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ISLEC: An Interactive Learning Scenario Framework

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Abstract

This paper presents an innovative interactive scenario framework called ISLEC for the learning of electrical circuits by high school students or beginners of higher education. This framework aims to develop investigative, critical, creative, and decision-making skills by trainees, as well as aiming to tackle and resolve misunderstandings and learning difficulties. During each section of ISLEC, the student teams, through inquiry-based simulations, discover electrical principles by comparing a known to an unknown electric circuit for similarities and differences and make and verify predictions. Making use of the inductive reasoning, they come to conclusions and generalizations. The ISLEC was evaluated by students of civil engineering of the School of Pedagogical and Technological Education of Athens and, except other things, it considered by them as useful and usable.

Keywords: Interactive educational scenarios, Misconceptions, Comparative teaching, Inquiry-based simulations.

1. Introduction

Traditional teaching about electricity using textual learning material, concrete application tasks or hands-on laboratory work has been quite ineffective. After a series of instruction, learners have been still found to hold many misconceptions about electricity (Jaakkola & Nurmi, 2004). According to McDermott and Shaffer (1992), the laboratory-based hands-on activities can offer special benefits for an understanding of concepts and correcting misconceptions. According to Ronen and Eliahu (2000), some of the misconceptions are so strong and resistant that even direct experience with the real phenomena may not always be effective in changing students' views. These misconceptions seem to be very resistant to change (Chi, 2008).

According to Hung and Chen (2002), inquiry-based simulations may offer one solution. This argument is confirmed by Trundle and Bell (2010), who describe the impact of integrating computer simulations with inquiry-based instruction to promote conceptual change. Recent research of Srisawasdi and Sornkhatha (2014) showed that the inquiry-based learning with computer simulations is generally seen as a promising area for conceptual change in science. Cakir and Irez (2006) noted that inquiry-based science teaching and learning, with the support of computer simulation and collaborative contexts, help learners develop critical thinking and inquiry skills. Srisawasdi and Panjaburee (2015) argue that inquiry-based learning with simulations is a promising area for science-based instruction to foster learners' mental interaction with the physical and social world to develop scientific understanding, explanation, and communication among science ideas.

According to Johnson & Johnson (1989), with the help of sufficient scaffolding, or dynamic team support in cooperative environments, provided by inquiry-based computer simulations, an instructor, a more skilled partner, or a more capable peer, will enable concrete operational students to enhance their reasoning skills toward formal thought. Moreover, Abdullah and Shariff (2008) suggest that the students required resolving their cognitive conflict through visualization of physical phenomena via dynamic computer simulation and support in cooperative learning groups.

Hennessy et al. (2007) described a possible question sequence in the context of inquiry learning with computer simulations as predict, observe, explain and reflect. Winn et al. (2005) argued that high-quality simulation can prepare students for the learning of abstract concepts more effectively than direct field experience, and as Linn and Eylon (2006) support, inquiry-based simulations have shown promise for helping people understand complex abstract systems phenomena and for learning content knowledge. Generally, physics consists of abstract concepts and content and therefore is a scope for Winn's et al recommendation.

In general, computer simulations have been proven being effective in fostering conceptual change (McDermott, 1990). The cognitive conflicts arising from the simulations lead the learners to discover possible misconceptions and reconstruct their own cognitive models (Grigoriadou and Papanikolaou, 2000).

Inquiry-based learning is a pedagogic and teaching approach based on the scientific method of inquiry that draws upon constructivist learning approaches, which need integrating prior knowledge and experiences of the learner. Ahmed and Parsons (2013) argue that inquiry-based learning is an educational approach in which learners can get knowledge through exploration and investigation within authentic settings, and may enhance their critical thinking skills. Keys and Bryan (2001) described inquiry-based science instruction as, including opportunities for students to find and pose questions, design and conduct investigations, analyze data and evidence, use models and explanations, and to communicating findings.

