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Teaching Science with Technology: A Pedagogical Hypermedia for the Science Discipline

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Abstract

This is a research and development (R&D) study presenting the design and development of a pedagogical hypermedia environment for the science discipline (PHFSD) targeted fifth-grade students. It was developed based on a five-development model according to pedagogical hypermedia design, constructivist principles, and science curriculum. The PHFSD is intended to support fifth-grade students learn science, motivate them to learn the subject, enhance their scientific concept acquisition, and prompt their self-regulated learning skills. The PHFSD's quality was evaluated by a panel of experts and implemented on 50 fifth grade students in a private school in Amman, the result reveled that the quality of PHFSD is very good, it is efficient for learning and teaching, and appropriate for the targeted audience.

Keywords*: hypermedia, self-regulation, pedagogical design, scientific concept, motivation.*

I. Introduction

The hypermedia concept dates back to the 1940s (Fraase, 1991), though it first emerged in the early 1980s (Theng, 1999) and was widely accepted across the computer industry, commerce, and education by the 1990s (Yang & Moore, 1995). With technological advancements, hypermedia development requisites have changed significantly over the last 20 years (Hicks, 2019) and became even more common in education (Singh & Kalyuga, 2016). Hypermedia itself is a combination of hypertext and multimedia technologies (Tahmasebi et al., 2019). It primarily refers to computer-based applications that encompass nodes with connected links that present information in the form of multimedia elements (Mirzaeifard, 2018). Hypermedia's non-linear structure allows flexible navigation which facilitates learners' control of information sequences that accommodates different learners' needs (Moos, 2014; Ruttun, 2009).

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The science curriculum has been a popular target of reformers' zeal (Olson, 2017) were scientific concepts have garnered the interest of numerous science educators and researchers because it is the essential structure for permitting the clarification or prediction of many phenomena, scientific concepts are essential as the fundamental structure that permitting the clarification or prediction of many phenomena while some students have had severe problems conceiving them (Candan et al., 2006; Vania et al., 2018). Indeed, the results of the Trends in International Mathematics and Science Study (TIMSS) test revealed science weaknesses among students in many countries, with Jordan among the four countries with the lowest decline in the world in relation to the others in this test (Martin et al., 2016). This weakness in science forms a barrier to higher education and the 21st-century workplace (Liu et al., 2002). The main problem for this weakness is a lack of student interest in the instruction presented in schools (Liu et al., 2002). As Yen, Tuan, and Liao (2011) found a significant correlation between conceptual learning outcomes and students' motivational factors, which are considered the most important factors that educators can target to improve learning (Salih et al., 2016). Therefore, to overcome science learning difficulties, instruction methods alongside student motivation and interest in science must be enhanced.

This research study presenting a design and development for pedagogical hypermedia for the science discipline (PHFSD) to enhance student's scientific concept acquisition, motivation, and self-regulated learning, as well as describe and evaluate the developed hypermedia product that targeted fifth-grade Jordanian students. The rest of the paper is organized as follows: First presents the literature reviews, followed by the methodology that describes the proposed model and the PHFSD then introduces the data collection tools, after that investigates the finding and discussion, finally provides the conclusions.

II. Literature Reviews

Pedagogical Hypermedia

Hypermedia offers multiple representations that are hyperlinked, Yang and Moore (1995) identified some potentials of hypermedia in instruction, including its non-linear information accessing and ability to concentrate learner attention on the relationship of facts, encourage student-centered learning, afford rich and realistic contexts for multichannel learning, and inspire collaboration. Browsing flexibility further allows learners to adapt reading sequences to their cognitive needs for specific information (Kommers et al., 1996).

