ISSN: 2149-214X

Journal of Education in Science, Environment and Health

www.jeseh.net

The Nested Knowledge System of TPACK: A Case Study on Physics Teachers' Educational Resource Selection and Integration

Bassel Chazbeck, Zalpha Ayoubi
Lebanese University

To cite this article:

Chazbeck, B., & Ayoubi, Z. (2024). The nested knowledge system of TPACK: A case study on physics teachers' educational resource selection and integration. *Journal of Education in Science, Environment and Health (JESEH), 10*(3), 245- 260. https://doi.org/10.55549/jeseh.707

Journal of Education in Science, Environment and Health
Volume 10, Issue 3, 2024 https://doi.org/10.55549/jeseh.707

The Nested Knowledge System of TPACK: A Case Study on Physics Teachers' Educational Resource Selection and Integration

Bassel Chazbeck, Zalpha Ayoubi

Article Info

Article History

Published:
01 July 2024

Received:
30 November 2023

Accepted:
12 April 2024

Keywords

TPACK
Technological knowledge
Pedagogical knowledge
Content knowledge

Abstract

The aim of this research is to explore the system of knowledge of the Lebanese secondary physics teachers that affects the selection and integration of educational resources. This teachers' knowledge was studied through their pedagogical and technological pedagogical content knowledge (PCK and TPCK) concerning instructional strategies, students understanding, curricula, and curriculum materials, including technology that is mobilized in their practice. For this aim, a qualitative approach was employed, and four physics teachers purposefully selected from four secondary schools participated in this study. Classroom observations and interviews were used as research data collection tools. The data analysis revealed that the system of the different teachers' knowledge studied in this research could be seen as a whole, while one system of knowledge was highly related to another. This study, hence, called these consistent knowledge systems "nested knowledge system." This study also showed that this "nested knowledge system" determines teachers' didactical decisions in general and influences the selection and integration of resources in particular. It also revealed that misconceptions are persistent and cannot be changed easily. Moreover, the context of the teaching-learning process reshapes the teacher's knowledge about students' understanding, which is the only knowledge that shows inconsistency between intended and operational practice. In addition, it showed that teachers' knowledge about students' understanding (PCK/U) has a significant effect on teachers' knowledge about curricula and instructional strategies (TPACK/C & TPACK/S).

Introduction

Investigating a teacher's professional knowledge is one of the ways to understand the act of teaching and the objectives of the different activities adapted by teachers in classroom (Sarkim, 2004). Planning and teaching processes are complex activities where teachers should use knowledge from different domains (Chazbeck & Ayoubi, 2018). The education research did not consider the importance of studying the influence of the content taught on the teaching process; it just dealt with the pedagogical knowledge independently (Shulman, 1986a). Shulman was the first in the literature to introduce a new concept where pedagogical knowledge and content knowledge are treated together as one domain of investigation named Pedagogical Content Knowledge (PCK). This concept is also known as content-specific or subject-specific pedagogical knowledge (McDiarmid et al., 1989). The main question of Shulman (1986b) that drove his research was about the essential knowledge of teachers to transform their disciplinary knowledge into effective teaching. Shulman developed a new framework for teacher education by introducing the concept of PCK as the knowledge base for teaching. Thus, teachers must mobilize their pedagogical knowledge (PK) and their content knowledge (CK) in order to introduce.

Nowadays, the proliferation of technologies and their use become an essential element in most domains of human work. In the last decade, research in the field of education focused on technology and not on its usage, which could be attributed to the lack of a theoretical framework that can develop, explain, and understand the process of integration of technology (AAAS, 1999). Nowadays, the integration of technology enables teachers to develop their system of resources to a certain extent and make them easy to share (Webb, 2008). Merely introducing technology in the classroom is not sufficient; teachers should be knowledgeable about how this technology is better used and adapted in order to present comprehensive materials to students. Moreover, the content and the nature of knowledge play a role in the determination of the type of the chosen technology. This progression has changed the routines and practices of the teaching and learning process in the domain of education (Mishra & Koehler, 2006). Mishra and Koehler (2006) developed a new theoretical frame to study the integration of technology in education and the factors affecting it. This framework conceptualized the relationship between technology and teaching. It related the triad of teachers' knowledge about technology, pedagogy, and content in one frame called the Technological Pedagogical Content Knowledge (TPCK).

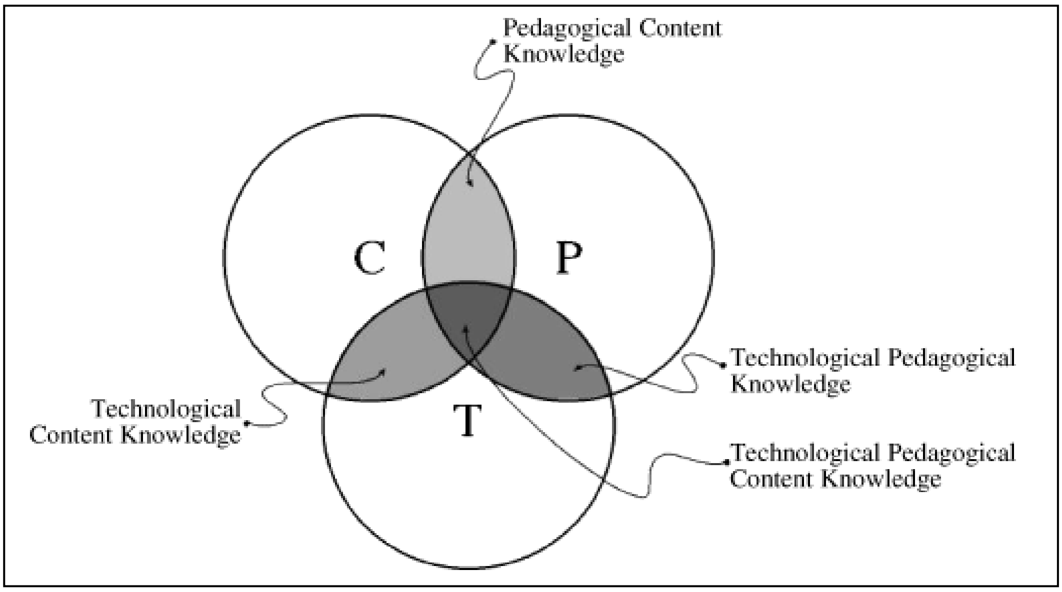

Figure 1. The technological pedagogical content knowledge (Mishra & Koehler, 2006).

Figure 1 shows the new frame developed by Mishra and Koehler, represented by the intersection of three circles presenting the technology (T), the pedagogy (P), and the content (C). However, this relationship emphasized the interrelations, affordances, and constraints between and among the triad of teacher knowledge: the content, the pedagogy, and the technology. Moreover, this frame distinguished between this knowledge and looked at them as pairs: Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), and Technological Pedagogical Knowledge (TPK).

A few research in Lebanon studied teachers' professional knowledge or pedagogical content knowledge (PCK) that affects the selection and the use of available resources. The PCK has become one of the essential elements of investigation in science education and the most affecting factor in the pedagogical decisions of teachers (Chen & Wei, 2015). Therefore, the present study came to fill a gap in the literature in Lebanon about Physics teachers' professional knowledge and its influence on the selection and integration of resources in general.

The selection and the integration of different resources are affected by many factors. One of the ways to study these factors is to explore teachers' professional knowledge through their PCK. Moreover, some of the resources used are digitals and require some technological skills. Thus, this study attempts to investigate teachers' technological knowledge through the investigation of their TPCK. This research aimed to investigate teachers' professional knowledge, particularly their pedagogical content knowledge (PCK) and technological pedagogical content knowledge (TPCK) that affects the selection and integration of educational resources. For this purpose, this study intended to answer the following questions:

1. What are the secondary physics teachers' PCK and TPCK that directed their documentary work on the available educational resources?
2. What is the difference between the intended practices and the operational practices in teaching electricity in terms of teachers' PCK and TPCK?