Taking into consideration the views of the above-mentioned researchers we implemented an innovative interactive scenario framework called ISLEC that we present in this paper. This interactive scenario framework uses inquiry-based simulations aiming at helping students understand better electricity and confronting and overcoming their misconceptions and learning difficulties in learning electrical circuits.

The rest of this article structured as follows. Section 2 presents a literature review on interactive scenarios using inquiry-based simulations. Section 3 describes the ISLEC interactive scenario framework. Section 4 presents the evaluation of the interactive scenario framework, and Section 5 presents discussion and future work for the present paper.

2. A Literature Review on Interactive Scenarios Using Inquiry-based Simulations

The interactive learning environments allow learners to engage in tasks that are able to simulate aspects of real-life scenarios and have consequently been used in a variety of science learning materials. Scenario-based learning makes use of interactive scenarios to support active learning strategies. An interactive scenario is a representation of a set of facts and circumstances, real or hypothetical, with which the student can interact through various actions. A learning scenario consists of a description of a realistic situation, accompanied by one or more questions that challenge the learner to respond to some aspect of that situation. At its simplest, a scenario could consist of a single description followed by a single question, but it could also develop in stages with one or more questions at each stage. Creating an interactive scenario is not a simple task. In order for it to be authentic, one must try to make the scenario as realistic as possible. Elements of a scenario include the role the students will play at each stage of scenario, the tools they will use, and the sequence of activities in which they will be engaged.

According to Harlen (2013), for principle-based tasks, a learning scenario is the most commonly used to help a learner gain insight into key principles that influence the problem-solving and decision-making elements of their work, and a strategy of guided discovery is usually applied. The scenario provides a chance for the learner to experiment with different approaches and to reflect upon the possible outcomes. Learners come to new experiences with open minds and develop their ideas by inductive reasoning about what they observe and find through their inquiries. In contrast, the model embodies a constructivist view of learning, acknowledging that students come to new experiences not with empty minds but with ideas formed from earlier experience.

According to Caroll (1999), scenarios evoke effective reflection in a way that addresses some of the most difficult properties of the design. Scenarios can also be abstracted and categorized, helping designers to recognize, capture, and reuse generalizations, and to address the challenge that technical knowledge often lags the needs of technical design.

Abdi (2014) showed that students have a higher understanding of scientific principles if the inquiry-based learning method used in a science classroom. Moreover, Lee et al. (2010) reported findings that well-designed inquiry science units can improve student understanding of complex topics across science courses and teaching contexts.

There are several applications in interactive scenarios using inquiry-based simulations, from which the most well-known of them will be mentioned below.

OsmoBeaker (Meir et al., 2005) is a virtual laboratory which allows students to perform inquiry-based simulations on diffusion and osmosis at the molecular level. Even though their simulated laboratories lead to improved understanding and can help students overcome several common misconceptions about diffusion and osmosis, the authors emphasize the key role that written instructions accompanying the simulations play a significant role in promoting learning, as simply presenting a simulation environment to students is not enough. OsmoBeaker uses balls of different colors and sizes to represent different types of molecules. The screen contains one or more compartments surrounded by walls, and the molecules bounce within these compartments. One or more walls can be made to move; meaning that when a molecule hits it, the molecule imparts some of its momentum to the wall and the wall is pushed slightly as the molecule bounces off. After trying different configurations of walls, we settled on a single compartment for most of the experiments in the diffusion lab and two compartments with a movable wall between them for the osmosis experiments. Students are given three available tools to conduct experiments: 1) they can change the initial concentrations of each molecule in each compartment, 2) they can define a wall as either permeable or impermeable to the different molecules, or 3) they can manually slide a movable wall and then release it from its new position (an action that can be used to test equilibrium).

Scenario Based Learning –interactive (SBLi) tool developed by Norton et al. (2012) is an authoring and delivery suite for implementing the pedagogical approaches involved in active learning strategies and incorporating situated learning theory. The aim is to foster synergies between learner, task, and technology and to create innovative, immersive and authentic problem-based learning environments for student collaboration and interaction on realistic tasks, behaviors and roles. The activities within scenarios can be sequenced, partially sequenced, or students can have complete freedom over what they do and when.