Pedagogical hypermedia may face some barriers, One such barrier is disorientation, which has a direct and significant negative influence on satisfaction (Çebi & Güyer, 2019), thus affecting goal achievement. This issue arises from the difficulties that learners may encounter in browsing and leads to their loss in the hypermedia environment (Conklin, 1987). This ineffective information access and loss in such a system indicates a problem with two aspects: the first is to know the user's location in the hypermedia, and the second is to discover how to proceed to another point elsewhere in the hypermedia (Çebi & Güyer, 2019). second cognitive overhead that students may meet in hypermedia learning environments occurs due to human working memory capacity limitations, such as when learners concurrently process information represented in hypermedia and schedule a supplemental navigation plan. This requires higher working memory recourses and thus leads to cognitive overhead (Zumbach & Mohraz, 2008). Learner cognitive style can also prove a barrier to the hypermedia learning environment. Learners can have different characteristics, such as field dependent learners who tend to prefer a more restricted interface and follow a linear route and field independent learners who tend to prefer a flexible interface and take non-linear approaches. To overcome this discrepancy, field dependent learners must receive additional support in the hypermedia environment (Ruttun, 2009). Also, The variation in learners' prior knowledge is another barrier, where existing learner knowledge is the most important predictor of future learning. Typically, high-knowledge learners perform better when given more control, while low-knowledge learners perform better when given less control and more navigational guidance (Shapiro, 2008). These four barriers must be taken into account when developing hypermedia learning materials to predict and prevent the possible problems that students may encounter in hypermedia learning systems.

Pedagogical Hypermedia Design

Hypermedia application design varies from system design in that it encompasses user interface information processes and navigational matters (Isakowitz et al., 1995). This renders hypermedia design a challenging process, where there are several difficulties the hypermedia designer has to overcome (Schwabe et al., 1996). Therefore, a number of hypermedia development methods have been proposed by researchers, such as object-oriented hypermedia and scenario-based hypermedia (Lee et al., 1999; Schwabe & Rossi, 1995), but these methods are not always used practically (Barry & Lang, 2001) and this may be attributed to the lack of practitioner awareness about the presence of these methods, the complexities of grasping the proposed design methods and their insufficient examples, the individuals' limited interest in academic articles and conferences, and because there is no method appropriate for all, meaning one cannot be useful generally (Lang, 2002). As well as these methods did not overcome the hypermedia's barriers in the learning context.

Educational researchers have conducted studies to develop an effective hypermedia learning environment that addresses design barriers to achieve learning goals. Mirzaeifard (2018), meanwhile, emphasized some implications that instructional hypermedia designers must take into account, such as learners' differences and including tools based on learning objectives to accommodate a wide range of learning styles and metacognitive reading strategies. Also, Oliver and Herrington (1995) explored instructional issues that developers and designers must consider in designing instructional hypermedia. Theng (1999) discussed how to translate the basic principles of successful learning experiences into a practical design to develop an effective instructional hypermedia. Chen (2002), presented a cognitive model to illustrate how students with different cognitive styles react to non-linear learning within hypermedia programs, and Garzotto, Retalis, Tzanavari, and Cantoni (2004) proposed a design pattern to support learning preferences in educational hypermedia. Moreover, Kumar (2008) provided an overview of instructional design principles to create engaging hypermedia learning environments, which Yamat, Ismail, and Shah (2012) did as well in developing English hypermedia reading courseware to assist students' understanding of scientific and technical terminologies in reading comprehension tests. Singh and Kalyuga (2016) offered recommendations for enhancing the effectiveness of educational hypermedia, and Cueli, González-Castro, Krawec, Núñez, and González-Pienda (2016) presented and described the design and development of a hypermedia learning tool for mathematics to enhance self-regulated learning, specific math skills, and effective problem-solving. Additionally, Vieira (2016) developed a hypermedia application for mathematics and investigated its improvement of students' self-regulated learning strategy use and self-efficacy. Oliveira et al. (2019) also methodologically developed an educational hypermedia for undergraduate nursing students, presenting evidence of expert validation for appearance and content.

Pedagogical Hypermedia and Science Education

pedagogical hypermedia gains the attention of researchers in the context of science disciplines, therefore, the studied were conducted to develop pedagogical hypermedia and investigate the impact of using it on the learning process. For instance, Alien Rescue, a hypermedia problem-based learning were developed to engages sixth graders in scientific investigations, it was designed according to the National Science Standards and the Texas Essential Knowledge and Skills (TEKS) for science (Liu et al., 2002; Pedersen, Liu & Williams, 2002; Pedersen & Williams,2004). Further, Amin and Mahmud (2016) developed a hypermedia learning instrument for physics and revealed that the instrument was valid and reliable, which motivated students to participate in the learning process and improve their problem-solving skills. In addition, Amin et al. (2017) revealed that the hypermedia learning environment in physics improve students' problem-solving skills.