Theoretical Background

The aim of this study is to investigate teachers' pedagogical and technological content knowledge (PCK and TPCK) that affects the selection and integration of different resources in the professional work of secondary physics teachers. Educational resources include everything that can be selected by the teacher and help him to present his course to enhance students' understanding, and it exceeds the material resources to cover human resources, social and cultural resources, and time (Adler, 2010). In this study, the resources are divided into two categories: the material resources (MR) and the non-material resources (NMR). Moreover, they are distinguished between object resources (OR), audio-visual resources (AVR), paper resources (PR), and evoked resources (ER) (Chazbeck et al., 2018).

Teachers' knowledge, or simply "knowledge," formed the subject of much research in the field of education for many years. This word took many forms in the literature and carried different definitions, including several components. Shulman differentiated several types of teachers' professional knowledge and introduced, for the first time, the notion of pedagogical content knowledge (PCK), and he categorized PCK into two main categories: knowledge of teaching strategies and knowledge about student difficulties. These two categories are based on the strategies and methods used by teachers to build and present disciplinary content, taking into consideration the misconceptions of students and their learning difficulties. The debate on the categorization of PCK and the nature of knowledge that constitutes it remains unclear. From the literature, scholars distinguished many components in the system of knowledge constituting the PCK; some of them were similar, while others were different (Park & Olivier, 2008). These components varied between students' understanding, instructional strategies, and many other components about assessment, media, curriculum, context, pedagogy, and subject matter. Indeed, the views of researchers differed about the categorization reference components of PCK while they all argued about the importance of PCK in the field of education. This importance is manifested in teaching as a whole, teachers' preparation programs, studying teachers' professional knowledge, enhancing the learning process, etc. The commonly argued definition of PCK is the needed professional knowledge for teachers to link their pedagogical knowledge to their disciplinary knowledge in teaching specific content for particular students in a specific context.

What makes the categorization of PCK in science education difficult is the inconsistency of research on it (Abell, 2007). Kind (2009) suggested that among the various models of the categorization of PCK, the model of Magnusson et al. (1999) is best adopted to characterize the work of science teachers since it includes the best needs of the scientific training of teachers. In physics education, Sarkim (2004) and Cross (2009) adopted the model of Magnusson to study secondary teacher's professional knowledge. This model distinguished five components of knowledge: *knowledge of science curricula, knowledge of instructional strategies, knowledge of students' understanding of science, knowledge of assessment of scientific literacy, and orientation towards teaching sciences.*

In the 21st century, technology has become a very important domain that affects the majority of professional domains, especially in the field of education. For example, Computer Assisted Teaching (CAT) in science has become affordable to a larger population. By using CAT, physics teachers may enhance visual characteristics in teaching specific topics (e.g., radioactivity, complex motions, electricity...) with less effort using available wizards. In addition, using technology in teaching physics requires teachers' skills in technology. Therefore, for teaching specific content using technology, teachers should be knowledgeable of the content itself, the general pedagogy, and the technology. Thus, by referring to the PCK conceptualization, scholars develop another domain of knowledge called "*Technological Pedagogical Content Knowledge*," or TPCK.

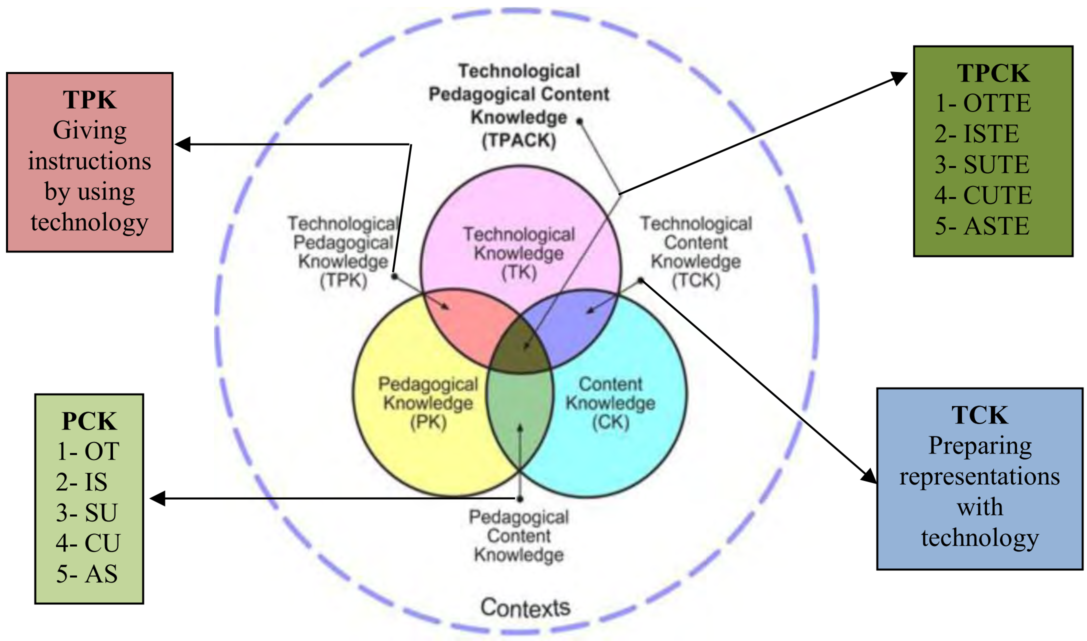

Figure 2. An expanded model of TPCK (adapted from Koehler and Mishra, 2006; conceptualization of TPCK (Magnusson et al. 1999)

According to Graham et al. (2009), when a teacher knows how technological tools transform pedagogical strategies and content representations for teaching particular topics and how it affects student's understanding, then TPCK is achieved. Extending Grossman's (1990), Niess (2005) proposed that teachers exhibit TPCK when they overmatch teaching particular subject for particular students by integrating particular technology to enhance students' learning. Therefore, the teacher mobilized TPCK mainly when he built a convenient strategy using a specific technology to teach particular topics from the curriculum of a specific discipline to enhance students' understanding of learning specific topics. Thus, TPACK covered the components of PCK with a specification of using a specific technology.

Figure 2 shows an expanded model of TPCK, developed by TaȘar (2010) and based on the work of Magnusson (1999) and the model of Mishra and Koehler (2006). This model conceptualized the TPCK by: *Knowledge of instructional strategies and representations for teaching specific topics with technology* (ISTE); Purposes and goals of teaching *specific content using technology (OTTE) (Orientation to teaching with technology); of students' understandings, thinking, and learning with technology in a particular subject* (SUTE); *Knowledge of curricula and curriculum materials that integrate technology with learning* in the subject area (CUTE) and *knowledge of assessment with technology* (ASTE).

Indeed, during their professional work, teachers were expected to facilitate students' learning of a specific concept. Therefore, they should be aware of the typical students' learning difficulties and misconceptions related to specific content. Furthermore, students might also have trouble with teaching strategies adopted by teachers. Therefore, to help students overcome their difficulties at several levels (content or teaching strategies), physics teachers were expected to develop their teaching by selecting appropriate strategies in order to promote students' understanding of specific physics content. Then, they should be knowledgeable about the specificity of the content, the objectives of the physics curriculum, and the teaching strategy that can enhance learning of specific content. Thus, special attention goes to three components of PCK among the five proposed by Magnusson et al. (1999): PCK/students' understanding, PCK/curriculum, and PCK/teaching strategies. Two of these categories (PCK/understanding and PCK/strategies) that Shulman called the knowledge base for PCK (Shulman, 1987). In addition, the corresponding TPCK related to these three categories are TPCK/ISTE, TPCK/CUTE, and TPCK/SUTE. The third component about students' understanding, thinking, and learning with technology consists of knowledge about students' learning difficulties in using technology. However, this component is not explored in this study because it is not related to any of its objectives.