SBLi consists of two desktop applications: a builder and player, for creating and exploring scenarios respectively; and a server-based player and scenario management tool, for deploying scenarios online. The authoring tool allows a problem-based scenario to be easily constructed, with representations of sequenced activities, tests, and test results. The use of SBLi allowed the design of several scenarios that incorporated many experiments and required students to make choices about protocols, similar to real laboratory research. Scenarios consist of a series of locations, each of which may contain a number of actions, items, or quizzes. A simple system of prerequisites allows the designer to create a narrative flow by specifying under which circumstances an object should be available. Students assessed on the quality of their decision-making and/or on the path that they have chosen to solve a problem.

SMALLab (Situated Multimedia Art Learning Lab) developed by Birchfield, et al. (2006) and it is a mixed-reality learning environment that advances situated and embodied learning by allowing the body to act as an expressive interface. Within SMALLab, learners use a set of *glowballs* to interact in real-time with each other and with dynamic visual, textual, physical and sonic media through full body 3D movements and gestures. Within SMALLab students can interact in a productive and embodied way with virtual spring-mass systems and they can change symbolic representations that exemplify—and let learners produce—the core dynamics of force and motion in physics.

WeSPOT (Mikroyannidis et al., 2013) is a novel approach for personal and social inquiry-based learning in secondary and higher education. The weSPOT aims at enabling students to create their mash-ups out of cloud-based tools and services in order to perform scientific investigations. Students will also be able to share their inquiry accomplishments in social networks and receive feedback from the learning environment and their peers. The weSPOT's model aims to provide teachers and learners with the support and the technology to personalize their inquiry-based learning environment, and build, share and enact inquiry workflows individually and/or collaboratively with their peers. In inquiry-based learning learners take the role of explorers and scientists and are motivated by their personal curiosity, guided by self-reflection, and develop knowledge personal and collaborative sense-making and reasoning.

WISE (Slotta, 2004) created by the Berkeley University of California supported by the National Science Foundation. This is a virtual learning environment for engaging students in the intentional process of diagnosing problems, critiquing experiments, distinguishing alternatives, and planning investigations with simulations, discussion tools, journaling and note-taking tools, drawing tools, sharing tools, and several other tools. Moreover, it is a toolset for designing, developing, and implementing science inquiry activities collaboratively, such as visual graphical representations, reflective notes, interactive simulations, and assessments. The WISE pedagogical approach is to emphasizing collaborative inquiry engaging students to both self-monitoring and collaborative reflection. Students can develop their inquiry projects through four steps: Prediction, Observation, Explanation, and Reflection. In the Probing your Surroundings project, for example, students collect real-time data about the temperatures of objects and explore interactive simulations dealing with heat transfer, thermal conductivity, and thermal sensation. Students then work in online forums toward a consensus in explaining the patterns observed in the empirical data.

NIELS (NetLogo Investigations in ELectromagnetism) (Sengupta & Wilensky, 2009) is a suite of low-threshold and high-ceiling emergent embedded models built on the NetLogo modeling environment that can be used by students across different ages (fifth grade through undergraduate). These models represent phenomena such as electric current and resistance, emergent from simple, body-syntonic interactions between electrons and other charges in a circuit, in simple linear circuits as phenomena that emerge from simple rules of interaction (push, pull, collisions, or bouncing) between thousands of individual level agents (such as electrons and atoms) inside the conducting material. NIELS models are based on Drude's free electron theory, and enable learners to develop a qualitative sense-of-mechanism of the aggregate-level formal representations (such as equations and graphs representing Ohm's Law). NIELS enables students as young as fifth grade to (a) understand and explain the concepts of electric current and resistance, their relationships, as well as the behavior of novel electrical circuits, (b) alleviate commonly held misconceptions in introductory electricity, and (c) construct scientifically correct explanations of the behavior of electric current as represented in traditional circuit diagrams, as well as physical setups of commonly used electrical circuits. Sengupta & Wilensky proposed a cognitive framework specifically for analyzing misconceptions in introductory electricity from an emergent, knowledge-in-pieces perspective. Furthermore, they have also presented a cognitive (epistemological) argument for adopting instructional approaches based on Drude's (1900) theory in electromagnetism education - a theory that is typically taught in calculus-based (or equation-based) advanced undergraduate - level or early graduate-level physics courses. NIELS provides an alternative way of introducing students to Drude's theory without the need of the traditional formalism of equations.