III. Methodology

This methodological research involved the design and development of the pedagogical hypermedia, as well as the evaluation of PHFSD which were conducted by a panel of experts and the targeted audience. First the formal consent to conduct the study was taken from the ministry of education in Jordan, after that the PHFSD was developed based on the proposed Six-D model, and was evaluated by a panel of 11 experts using web-based hypermedia courseware questionnaire developed by Elissavet and Economides (2003), as well as it was implemented on (50) fifth grade female students who enrolled in a al Jama'a school group (JSG) in Amman, in the scholastic year (2020/2019), the students taught the force and motion unit using PHFSD for 8 weeks,18 hours classroom sessions, then, the student experience questionnaire were administrated and completed by the whole students and the collected data were analyzed using SPSS software.

PHFSD description and development

PHFSD was developed to support fifth-grade students in acquiring scientific concepts, motivation, and self-regulated learning. It is hosted at http://www.JSG5a.com and accessible to both teachers and students. it was developed based on the proposed Six-D Model according to Piaget's constructivist principles, a science curriculum of Jordanian ministry of education, and fell in line with pedagogical hypermedia design guidelines proposed by Singh and Kalyuga (2016) and Oliver and Herrington (1995). PHFSD represented content in multiple formats so the learners could navigate the motion and force lessons and their educational items in as non-linear way as needed. The PHFSD had enrichment and remediation plans as well, as it required existing knowledge recall in the students' mental models. First, it provided the LOs (learning outcomes) of lesson, then activated existing knowledge through instructional videos and games, followed by new knowledge which is present to student using activity, interactive presentations (I-

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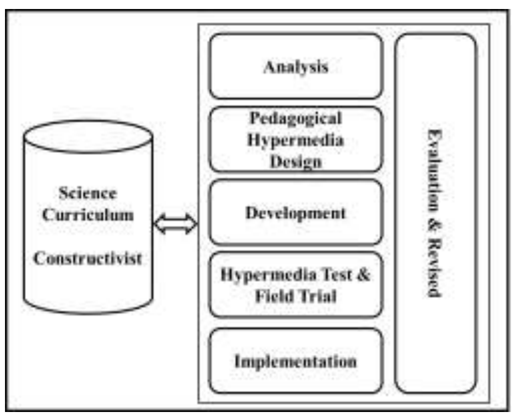
PPT), videos and games, each activity has the LOs of the activity, procedures, tools and working area, it allow students to experiment and test their hypothesis, it based on inquiry based instruction and simulate the concept and learning assessments through worksheets, instructional games, and quizzes that gave immediate feedback once completed. Finally, the PHFSD provided a glossary of terms for the lesson. Between the LOs and glossary, the students could engage in the learning activities' tasks and the educational items in each lesson, skipping or proceeding with items as needed. In general, the PHFSD emphasized scientific concepts in presenting them in a sensory manner using verbal and non-verbal channels, which helped the learners grasp and acquire the concepts, especially concrete ones, The PHFSD presented definitions, examples, and non-examples and highlighted a given concept's characteristics in each I-PPT, followed by practice, assessments, and feedback. The PHFSD could be used in and out of the classroom, and the activities could be practiced in groups or individual, as the e-forms were organized to also work between group members.

It was developed based on the proposed six development (Six-D) model presented in Figure 1. In the analysis phase, the data gathered included students' needs and characteristics which conducted by interviewing science teachers from private schools, science supervisors from the Jordanian ministry of education as well as private schools, and fifth-grade students In addition to analyzed the fifth grader science curriculum for Jordanian ministry of education.