Thus, professional knowledge was divided into two categories: PCK and TPCK. In turn, teachers' PCK was divided into sub-categories, which are the strategies of teaching (coded by PCK/S), the students' understanding (coded by PCK/U), and the curricula and curriculum materials (coded by PCK/C). TPCK was also divided into two sub-categories about teaching strategies using technology (coded TPCK/ST) and curriculum materials using technology (coded TPCK/CT), as shown in Figure 3.

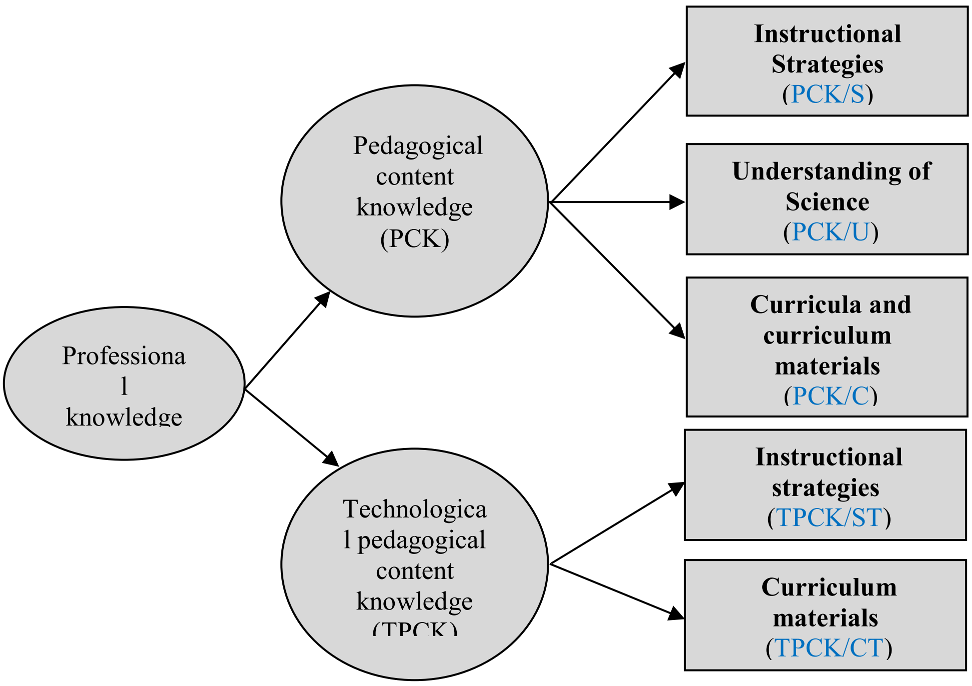

Figure 3. Categories and sub-categories of the theme "professional knowledge, K."

Figure 3 shows the system of teachers' professional knowledge (K) inspired by the model of PCK developed by Magnusson (1999) and that of TPCK developed by Mishra and Koehler (2006). From these two models, five components of knowledge were identified as crucial for this study: PCK/U, PCK/S, PCK/C, TPCK/ST, and TPCK/CT. In this study, the differentiation between PCK/S and TPCK/ST is not primordial since the main objective is to study the inferred knowledge behind the selection and integration of educational resources. Thus, these two sub-categories will be combined into one only named the total package of pedagogical and technological knowledge related to the instructional strategy with or without using technology denoted by TPACK/S. Consequently, the total package of pedagogical and technological knowledge related to the curriculum material with or without using technology is denoted by TPACK/C.

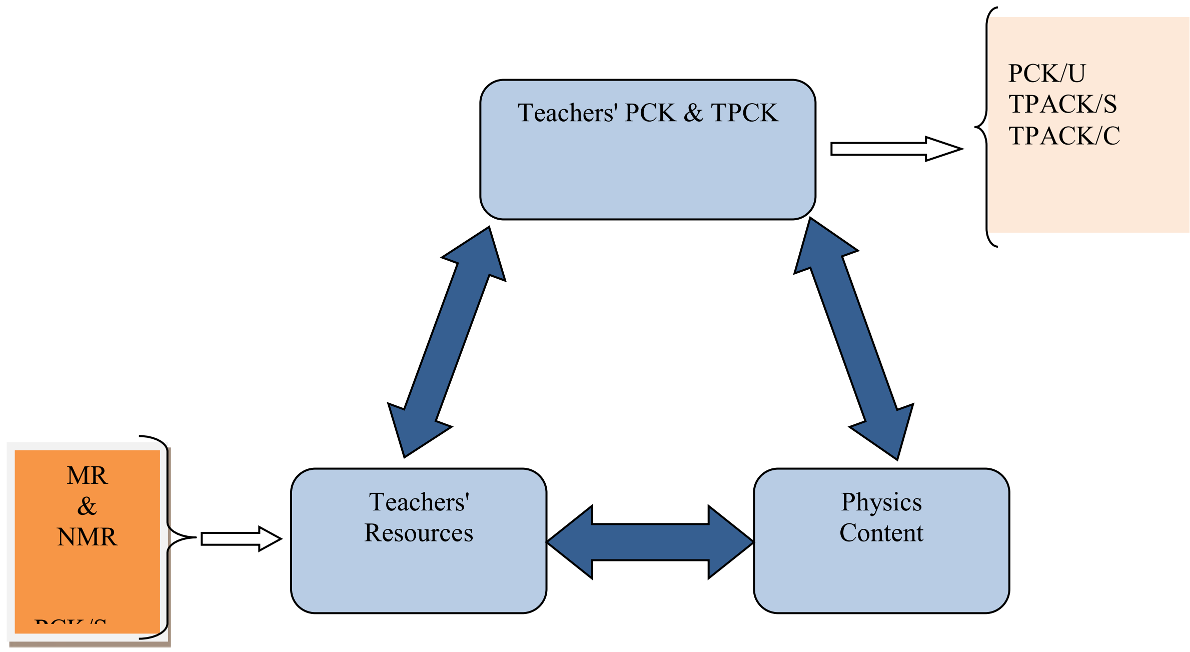

Figure 4. Schematic representation for the theoretical framework

In summary, this study focused on the secondary physics teachers' professional knowledge (K) through their *pedagogical content knowledge* (PCK) and their *technological pedagogical content knowledge* (TPCK) that drives their choices for the educational resources and its integration into their professional work. To explore this knowledge and the selected resources, the researchers referred to the concept of PCK (Magnusson, 1999) and TPCK (Mishra & Koehler, 2006) in addition to the categorization of resources developed by Chazbeck *et al.* (2018). Figure 4 presents the three parts characterizing the theoretical framework of this research, which are interrelated: the resources, teachers' PCK and TPCK, and the content included. The analysis of the content included in the usage of a resource characterized the objective of the use of the resource as an interaction with the professional knowledge of the teachers (PCK and TPCK).

Method

Research Design

This research is designed to investigate secondary physics teachers' technological pedagogical content knowledge (TPACK). More precisely, it permits the researcher to explore the systems of teachers' professional knowledge that drive their work on the educational resources in their teaching in general and particularly for teaching electricity. The setting and the participants of the research were selected purposefully.

Participants

The participants were four secondary physics teachers at Lebanese private and public schools. These teachers were selected based on some specific criteria related to their teaching experience, their proficiency in using educational technology, and their school settings. The four teachers selected for in-depth investigation were given the pseudonyms Albert, George, Pascal, and Curie. Two of them are beginning teachers; they have less than ten years of teaching experience, and the two other participants are in mid-career, having more than 15 years of teaching experience.

The four teachers worked in different schools with different levels of equipment. They had different profiles, but they all believed in the importance of educational technology to enhance students' understanding, and they all taught secondary classes. Table 1 shows a comparison between the different profiles and work environments of the selected participants.

