	N	Pretest		Posttest	
		SD	M	SD	M
Experimental Group	25	1.93	5.84	0.76	15.80
Control Group	25	1.21	5.72	2.10	12.92
Total	50	1.59	5.78	2.14	14.36

Note. N: number of students in the group.

To decide whether these differences were statistically significant, a two-way ANCOVA analysis was employed, and the partial eta squared (η2) was extracted to investigate the magnitude of the teaching method's effect. The results of these analyses are shown in Table 2.

Table-2. Summary of ANCOVA results for Fifth-grade students' posttest SCT scores.

Source of Variation	Sum Square	Df	Mean Square	F	Sig	(η2)
Pretest	0.001	1	0.001	0.000	0.984	0.000
Teaching Method	103.555	1	103.555	40.614	.000*	0.464
Error	119.839	47	2.550			
Adjusted Total	223.520	49				

Note. Sig: significant, Df: degrees of freedom, and F: F-test.

The value of F (40,614) reveals that there was a significant difference (α=0.05) between the two groups' SCT posttests. As the eta effect (η2) was equal to 0.46, 46% of the improvement in concept acquisition in the hypermedia classroom can be attributed to the hypermedia method. The adjusted means and the standard error of the posttest scores were computed to decide which group was favored by this difference, as shown in Table 3.

Table-3. Adjusted means and standard errors of the posttest SCT scores.

Group	AM	SE
Experimental Group	15.80	.32
Control Group	12.92	.32

The adjusted mean of the posttest SCT scores of the students in the hypermedia classroom was 15.80, higher than that of the students in the traditional classroom (12.92). These results revealed that there was a significant difference in the mean posttest scores of the students taught with and without the hypermedia method. The better performance of the experimental group could be attributed to several factors of the pedagogical hypermedia.

Perhaps the pedagogical hypermedia design had an important role in the improved acquisition of scientific concepts; PHFSD was designed according to constructivist principles and in line with pedagogical hypermedia design guidelines that accommodate the multimedia cognitive theory (Ajlouni, 2020). PHFSD presented information in two modalities (visual and auditory), taking into account the limited space of working memory to decrease the extraneous cognitive load produced by the instructional material and providing opportunities to generate the germane cognitive load (Mishra & Sharma, 2005) this lead to better understand concepts and overcome the challenge of memory overload. PHFSD includes multi-formatted material, such as text, video, animation, audio, and images, to enhance the learning process, especially in the case of complex abstract concepts. This is in line with findings by Evans (2014) that videos can clarify concepts.

PHFSD simulations and animations helped experimental group students grasp physics concepts; this is supported by the research of Swandi, Haris, and Subaer (2015) who demonstrated that hypermedia made understanding abstract concepts easier. In accordance with findings by Swandi, Amin, and Muin (2018) the use of

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computer animation and simulations make physics concept easily understood and enhance student achievements. The pedagogical design of PHFSD overcomes the problem of disorientation in hypermedia spaces by providing guidance and directions. PHFSD offers an active learning environment through activities that explain phenomena using experiences and social context. This helps students realize the scientific truth of an activity by visualizing phenomena and examining the relation between concepts. Doing these activities in small groups using tablets allowed students to engage in their learning tasks and actively interact with the learning materials. These factors accommodated constructivist perspectives that assert " learning is determined by the complex interplay among learners' existing knowledge, the social context, and the problem to be solved (Tam, 2000).

PHFSD's instructional games and videos attracted the attention of students and encouraged them to continue learning outside class. PHFSD materials had several examples and experiences to help students comprehend abstract physical concepts through visual experience during their concrete operational phase (Ghazi et al., 2016). Instructional games also provided a challenging element that actively engaged students and encouraged them to persevere in the learning process, which helped them to acquire the concepts. This is in line with the constructivism assumption that the "learner is actively constructing knowledge rather than passively receiving it from the environment" (Liu & Chen, 2010). Hypermedia support both linear and nonlinear navigation of contents, which permits learners to control where they can skip or expand the material. It gives examples appropriate to their knowledge and understanding, which helps students learn according to their capabilities. This leads to more students understanding and acquiring scientific concepts, as they can access prerequisite, remedial, and enrichment material. The feature of control navigation allows students to organize individual processes that facilitate learning a complex and challenging science topic (Azevedo, 2005; Nakic, Granic, & Glavinic, 2015).

Students can assess their misunderstandings of the concepts themselves by using the assessment tools embedded in the PHFSD, as exercises and quizzes provide immediate feedback. The feedback mechanisms provided by PHFSD, such as cognitive feedback and behavioral feedback, can also be considered a form of co-regulated learning that facilitates learning complex topics. According to Hadwin, Järvelä, and Miller (2018) -regulated learning occurs when the learning environment guides the student's regulatory activities and provides information to students about their success or failure in the learning task at hand through cues and questions. This feedback was provided to students in experimental group through the PHFSD, which helped them improve their understanding of scientific concepts and correct their misunderstandings. Furthermore, the PHFSD supports individual and collaborative learning in which students can control experiments and do worksheets in small groups, as they can access the PHFSD anywhere, at any time. rom the results, it can be concluded that this use of multi-representative material with nonlinear navigation, the PHFSD for learning and teaching science, might significantly improve scientific concept acquisition among fifth-graders in the Motion and Force unit. Consequently, it is suitable to teach science in primary schools using hypermedia instead of the traditional method. The findings of this study support those of previous studies on the effectiveness of hypermedia in science education.

5. CONCLUSION

The importance of integrating technology with learning has been well covered by researchers. Teachers can improve scientific concept acquisition by incorporating technological advancements in their teaching practices. The purpose of this research was to investigate the effect of a pedagogical hypermedia environment on primary students' scientific concept acquisition. The PHFSD is an efficient and very good for teaching and learning science. It covered the Motion and Force topics studied by fifth-grade students in Jordan. The hypermedia environment offered multi-representative content and enabled nonlinear navigation accessible at any time.

The findings of this study demonstrated the significant positive influence of hypermedia on the acquisition of scientific concepts among fifth-graders. It also provides evidence of the effectiveness of PHFSD at communicating scientific concepts to primary students. This pedagogical environment is suitable for teaching and learning science.

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These results may inspire teachers to use hypermedia in their teaching processes to improve students' acquisition of scientific concepts. This research had one limitation: it was solely implemented with female students. This is because male and female students in Jordan are most often separated into different schools due to cultural and religious issues. Regardless, the results of this study provided an indication of the effectiveness of hypermedia to improve students' acquisition of scientific concepts. Forthcoming research could be conducted on male students and students in other stages of education.

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