Figure 1: Six-D model

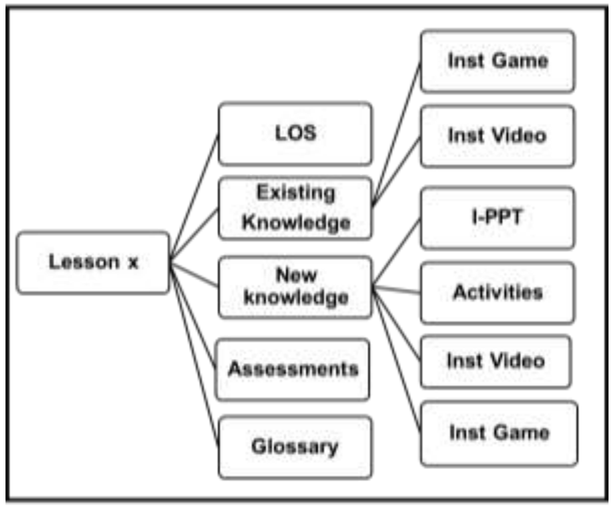


The analysis output phase was situated in a real-world context, and the design phase followed specifications based on the pedagogical hypermedia guidelines Singh and Kalyuga (2016) and Oliver and Herrington (1995). Learner prior knowledge implications and cognitive load theory were also considered, as well as content, text structure, and display presentation, document readability, information fragmentation, navigation, and orientation. The hypermedia itself included individual and group experiences; active learning strategies; constructivist assessments; and activities, support, and feedback. Navigation and interactivity means were set.

Content Organization

The hypermedia database consisted of educational elements related to the force and motion topic, with the content organized into nodes linked together in a network structure. The root node linked to eight parents nodes representing lessons. Each lesson was then linked to child nodes that represented the educational elements that make up the lesson, as shown in Figure 2.

Figure 2. Content organization

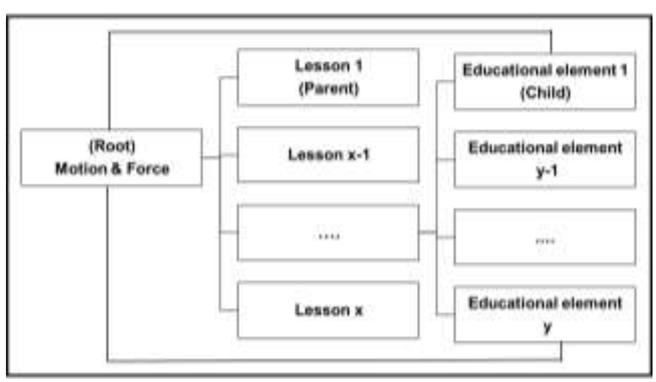


*Where x: number of lessons; y: number of educational elements in a lesson.

Each lesson's content (instructional videos and games, e-activities, I-PPT, and assessment tools) consisted of multimedia elements (image, voice, text, and animation) in addition to a glossary of terms, list of learning outcomes, and URL references. Thus, all the nodes in the system were linked together according to the network structure to allow the students to move between the different lessons and educational elements according to their capabilities. Each lesson involved existing knowledge recall, new knowledge, and enrichment and remediation plans. Figure 3 shows the educational elements of the lesson.

Figure 3. Lesson content (child node)

Screen Layout and Content Display



The main interface design was characterized by simplicity, consistency, and ease of use. For example, when moving between screens, the only thing that changes is content while the options, menus, and buttons remain fixed on the screen with the same design. The screen was also divided into regions specialized by functionality, such as the display area, and the left-hand menu to reduce the unnecessary eye movement. As well as maintaining high contrast between content and the background color.

The content was presented in a similar and homogeneous format to facilitate mental model building. The language used was clear, specific, brief, and simple, with short sentences and plain expressions to reduce memory load and not disturb the learners. The text was displayed and formatted appropriately; for example, wide character spacing and bigger font size were chosen to suit the fifth grade students, and the contrast of the dark text on the light background was also taken into account. Graphics, images, and highlighting methods were used for educational purposes, and Meyer's (2008) principles of multimedia design were considered.

Navigation, Interaction, and Direction

In designing the browsing and navigational methods, the target students' abilities and learning styles were taken into account to reduce cognitive load and student loss in the hypermedia environment. Guidance methods were also provided to accommodate individual abilities and differences for students with lower levels of organization or skills, as well as dependent students.

A search bar was provided on the site to enable students to search for specific content, as was a site map to help students build a mental model for the hypermedia environment. The achievement bar was designed to show the percentage of what each student had accomplished, the required learning time for each item was labeled, In addition to next, previous, homepage, and continue buttons that allow the students to proceed with their learning from where they last finished. A message box for chatting with a teacher also appeared at the bottom of each page. Related, immediate feedback was provided in all instructional games and quizzes.