Table 1. Teachers participating in the research

Name*	Diploma	Teaching experience	School' setting
Pascal	BS+TD	Eight years	Poor
Curie	BS+TD	Seven years	Average
Albert	BS	18 years	Good
George	BS	22 years	Average

* Pseudonyms

Data Collection Tools

The data was collected purposefully through semi-structured interviews and classroom observations. The interviews and the classroom observations helped the researchers to investigate the intended and operational practice of secondary physics teachers in general and the use of educational resources in particular. All the interviews and the observations were recorded or videotaped, then were all transcribed and checked again by the participant to ensure the exactitude of the collected data.

In this study, semi-observation is employed where the observer does not use a particular instrument, such as a checklist. The purpose of the classroom observations was to observe the teaching activity and the integrated educational resources in the setting (Patton, 1990b). Video recordings of observed sessions enabled the partial reconstruction of the studied situation and allowed the viewing and reviewing of videotapes. Additionally, it allowed them to observe verbal and non-verbal interactions between students and teachers (teacher-student, student-student). In order to clarify the overall picture of the teaching-learning process, notes and reflections were taken excessively during classroom observations. The researcher observed the activities (Fraenkel & Wallen, 2000) but did not take part in them. Thus, he is said to be the data-collection instrument (Johnson & Christensen, 2008). The length of the observations varied depending on the teaching time observed.

Despite knowing they were being observed, the research participants did not know the purpose of the observations. By using the interview guide approach (Patton, 1990a), the interviews were conducted to explore teachers' opinions and practices about their teaching and how their experiences might inform their current practices. In the data analysis, the forms of PCK used by teachers were extracted from their teaching content and strategies. Researchers also investigated how teachers perceive the teaching and learning process by conducting informal conversations and interviews with them. Analyzing the data using thematic analysis was conducted (Boyatzis, 1998).

Method of Data Analysis

The analysis of the data collected from the interviews and classroom observations was conducted on the basis of criteria inspired by the theoretical framework of this study. The interviews and the videos were first transcribed, and then the discourse was segmented into meaningful analytical units before being coded and categorized into themes. The themes were coded using descriptive words in relation to the objectives of the research (Johnson & Christensen). The main themes in this research in relation to the purpose are the educational resources and teachers' professional knowledge. The resources were categorized into their types: material and non-material resources coded by MR and NMR (Chazbeck et al., 2018).

The material resources included documents, books, copybooks, lab tools, real-life tools, videos, CDs, software, images, etc.) whereas the non-material resources, also called Evoked resources (ER), were examples of natural phenomena, features, or any material situation related to the taught subject that teachers could use it in their professional work. Concerning the second theme, this research aimed to study teachers’ professional knowledge (coded by K) behind the use of diverse resources. In this research, this theme covered teachers' knowledge about the general pedagogy, the subject matter, the curricula, the instructional strategies, the students' difficulties, the educational supports, and the educational technology. This knowledge could be viewed as the total package of knowledge (TPACK) called the technological pedagogical content knowledge (Mishra & Koehler, 2006). This knowledge is categorized into three main categories: knowledge about students' understanding (PCK/U), knowledge about curriculum including technology (TPACK/C), and knowledge about instructional strategies including technology (TPACK/S).

The criteria of analysis of the declarative and operational knowledge in terms of teachers' TPACK are inspired by Cross (2009) and the model of Magnusson (1999). The inferred TPACK/C is divided into three main categories: knowledge about the different resources that can be selected and integrated into teaching, knowledge about educational technology, knowledge about the objectives of the physics curriculum, and knowledge about the other interrelated curricula. The criteria to infer PCK/U covers the mathematics students' difficulties in solving problems, difficulties in learning scientific concepts, and students' difficulties in the application of scientific concepts in real life. However, the criteria to infer TPACK/S are related to the main characteristics of instructional strategies applied to present physics content.

In order to study the main system of knowledge affecting the selection and the integration of educational resources, a comparison between the inferred PCK and TPACK about students' understanding, curriculum, and instructional strategies is made. This helps the researcher to understand which system of knowledge drives the didactical decision of the teacher concerning the relevant resource to present specific content in an understandable way. Moreover, the comparison between the inferred PCK and TPACK from the declarative data (interviews) and operational data (practice) permits the researcher to study the role of the context of the teaching/learning process on the teachers and their pedagogical decisions.

Results and Discussion

In this section, the researcher presents the findings from the analysis of the interviews and the classroom observations in terms of teachers' TPACK behind the selection and the integration of pedagogical resources. Moreover, the analysis aimed to study the difference between the intended practice (declarative knowledge from the interviews) and the actual practice (operational knowledge from the classroom observation) in terms of teacher's TPACK. The analysis of data collected from the interviews and the classroom observation in terms of teachers' TPACK behind the selection and the integration of pedagogical resources corresponds to three main categories of knowledge related to students' understanding (PCK/U), the curriculum material (TPACK/C) and instructional strategies with or without using technology (TPACK/S).

Table 2. List of most common inferred teachers' TPACK/C

Categories	TPACK/C
Knowledge about NMR and MR	1. Teachers know the objects from real life, and students' pre-knowledge permits them to introduce and define an electric generator and receiver. Explain or clarify a law. 2. Teachers know relevant examples from students' everyday real life (battery, motor, electro-dynamic flashlight..., etc.) that they can evoke to illustrate the principle of conservation of energy relative to generators and receivers. 3. Teachers know that there are visual educational aids (e.g., videos, software, phone applications...) that they can use for specific physics content (e.g., electricity, radioactivity, astronomy...).
Knowledge about different curricula	1. Teachers know what students have as pre-knowledge from previous classes about the unit of electricity in general. 2. Teachers know different physics books of different levels and from different educational systems that they can use in relation to specific content.
Knowledge about the objectives of the curriculum	1. Teachers know the objectives of the Lebanese physics curriculum of teaching the chapter on generators and receivers in grade ten. Find exercises and problems. 2. Teachers know the curriculum of chemistry in grade nine related to electric generators and receivers and can serve them to illustrate the principle of conversion of energy.

Table 2 shows the most common TPACK/C inferred from the individual analysis of the four case studies. It reveals that teachers are knowledgeable about the vertical curriculum and its objectives, in addition to the availability of materials and non-material resources (MR and NMR) related to specific physics content and its application in real life. Furthermore, it also shows that teachers are knowledgeable about technology and its integration in the field of education and its importance for some specific content.

The cross-case analysis in terms of TPACK/C shows that teachers who are knowledgeable about the applications of many physics principles in real life refer mainly to the evoked resources and the real-life objects to introduce many physics content. Moreover, their knowledge about the availability of some simulation software or videos permits them to illustrate some particular physics content (astronomy, radioactivity, etc.) and to help students overcome their learning difficulties. However, George, who did not use any object or visual resources and who has more teaching experience than the other three cases, showed more proliferation in SMK (subject matter knowledge) in his teaching. He was the only one who could explain that there is no distinction between the theoretical and experimental value of the open circuit voltage. Moreover, he explicitly presented some extra knowledge in relation to the taught chapter that could enhance students' understanding.

On the other hand, all the teachers were knowledgeable about the curriculum objectives, and they followed the same divisions stated by the official textbook. Therefore, teachers' knowledge about the available materials in their work environment and their relevance for specific content, in addition to their knowledge concerning the interrelated curricula, affect the selection of the pedagogical resources. Thus, TPACK/C forms one of the basic knowledge behind the selection of specific resources and their implementation in a specific strategy to present specific content.

The knowledge of teachers about the sources of difficulties that students struggle with during their learning process is studied through teachers' PCK/U. The analysis in terms of PCK/U inferred from the interviews showed that the four teachers knew a set of students' learning difficulties related to various physics content. Table 3 shows the most common teachers' PCK/U inferred from the declarative data of the four case studies. These difficulties correspond to different topics in physics, such as the period of oscillations of a pendulum, the time dilation in relativity, the nuclear reaction, the potential difference, the current and the short circuit, the principle of conservation of energy, the term confusion, the electromotive force, and the back electromotive force.