Co-Lab (Joolingen, et al., 2005) is a collaborative learning environment in which groups of learners can experiment through simulations and remote laboratories, and express acquired understanding in a runnable computer model. In Co-Lab the demarcation between inquiry, modeling, and collaboration is less clear-cut. Collaboration, for instance, runs as a continuous thread through the discovery learning process, affecting the way inquiry and modeling processes performed and should be supported. Furthermore, modeling is integral to the inquiry process. Learners express their initial understanding of scientific phenomena in a model sketch, which is then used to predict and explain what will occur in the phenomena being modeled. By testing these hypotheses with the simulation or the remote lab, learners gain the knowledge they can use to refine or extend their model.

3. The Interactive Scenario Framework ISLEC

Taking into consideration all the above mentioned about inquiry-based simulations and interactive scenarios, we designed the Interactive Scenario Framework for the Learning of Electrical Circuits (ISLEC) presented in this paper. As we mentioned above the ISLEC aims at helping students develop a deeper understanding of electricity and to confronting and overcoming their misconceptions and learning difficulties in learning electrical circuits.

ISLEC was designed, developed and implemented as a supplementary tool of the MATHEMA tool (Papadimitriou et al., 2012). It is a goal-based scenario framework (Stewart and Brown, 2008), where students required to make predictions and test them to get to the root of a problem, the scope (and limits) of what they can do within the scenario must be carefully thought about. Moreover, ISLEC uses comparative teaching, guided inquiry-based simulations, explorations, guided discovery, and communication. Students actively construct knowledge by using experiments, comparing, making observations, proposing, predicting, solving problems, answering questions, gathering and analyzing data, synthesizing, creating explanations, and making decisions.

In comparative teaching, seeing similarities and differences is a fundamental cognitive process (Gentner & Markman, 1994). As an instructional strategy, it includes various activities that help learners see patterns and make connections. Through a process of inquiry, the empirical evidence is transformed (e.g., natural phenomena) into revised and new knowledge structures (Lee, 1999). As we mentioned above, inquiry-based learning is a student-centered learning approach in which students work collaboratively in an active and social process to construct new meaning from their learning.

Explorations promote a new state of understanding or equilibrium or self-regulation when new concepts and principles derived from the exploration experience where students collect and analyze data via computer simulation in cooperative learning team (Abdullah and Shariff, 2008).

Guided discovery, also known as an inductive approach, is characterized by convergent thinking. The instructor devises a series of statements or questions that guide the learner, step by logical step, making a series of discoveries that lead to a single predetermined goal. In other words, the instructor initiates a stimulus and the learner reacts by engaging in active inquiry thereby discovering the appropriate response. By actively doing and consequence discovering facts or concepts, the learner will understand and therefore remember the subject matter. According to Mayer (2004), guided discovery appears to offer the best method for promoting constructivist learning.

The presented interactive scenario, like all scenarios, supports socio-cultural perception by emphasizing prior knowledge, interacting with the social environment, and promoting inductive and abductive learning, as students encouraged discovering, control structures, and applying new knowledge and skills in new contexts.

The interactive scenario is based on simulations through exploratory questions, guided discovery, and communication to help learners understand electricity and acquire correct scientific models on electrical circuits. In general, the scenario promotes and supports problem-based learning where students can become creative, able to think critically, analytically, synthetically, practically, and learn how to solve real problems. While solving problems, they are instructed to learn the relevant concepts and procedures.