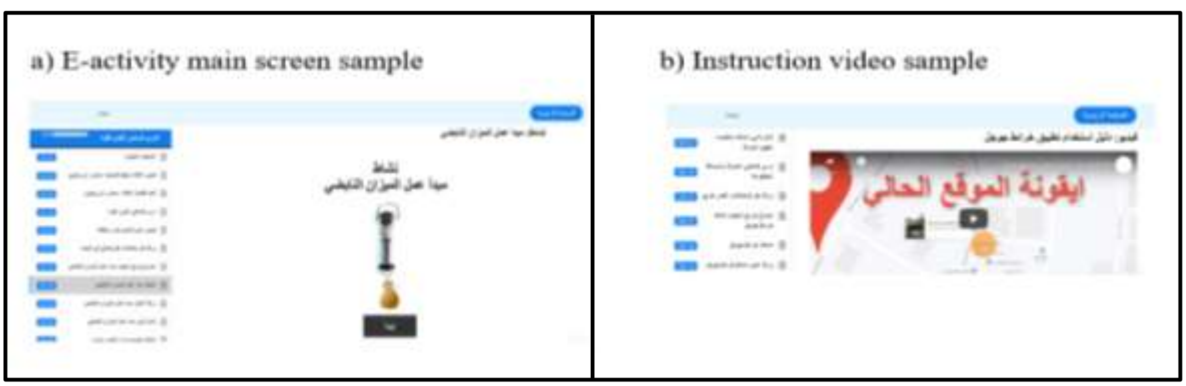
The output of this phase were the script and storyboard that written by translating the outlines of detailed procedures that show what will appear on the screen, these items' location, the sequence of occurrence, and the time intervals between them, plus sound and visual effects and how they appear on screen. Then, the hypermedia website and multimedia objects were developed according to the design specifications using Camtasia, Magisto Video Editor, HTML, PHP, CSS, CMS, as well as a set of plugins, Microsoft Office PowerPoint and Word, Adobe Photoshop, Google Forums (to create electronic forms), and YouTube. Image resolution, download speed, adaption to different browsers and devices, the ability to serve a group of concurrent learners at the same time, propagation time, and availability and privacy were also considered in the production process. The output of this phase is the PHFSD product which is hosted on jsg5a, the domain name for the hosting was chosen as the school name followed by the grade to be easily remembered by students to encourage them to log in and learn at any time they want.

PHSFD Product

The PHSFD homepage have status bars for accomplishments and topic information and buttons and two one for hyperlinked list of lessons and the other for the list of manuals. The learners could access and navigate the full lessons from through the hyperlinked lessons' list which activated by a click, as well as on the left of each lesson in the lessons list appeared the number of educational items that made up the lesson, as well as a status bar colored in orange to help the students see their lesson accomplishments (Figure 4).

Figure 4: Homepage

When the learners clicked on a lesson, a submenu appeared on the left of the screen with links to that lesson's educational elements as the required time to accomplish each item as shown in Figure 5. When a learner clicked on a specific item, the selected item highlighted in gray to indicate the learner's location in the hypermedia, and its content

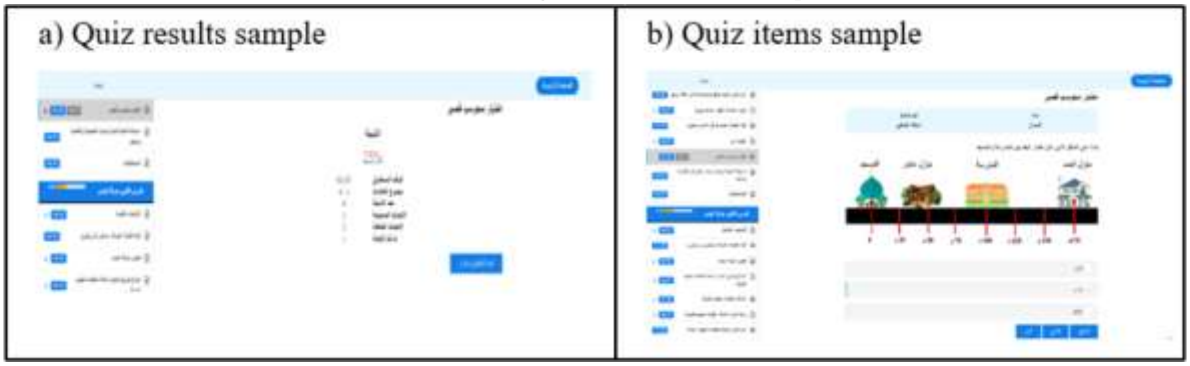


appeared in the display area.