Table 3. List of the most frequent PCK/U inferred from teachers' declarations in the interviews

PCK/U
Students have difficulty understanding that the period of oscillations of a simple pendulum is independent of its mass and its amplitude.
Students have difficulty understanding the principle of conservation of energy.
Due to its abstract nature, the electric current formed a source of difficulty for the students in learning electricity.
Students have difficulty understanding the concept of time dilation in relativity.
Students have difficulty understanding the equivalence of many electric generators.
Students have difficulty identifying series resistors, in particular when they are geometrically parallel in the circuit.
Students have difficulty understanding the meaning of an electromotive force for an electric generator and the back electromotive force for an electric receiver.
Students have difficulty understanding that an electric short circuit puts two or many electric points on the same electric potential.

According to teachers' declarations in the interviews, teacher's knowledge about the sources of learning difficulties came from teachers' professional knowledge and their experience as teachers and as students. Therefore, to help students overcome their learning difficulties or to remove students' misconceptions, they mobilize many types of educational resources. Table 4 shows the most common educational resources selected by the teachers to enhance students' understanding of specific content. Thus, one of the factors that affect the selection of educational resources is the professional knowledge of teachers about the sources of difficulties that students struggle with. Then, PCK/U forms one of the basic knowledge that teachers mobilize behind the selection of resources from one side, and it affects teachers' TPACK/C from the other side.

Table 4. Some educational resources that teachers select in relation to PCK/U

MR and NMR related to PCK/U.
Making experiment using concrete materials help students understand that the period of oscillation of a simple pendulum is independent of its mass.
Using real objects from everyday life, i.e., a battery, a motor, an electrodynamics flashlight, etc., illustrates the principle of conservation of energy in electricity.
Using a video showing a historical experiment of Einstein permits students to understand time dilation.
Using real resistors connected in series but geometrically parallel in the circuit permits students to identify series and parallel resistors.
Using many batteries connecting differently and using a voltmeter clarifies the concept of the equivalence of many electric generators.
Referring to the evoked resources, such as the motor of a domestic water pump, helps students to overcome their difficulty about the meaning of the back electromotive force of a receiver.
Simulation or virtual lab is a way to show how the nucleons go out from the nucleus during nuclear fission.
The projection of a video showing the free fall of a parachute explains the influence of a frictional force (air resistance) on the motion.
Using simulation programs like Phet helps students to understand nuclear fission and fusion in radioactivity.
Using a phone application (i.e., Solar Walk) shows the rotation of the solar system and its period of revolution.

However, the analysis of data in terms of educational resources showed that virtual laboratories and simulations are chosen mainly for astronomy, relativity, and radioactivity. However, when there is a lack of equipment, this type of resource replaces the use of concrete materials in real laboratories for electricity, mechanics, and other topics. Otherwise, teachers declared that real laboratories form the most common way to help students understand physics in a good way and remove their misconceptions. Therefore, teachers' PCK/U led them to find specific support and specific strategies to overcome students' learning difficulties in teaching specific physics content. Thus, many of the teachers' TPACK/S was based on their PCK/U, and then many resources were mobilized to this aim.

The analysis of data collected from the interviews and the classroom observations in terms of TPACK/S showed that teachers referred mainly to the in-door lab and Socratics' questioning as instructional strategies in teaching physics in general and to the classroom technology (videos, simulations, software, etc.) specifically for the inapplicable experiments in the school lab, such as the nuclear reactions and the observation of the solar system. Therefore, the inferred TPACK/S showed an advantage for the virtual experimentation against the real one for particular topics. Furthermore, due to a lack of materials, visual resources were also used to replace real experiments and to show some scientific laws. The analysis in terms of instructional strategies also shows when the equipment cannot cover all students' needs to do the experiment individually; teachers conducted the experiment by themselves. However, Albert believes that doing experiments by himself, where the role of students is limited to observation and answering the questions asked by the teacher, is time-saving.

The analysis of the classroom in terms of TPACK/S also showed that teachers selected different types of resources and integrated them into specific strategies to present specific content. For example, Albert, who is in his mid-career and teaching in an equipped school, applied in his teaching approach the "indoor lab" strategy most of the time, and he used for this aim the real object resources to perform experiments about all the main ideas of the chapter. However, Curie and Pascal, who are beginners (having less than ten years of teaching experience) and teaching in poorly equipped schools, applied classroom technology as an instructional strategy in their teaching in general and electricity in particular.

In addition to the visual resources (simulations, software, etc.), Pascal used examples from real life as non-material resources to present the different ideas of the chapter. George, who has more teaching experience (more than 20 years of teaching experience) and works in a non-equipped school, uses the traditional way in his teaching in general by using his drawings, demonstrations, and examples from everyday life. Table 5 presents examples of teachers' TPACK/S inferred behind the integration of different resources in the classroom to present the same content.

Table 5. List of some teachers' TPACK/S inferred behind the integrated resources to present Ohm's law

Teacher	TPACK/S
Albert	The experimental activity using concrete materials is a way to determine the (I-V) characteristics and to show Ohm's law relative to electric generators.
Curie	Betta uses classroom technology by referring to some software, i.e., the Edulab software, the Crocodile, and the Multisim, to show laws in electricity.
Curie & Pascal	Using the Multisim is a way that allows the teacher to determine the (I-V) characteristics of an electric generator and to show Ohm's law.
George	Referring to the examples from real life and then to the theoretical demonstration supported by the graphs is a way that permits us to determine the (I-V) characteristics and to show Ohm's law relative to electric generators.

It shows additionally that some of the selected specific visual resources depend on the specificity of the content itself while others replaced the lack of materials. The four case studies believed in the role of the experiment and the use of the real object, but the lack of materials and equipment in schools controlled the selection of the resources. However, Curie, who believed that the virtual laboratory is safer, easier to manage, more accurate, and saves time in comparison with the real laboratory, referred to visual resources in his teaching. Therefore, the availability of material and technologies in the teacher's work environment (school setting), teachers' pedagogical knowledge, and the specificity of the content included were determinants for the chosen teaching activity.

Thus, in order to select and integrate specific resources that are suitable to specific physics contents, teachers should be knowledgeable about the curriculum, students' learning difficulties, the availability of educational aids, the subject matter knowledge (SMK), and the objectives of related curricula. These factors were studied in this research by teachers' PCK/U and TPACK/C. Therefore, teachers' knowledge about specific instructional strategy (TPACK/S) that can be selected relies strongly on this knowledge (PCK/U & TPACK/C).

The "Nested Knowledge Systems"

The individual and the cross-analysis of the four case studies in terms of teachers' knowledge about students' understanding, instructional strategies, and curriculum materials behind the use of educational resources and the comparison between the intended and the operational practice were the main objectives of this study. The analysis of collected data from the interviews and the classroom observations shows that teachers are knowledgeable about the curricula and the educational resources (MR and NMR) in addition to the use of technology.

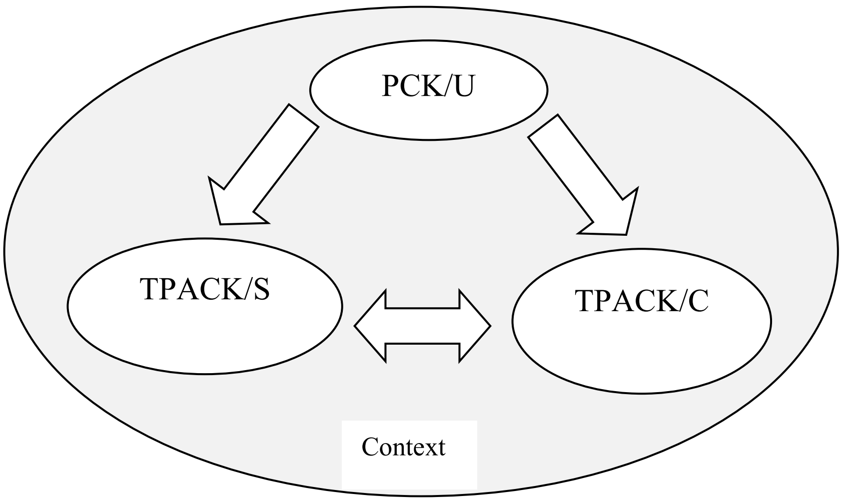

Figure 5. The nested system of teachers' professional knowledge behind the selection and integration of resources

Furthermore, teachers are also knowledgeable about the sources of difficulties that students struggle with in general and in the observed chapter in particular. Moreover, teachers are knowledgeable about different instructional strategies that they may apply to present specific content in a comprehensive way and to enhance students' understanding. Thus, for this aim, they mobilize different types of educational resources and implement them in a specific strategy to facilitate the process of learning specific content and to prevent or remove students' misconceptions. Therefore, teachers' PCK/U has a great effect on teachers' knowledge about the curriculum material and the instructional strategies. Thus, there is no one system of teachers' knowledge that drives the selection and the integration of educational resources in a relevant strategy to specific content, but interrelated systems of knowledge do.

Consequently, figure 5 shows a system of nested teachers' knowledge behind the selection and integration of different resources. Teacher's PCK/U, TPACK/S, and TPACK/C could be viewed as one whole system where different types of knowledge are interrelated. This study calls these consistent knowledge systems "nested knowledge systems." This system corresponds to teachers' knowledge about teaching and learning science as well as about the curricula, the curriculum materials, and the educational aids that can support teachers' practice. The "nested knowledge systems" determines teachers' didactical decisions in general and influence the selection and the integration of educational resources to present specific content in a specific context.

Comparison between Intended and Operational Teachers' Practice in terms of TPACK

One of the objectives of this research is to study the difference between declarative data (from the interviews) and operational data (from the classroom' practice) in terms of PCK and TPCK and between the stated resources and the integrated ones. This could help to understand how the teacher mobilized his professional knowledge in his work environment (equipment, students, content, etc.). The main findings about teaching strategies showed that they all give great importance to the indoor lab instructional strategy, but due to lack of school equipment and poor laboratories, the examples from real life and the software formed the main resources for their documentation work, especially for Pascal and Curie. However, George's PCK/S shows consistency between declarative data and the real practice only about the use of evoked resources, while no other type of resources appears in his practice. Teachers' declarations in the interviews about their teaching in general and teaching electricity in particular and the observation of their classroom did not show any specification concerning the instructional strategies. More particular, there is consistency between teachers' declarations and their practice about how to introduce a new concept and how to show the law relative to it.

The comparison between the inferred TPACK about the curriculum materials shows that there is coherence between declarative data and real practice. However, the four cases are all knowledgeable about the curriculum objectives, the different curricula, and the curriculum, in addition to their knowledge about the available technology that can be used in their teaching practice.

Concerning the inferred teachers' PCK/U, it shows inconsistency between the declarative data in the interviews and the real practice from classroom observations for three of the teachers (Curie et al.). In the classroom, students struggled with learning difficulties, which were slightly different from those stated by the teachers in the interviews. Albert was the only one to show consistency between declarative data and real practice in terms of PCK/U. However, George showed inconsistency between declarative data and real practice in terms of PCK/U, but on the other side, the analysis shows that he is knowledgeable about the applications of physics in everyday life and their relation with the taught subject. It also showed that he is knowledgeable about the subject matter and about the objectives of the curriculum. Furthermore, he knew how to clarify some confusing ideas that were not presented explicitly in the official book and could form a source of students' learning difficulty or even a misconception. Only Pascal's PCK/U about *term confusion* figured in the declarative data as well as the real classroom practice. Thus, the analysis of the classroom practice shows inconsistency in general between PCK/U inferred from the interviews and those inferred from the class observations. This inconsistency could be explained by the fact that the PCK/U changes with the context or the situation of learning in class according to the students' capacities and students' questions. This means PCK/U is strongly affected by the context of the teaching-learning process and its particularity. Thus, the context of the class is a determinant of the PCK/U.

In conclusion, the main findings related to the research questions can be summarized by the following points:

- Time constraints, school equipment, content specificity, and teachers' knowledge affect the selection of resources.
- Teachers' TPACK could be captured using interviews and classroom observations.

- Studying teachers' PCK about students' understanding showed the misconceptions that students and teachers have about learning different physics topics. Moreover, it also showed that misconceptions are persistent and highly resistant to change.
- The interaction between the available resources and the teacher's knowledge showed that TPACK/C and PCK/U are determinants for TPACK/S.
- Teachers with more experience developed better PCK, particularly about the content.
- Teacher's professional knowledge, particularly the teacher's PCK, is one of the main factors that affect teacher practice and his documentary work on the available resources.
- Teacher's PCK/U, TPACK/S, and TPACK/C could be viewed as a whole, while one knowledge system was highly related to another. This study calls these consistent knowledge systems "*nested knowledge systems*," which is responsible for teachers' didactical decisions.

Discussion of the Results

According to Gueudet and Trouche (2009), the documentation work about teaching resources is affected by teachers' professional knowledge in a specific context. In this study, teachers' professional knowledge was explored through some components of PCK and TPCK seen as relevant for the documentary work of the teachers. To infer this knowledge-namely, PCK/U, TPACK/S, and TPACK/C- data were gathered through interviews and classroom observations. This methodology was consistent with many researchers who used interviews (Fernández-Balboa & Stiehl, 1995; Koballa et al., 1999), classroom observations (van Driel, Verloop, & de Vos, 1998), and a combination of methods using the interviews and the classroom observations (Bellamy, 1990; Sanders et al., 1993).

The individual analysis of the four case studies about PCK/U showed that the participants were knowledgeable about a lot of students' learning difficulties related to different physics topics in general. In teaching electricity, they stated some misconceptions related to many ideas, such as the potential difference, the current, the resistance, the generation of electricity, the open circuit voltage, the short circuit, the misuse of some scientific words, etc. At this level, the literature review showed that many researchers had studied students' misconceptions of electricity (Dupin & Johsua, 1986; Guillaud & Robardet, 1997; Michelet, 2006; Osborne, 1983; Osborne et al., 1985), and they showed many models of them. These models were: "the unipolar or sink model," "the clashing currents model," "The weakening current model," "The shared current model," "the statement model," "the local reasoning model," "the short circuit model," "the battery as a current source," "battery and resistive Superposition principle," "topology," "term confusion," "rule application error" (Kapartzians, 2010). Some of the students' misconceptions stated by the teachers showed consistency with the literature review, such as "the weakening current model," "the battery as current source," and "the term confusion ."The analysis of classroom observation shows that the open circuit voltage across a device forms one of the students' misconceptions. Indeed, the analysis of the discourse of the teacher revealed that this misconception came from the teacher's misconception about this notion. When misconceptions are embedded, they are persistent and highly resistant to change (Clement, 1987). This could explain the inconsistency with the literature review about this misconception. To remove misconceptions, the teachers claimed that they used some available resources in the elaboration of their teaching activities. Therefore, teachers should be knowledgeable about the available materials adequate to an idea in order to integrate it in a convenient strategy and present this idea. Thus, based on the students' understanding, the teacher mobilized his knowledge about the content, the resources, and the strategies of teaching to present specific content. This is consistent with one previous study, which revealed that the resources and the strategies of teaching, in addition to the knowledge about the content and students' understanding, formed the main components of the PCK (Bertram, 2010).