Figure 5: Sample of the lessons' educational elements

Each page had interactive content and was made of multimedia elements. Further, each lesson had a quiz, as shown in Figure 6. Once the students reached the end of the quiz, their results appeared; if a student did not pass the quiz, they were given the chance to repeat it. The students could complete the quizzes whenever they wanted, anywhere and anytime.

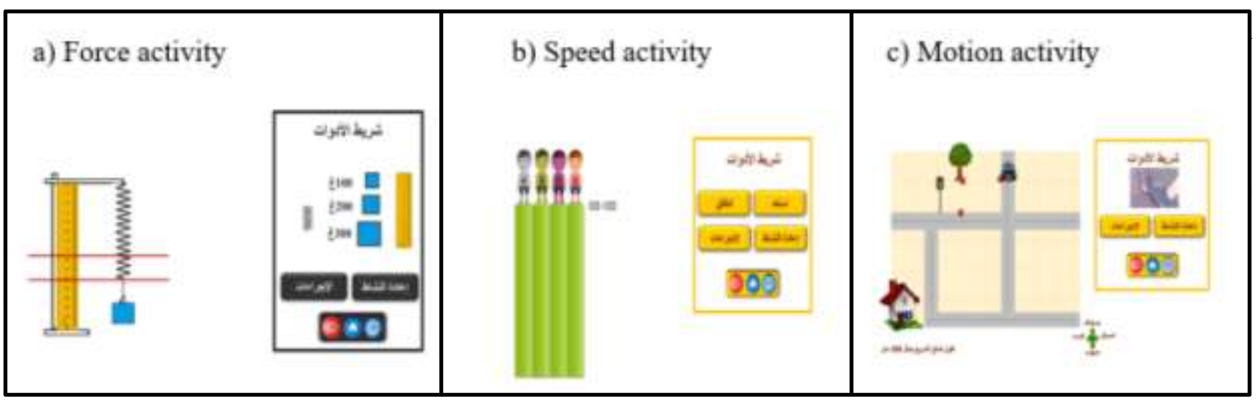
Figure 6: Quiz screen samples



Each activity presented the related learning outcomes, procedures, guidance, worksheet, and reflection form. When a learner started the activity, the display area showed a tool menu on the right-hand side of the screen to control the activity, as shown in Figure 7. The learners could select a tool, stop and restart the activity, as well as skip the procedures, learning outcomes, and guidance.

Figure 7: Activity display area samples

PHFSD Evaluation



motion and force unit using the PHFSD for 8 weeks in 18 hour-long classroom sessions. These students used the PHFSD during the class sessions and from their homes. A web-based questionnaire survey was conducted among the participants after they were taught the motion and force unit to investigate the student experience; all participants answered this questionnaire.

Data Collection Tools

Evaluation Instrument for Hypermedia Courseware (EIFHC)

The EIFHC is a suitability scale questionnaire for web-based hypermedia courseware developed by Elissavet and Economides (2003) to ensure high-quality hypermedia courseware. It is concerned with practical hypermedia acceptability. The EIFHC evaluates content and its presentation and organization, pedagogical parameters, technical support, update processes, design factors, and learning evaluations. For this study, the EIFHC's effectiveness threshold was set to 80% to ensure that the PHFSD was efficient and has high quality of hypermedia courseware.

Student Experience Questionnaire (SEQ)

The researchers developed a student experience questionnaire (SEQ) based on a 4-point Likert scale rated from 1 (*strongly disagree*) to 4 (*strongly agree*) and consisting of 10 items, 3 of which that are negative experience (items 5, 6, and 10), and an open field for comments. The SEQ was administrated to 50 students to assess their learning experience using the PHFSD after they were taught the motion and force unit.