The knowledge of the teacher about content is characterized by PCK/C. The individual case analysis showed that George, who had a long teaching experience and a specialization in Electronics, was more knowledgeable about the content than the other participants were. On the other hand, Curie and Pascal, who had formation in education, used better visual resources in their teaching. Then PCK evolved with the years of experience and training at different levels, such as the content, the strategies, the use of technology, students' understanding, etc. This is consistent with many previous researchers (Baxter & Lederman, 1999; Gess-Newsome, 1999; Grossman, 1990; Magnusson et al., 1999; Sarkim, 2004; Van Driel et al.,2001) who also revealed that PCK develops through teaching experience.

A teacher's professional knowledge determines his or her view about the teaching/learning process. The teacher's TPACK/S characterized his way of teaching and the use of resources and technology to present subject material in a comprehensive way. This is consistent with Chen and Wei (2015), who revealed that the adaptation of the curriculum materials in practice depended on seven factors: the teacher's PCK, Teaching resources, belief about science, time constraints, and others. Therefore, he dealt with science by referring to facts and observations; this form or strategy of teaching is a form of demonstration in physics education (Dupin & Johsua, 1993). The availability of teaching resources in the teacher work environment was studied in this research through the teacher's TPACK/C. Hence, this research showed that the interrelation between these systems of teachers' professional knowledge directed the professional work of the secondary physics teachers behind the selection and integration of educational resources. This is in line with Chen and Wei (2015), who found that the more significant factor behind the professional work of chemistry teachers to adapt their curriculum materials to their practice was the teacher's PCK.

As a result, the model illustrated by Figure 5 formed the core of the teacher's PCK and TPCK (adopted from the model of Magnusson (1999) and Mishra & Kohler (2006) from the teacher's professional knowledge that affects the selection of the modification and the integration of resources in the elaboration of the teaching activity. This model of nested knowledge systems is similar to that found by Tsaii (2002) concerning teachers' beliefs about teaching science, learning science, and the nature of science. Beliefs and knowledge were seen as equivalent (Kagan, 1990) and critical to studying teachers' practices. Furthermore, science students' views about the nature of science were nested with their perceptions of learning environments in science (Tsai, 2000). In another way, the nested knowledge systems formed a part of the teacher's professional knowledge responsible for the phenomena of "instrumentation" and "instrumentalization" adopted by Gueudet and Trouche (2008) and formed the core of their representation of a documentational genesis (or instrumental genesis) and didactical decisions maker.

Conclusion

The investigation work in this study concerning the professional knowledge of secondary physics teachers, which they mobilize to select and integrate educational resources, had many findings. In their teaching practice, teachers referred to all types of material and non-material available resources. School setting, time constraints, the specificity of the content, and teachers' professional knowledge are the main factors that affect the didactical decision of teachers about educational resources. The comparison between the intended and the operational practice in terms of TPACK shows that there is inconsistency in PCK/U where the context reshapes this knowledge. Moreover, the investigation of teachers' PCK/U shows that when misconception is formed, it resists change and has a great effect on teachers' TPACK/C and TPACK/S. Therefore, a new model of knowledge system is generated from this study that combines together many components of teachers' technological and pedagogical content knowledge called a *nested knowledge system* (figure 5). This model of knowledge is shown to be the main responsible for different didactical decisions of teachers in general and behind the use of different educational resources in particular.

Limitations of the Study

The current study presents some limitations. One of the limitations is the number of cases studied where four teachers were selected for this research, where they all work in the same region in Lebanon (for the feasibility of the study). Thus, and like most of the case study research, this type presents a lack of generalization. Another limitation of this study is that the analysis referred only to the verbal discourses of the teachers and students and neglected students' physical actions and reactions in the classroom, which could be helpful in inferring TPACK, which may affect the results of this study. Moreover, other components of TPACK/C, TPACK/S, and PCK/U could have an influence on the teachers' documentary work and practices and, afterward, the selection and integration of the resources. Additionally, other research can test teachers' knowledge of other disciplines, i.e., chemistry, biology, etc.

Implications and Recommendations

In light of the findings of this study, several implications could be applied at many levels. Since educational research appreciated the role of real experimentation as an effective way of teaching to help students acquire science knowledge and skills (ACS, 2011; Mallory, 2012; NSTA, 2007), and since most of the teachers (the participants) believed in the importance of the experimental activities and suffered from the lack of materials and schools' equipment in addition to the time consumed to search for other resources, the Ministry of Education should provide schools with the minimum of needed materials to perform hands-on experiments for small groups. Moreover, with the progression of technology in the field of education and the development of ICT, policymakers and curriculum developers should modify the curriculum and provide schools and students with simulation software to perform virtual experiments. Furthermore, they should elaborate teachers' training sessions concerning teachers' adaptation of the curriculum materials using virtual laboratories and simulations to form student-centered activities instead of teacher or content-centered ones. The findings of this study showed that physics teachers used ICT to replace the lack of materials. According to the literature, the virtual laboratory is adequate and efficient when teaching issues at the microscopic scale (Perkins et al., 2006).

The most common definition of PCK was the minimum knowledge required by the teacher to transform disciplinary materials into teachable materials in a specific context. Therefore, teacher education programs should focus on developing pre-service teachers' PCK and TPCK. Consequently, a teaching diploma should become a necessity for pre-service teachers to start teaching. Etkina (2010) showed that high school physics teacher preparation programs focused on three aspects of Physics teachers' knowledge: Knowledge of physics, knowledge of pedagogy, and knowledge of how to teach physics (PCK).

Despite the limitation of this study, future studies/interventions could arise from the discussion of the results of this study. The interaction among the theoretical framework in this study: the documentation approach (Gueudet & Trouche, 2009a), the PCK (Magnusson, 1999), and the TPCK (Mishra & Kohler, 2006) provided a new model of the "nested knowledge systems." Future researchers can utilize this model to study teachers' professional knowledge behind their documentary work in other disciplines. This study showed that the selection of resources is content-dependent. Thus, other research could test this result by choosing Physics topics other than electricity to explore if the selection and the integration of resources change.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

Acknowledgment

The acknowledgment in this study goes mainly to the four teachers that they have accepted to participate efficiently in this investigation and to the schools' directors who also accepted the intervention of the researchers and the classroom observations in addition to the access to all schools' settings.

References

Abell, S. K. (2007). Research on science teacher knowledge. S. K. Abell & N. G. Lederman (Eds.). In *Handbook of research on science education* (pp. 1105-1149). Mahwah, New Jersey: Lawrence Erlbaum Associates.

Adler, J. (2010). La conceptualisation des ressources. Apports pour la formation des professeurs de mathématiques. G. Gueudet & L. Trouche (Eds.). In *Ressources vives Le travail documentaire des professeurs en mathématiques* (pp. 23-39). Rennes : Presses Universitaires de Rennes et INRP.

American Association for the Advancement of Science (1999). *Dialogue on early childhood science, mathematics, and technology education.* Washington, DC: Author.

American Chemical Society (2011). *Importance of hands-on laboratory activities*. American Chemical Society Public Policy Statement. Retrieved from https://www.acs.org/content/dam/acsorg/policy/publicpolicies/invest/computersimulations/hands-on-science.pdf

Baxter, J. A., & Lederman, N. G. (1999). Assessment and measurement of pedagogical content knowledge. J. A. Gess-Newsome & N. G. Lederman (Eds.). In *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 147-161). Dordrecht, The Netherlands: Kluwer Academic Publisher.

Bertram, A. R. (2010). *Enhancing science teachers' knowledge of practice by explicitly developing pedagogical content knowledge*. (Unpublished doctoral dissertation). Monash University. Retrieved from http://arrow.monash.edu.au/hdl/1959.1/471685

Bellamy, M. L. (1990). *Teacher knowledge, instruction, and student understandings: The relationships evidenced in the teaching of high school Mendelian genetics.* (Unpublished doctoral dissertation) The University of Maryland, College Park, MD.

Boyatzis, R. E. (1998). *Transforming qualitative information*. London: Sage Publication.

Chazbeck, B., & Ayoubi, Z. (2018). Resources used by Lebanese secondary physics teachers for teaching electricity: Types, objectives, and factors affecting their selection. *Journal of Education in Science, Environment and Health (JESEH), 4*(2), 118-128.

Chen, B., & Wei, B. (2015). Investigating the factors that influence chemistry teachers' use of curriculum materials: The case of China. *Science Education International*, *26*(2), 195-216.

Clement, J. (1987). Overcoming students' misconceptions in physics: The role of anchoring intuitions and analogical validity. J. D. Novak (Ed.). *Proceedings of the Second International Seminar, Misconceptions and Educational Strategies in Science and Mathematics,* (Vol.3, pp.434-437). Cornell University.

Cross, D. (2009). *Les connaissances professionnelles de l'enseignant : reconstruction à partir d'un corpus vidéo de situations de classe de chimie*. (Doctoral dissertation). Université Lyon 2.

Dupin, J.J., & Johsua, S. L. (1986). Electrocinétique du collège à l'université : Evolution des représentations des élèves et impact de l'enseignement sur les représentations. *Bulletin de l'Union des Physiciens, °683*, 779-800.

Etkina, E. (2010). Pedagogical content knowledge, and preparation of high school physics teachers. *Phys. Rev. ST Phys. Educ. Res., 6,* 020110.

Fernandez-Balboa, J. M., & Stiehl, J. (1995). The generic nature of pedagogical content knowledge among college professors *Teaching and Teacher Education, 11*(3), 293– 306

Fraenkel, J. R., & Wallen, N. E. (2000). *How to design and evaluate research in education* (4th ed.). Boston: McGraw Hill.

Gess-Newsome, J. (1999). Pedagogical content knowledge: An introduction and orientation. J. Gess-Newsome & N.G. Lederman (Eds.). In *Examining pedagogical content knowledge: PCK and science educati*on (pp. 3–17). Dordrecht, The Netherlands: Kluwer.

Graham, C. R., Burgoyne, N., Cantrell, P., Smith, L., St. Clair, L., & Harris, R. (2009). TPACK development in science teaching: Measuring the TPACK confidence of in-service science teachers. *TechTrends*, 53(5), 70-79.

Grossman, P. L. (1990). *The making of teacher: Teacher knowledge and teacher education*. New York, NY : Teachers College Press.

Gueudet, G., & Trouche, L. (2008). Du travail documentaire des enseignants : Genèses, collectifs communautés. Le cas des mathématiques. *Education et Didactique*, *2*, 7-33.

Gueudet, G., & Trouche, L. (2009a). La documentation des professeurs de mathématiques. L. Coulange, C. Hache (Eds.). *Actes du séminaire national de didactique des mathématiques 2008* (pp.249-269).

Gueudet, G., & Trouche, L. (2009b). Towards new documentary systems for mathematics teachers? *Educational Studies in Mathematics*, *71*, 199-218

Johsua, S., & Dupin, J.-J. (1993). *Introduction à la didactique des sciences et des mathématiques*. Paris: PUF.

Johnson, B., & Christensen, L. (2008). *Educational research: Quantitative, qualitative, and mixed approaches.* Los Angeles, CA: Sage.

Kagan, D. M. (1992). Professional growth among beginning and pre-service teachers. *Review of Educational Research, 62,* 129-169.

Kind, V. (2009). Pedagogical content knowledge in science education: potential and perspectives for progress. *Studies in Science Education, 45,* 169-204.

Koballa, T.R., Ggraber, W., Coleman, D., & Kemp, A.C. (1999). Prospective Teachers' conceptions of the knowledge base for teaching chemistry at the gymnasium *Journal of Science Teacher Education, 10*(4), 269 – 286

Kriek, J. & Kapartzianis, A. S (2010). The perceptions of Cypriot secondary and technical and vocational education students about simple electric circuits. *ISTE Conference,* 215-230.

Magnusson, S., Krajcik, J. S., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In N. G. L. J. Gess-Newsome (Ed.). In *Examining pedagogical content knowledg*e (pp. 95 - 132). Boston: Kluwer.

Mallory, C. R., (2012). *Evaluating learning outcomes in introductory chemistry using virtual laboratories to support inquiry-based instruction* (Doctoral dissertation). Retrieved from ProQuest Dissertations and Theses database. (UMI No.3522177)

McDiarmid, G. W., Ball, D. B., & Anderson, C. W. (1989). Why staying one chapter ahead doesn't really work: Subject-specific pedagogy. M. C. Reynolds (Ed). In *Knowledge base for the beginning teacher* (pp.193-205). New York, NY: Pergamon.

Michelet, S. (2006). Remédiation, simulation, argumentation : Analyse de productions d'élèves en électricité. *RJC-EIAH'2006,* 149-156.
Mishra, P., & Koehler, M. (2006). Technological pedagogical content knowledge: A framework for integrating technology in teacher knowledge. *Teachers College Record, 108*(6), 1017-1054.
Neiss, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education, 21*(5), 509–523.
Osborne, R. (1983). Towards modifying children's ideas about electric current. *Science and Technology Education 1*, 73-82.
Osborne, R., & Freyberg, P. (1985). *Learning in science: The implications of children's science.* London:Heinemann.
Patton, M. Q. (1990a). *Qualitative evaluation and research method* (2nd ed.). London: SAGE Publications.
Patton, M. Q. (1990b). *Qualitative evaluation and research method* (2nd ed.). London: SAGE Publications.
Park, S., & Oliver, J. S. (2008). Revisiting the conceptualization of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education, 38*, 261-284.
Perkins, K., Adams, W., Dubson, M., Finkelstein, N., Reid, S., Wieman, C., &LeMaster, R. (2006). PhET: Interactive simulations for teaching and learning physics. *The Physics Teacher*, *44*(1), 18-23.
Robardet, G., & Guillaud, J.C. (1997). Les conceptions, cas de l'électrocinétique. In *Eléments de didactique des sciences physiques* (pp.173-183).
Sanders, L. R., Borko, H., &Lockard, J. D. (1993). Secondary science teachers' knowledge base when teaching science courses in and out of their area of certification. *J. Res. Sci. Teach.*, *30,* 723–736.
Sarkim, T. (2004). Investigating of secondary physics teachers' pedagogical content knowledge: A case study. *Post-Script, 5*(1), 82-96.
Shulman, L. (1986a). Those who understand: A conception of teacher knowledge. *American Educator, 10*(1), 9-15, 43-44
Shulman, L. (1986b). Those who understand: Knowledge growth in teaching *Educational Researcher, 15*(2), 4-14
Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1-22.
Teachers Association. (2007). *NSTA position statement: The integral role of laboratory investigations in science instruction*. Retrieved from http://www.nsta.org/about/positions/laboratory.aspx
Tsai, C. C. (2000) Relationships between student scientific epistemological beliefs and perceptions of constructivist learning environments. *Educational Research*, *42* (2), 193–205.
Tsai, C. (2002). Nested epistemologies: Science teachers' beliefs of teaching, learning, and science. *International Journal of Science Education*, *24,* 771-783.
Van Driel, J. H., Verloop, N., & de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching, 35*(6), 673-695.
Van Driel, J. H., Beijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. *Journal of Research in Science Teaching, 38*(2), 137–158.
Webb, M. E. (2008). Impact of IT on Science Education. In J. Voogt & G. Knezek (Eds.). In *International Handbook of Information Technology in primary and Secondary Education* (pp. 133–148). UK: King's College London.

Author Information

Bassel Chazbeck
Lebanese University, Faculty of Education
Beirut, Lebanon
Contact e-mail: *basselchazbeck@live.com*
ORCID iD: https://orcid.org/0009-0001-4681-7062

Zalpha Ayoubi
Lebanese University, Faculty of Education
Beirut, Lebanon
ORCID iD: https://orcid.org/0000-0002-9263-5147