IV. Findings and Discussion

The data were collected through the EIFHC from a panel of experts and showed that the scores for all evaluation factors were above the 80% threshold. This indicates that the PHFSD is an effective instrument for teaching and learning and considered valid according to a panel of experts. Meanwhile, the data from the target audience were gathered using the SEQ and analyzed with SPSS. To calculate the mean of all items, we flipped the response rate for the negative experience items (5, 6, 10) to be 1 (*strongly agree*) to 4 (*strongly disagree*). The mean and standard deviations for each item and all items are shown in Table 1.

Table 1. SEQ means and standard deviations

Items	**Mean**	**Std. Dev.**
1. I was satisfied with the hypermedia's response time.	3.68	0.68
2. The course was more effective with the hypermedia than it would have been without it.	3.80	0.50
3. I was satisfied with the hypermedia's quality.	3.34	0.92
4. The hypermedia enticed me to learn science.	3.72	0.64
5. I had technical difficulties with the hypermedia.	1.60	0.88
6. I had usage difficulties with the hypermedia.	1.32	0.62
7. The hypermedia helped me achieve the learning outcomes.	3.72	0.57
8. The hypermedia content material was adequate.	3.64	0.75

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9.	The hypermedia helped me understand science easily.	3.48	0.73
10.	The hypermedia disrupted my attention while learning science.	1.46	0.71
	Total	3.60	0.33

The student participants' responses to the SEQ measure items averaged between 3.80 and 1.32. The responses to the highest scoring item (*The course was more effective with the hypermedia than it would have been without it*) had a mean of 3.80, while the responses to the lowest scoring item (*I had usage difficulties with the hypermedia*) had a mean of 1.32. The mean of all items was 3.60, with a standard deviation of 0.33.

It was revealed that the hypermedia enticed and supported the students to achieve the learning goals and easily understand science. This is in accordance with Bunga, Haris & Swandi (2019) who found that students easily understood a hypermedia's content and motivated them to participate in the learning process. Ubaidah (2019) noted similar conclusions as well, finding that hypermedia helped students achieve debate competencies.

The SEQ findings revealed that the PHFSD is of very good quality, with efficient response time and adequate content to grasp knowledge, which indicates that the students had a positive experience using it. Further, this tells that the PHFSD was efficiently developed and thus attributed to hypermedia development and design. Moreover, the students' comments showed that they were engaged in their assignments using the hypermedia, and that motivated them to learn science, which aligns with previous results that found that students interested in the display of learning hypermedia simulation were happy to learn with the hypermedia's help (Amin et al., 2017).

In fact, previous research has indicated the need to include some considerations to translate the basic principles for successful learning experience into practical hypermedia material design. These are instructional design, constructivism, minimalism, and human-computer interaction (Theng, 1999), which were all included in the PHFSD. The design guidelines for enhancing the effectiveness of educational hypermedia were also included in the PHFSD (Singh & Kalyuga, 2016; Oliver & Herrington, 1995), which may have contributed to the present findings.

V. Conclusion

The PHFSD is a pedagogical science learning environment in the form of a website for Jordanian fifth-grade students with a pedagogical hypermedia design, constructivist principles, and science curriculum. The product was developed based on a six-D model involving analysis, design, development, test and field trial, implementation, evaluation and revision. The PHFSD was evaluated as an effective tool by a panel of experts based on the EIFHC, a suitability scale questionnaire developed by Elissavet and Economides (2003) to ensure high quality of hypermedia courseware. The PHFSD was also validated by the target audience using the developed SEQ, which is a web-based questionnaire that investigated students' experiences using this hypermedia.

Based on the conducted SEQ, which revealed the PHFSD is of very good quality, efficient and appropriate for the targeted audience, this hypermedia can be used in several schools in the next year. Further, it can be used in classroom sessions or from home, as the activities can be completed individually or in cooperative learning groups.

The PHFSD has just been completed, and the research on employing it has just been started. However, current and upcoming research plans compose investigations on the empirical evidence of this hypermedia's impact on student motivation, self-regulated learning, and scientific concept acquisition.

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