According to Stewart and Brown (2008), before creating any interactive scenario for course work, we must decide the following:

1) Synopsis: What role will students play and what will they be expected to do?
2) Expected Learning Outcomes: What skills/knowledge should students develop/learn from going through this exercise?
3) Placement and Course: What course and where in the scenario going to be placed?
4) Assistance in Interpretation: How much (if any) assistance will students be given in interpretation?
5) Reflection and Feedback: When and how will students be given feedback?
6) Assessment: Will the scenario be assessed and if so how?

7) Delivery: How will it be delivered?
8) Frequency: Will students be expected or allowed to go through the scenario more than once?
9) Team Play: Will this be a team exercise or will students go through these scenarios alone?

Thus for the ISLEC designs were decided the following:

***Synopsis*:** The pedagogical value of the scenario is that raise learners' interest towards the electric circuit investigation and discovery of principles and concepts through inquiry-based simulations, explorations, guided discovery, and communication.

The roles of student collaborative teams are coordinator, handler of simulations, handler of the interactive scenario (ISLEC), and recorder.

***Expected Learning Outcomes*:** After the study of scenarios, the learners should be able to:

1) generate knowledge through comparison and contrast;
2) make and verify predictions;
3) discover laws and principles of electrical circuits through experimentation;
4) interpret data and draw conclusions;
5) compose and construct complex circuits;
6) propose and prove solutions;
7) participate in groups for effective decision-making;

***Placement and Course*:** Subject: Physics (Electromagnetism); Context/level of study: Senior High school or Technical High School; Topic/domain: Simple Electric Circuits; in the current version, it includes the following sections: 1. Ohm's law, 2. Series circuits, 3. Parallel circuits, 4. Series - Parallel circuits, 5. Open-ended problem.

Each section has the following structure:

1) Focus lesson.
2) Synopsis.
3) Prerequisites.
4) Activity.
5) Audit conclusion from the system /Abstract.
6) Application on real-life problems and Self-assessment.

***Assistance in Interpretation*:** Through the ISLEC the learners will be given:

1) all the circuits that the learners will compare and make predictions;
2) guides and exploratory questions;
3) data entry tables, data control, and feedback;
4) the opportunity for creating graphical representations and comparing them with known representations in arriving at conclusions;
5) the ability to compare their conclusion with the scientific view;
6) the ability for self-assessment through interactive tests and feedback for reflection;

***Reflection and Feedback*:** Feedback for reflection will be given to learners in the following cases:

1) During the data entry.
2) When they asked to compare their conclusion with the scientific view.
3) When they asked to verify their predictions and make generalizations.

4) When they asked to self-assessed through the self-assessments.

In general, the system helps the learners find the correct answer through the feedback and reflection.

Assessment**:** The learners self-assessed through the self-assessments. The aim of the self-assessment is the learners to identify their weakness and to try again.

Delivery**:** The learners will be given all the necessary software and material.

Frequency**:** The learner allowed running the scenarios countless times;

Team Play**:** The learners go through the scenarios in collaborative teams;

In conclusion, learners encouraged to discover principles and laws through experimentations, observations and guided discovery, and in turn, use what they discovered, to solve challenging problems.

In order students to develop a deeper understanding of electricity and to confronting and overcoming their misconceptions and learning difficulties in teaching and learning of electrical circuits, the learning material in the ISLEC designed and organized in such a way to meet the following pedagogical and learning aspects:

1) support for reflection (turning experiences into learning), self-regulation, and problem-solving;
2) promoting deeper understanding, inquiry skills, meta-cognitive skills, observational skills, inference skills, critical and creative thinking skills, and inductive reasoning skills;
3) assistance in the discovery of knowledge;
4) fostering natural curiosity;
5) cover all learning pace;
6) encouraging students' cooperation;
7) leading to increased learner motivation;
8) activation of the learner's pre-existing knowledge.

Reflection is an important human activity, where people recapture their experience, think about it, mull over & check it. Boud et al. (1985) consider reflection to be the central part of a person's experiences that is important in learning. Some reflective practice providing by the ISLEC are: (a) prompting students' reflection by asking questions that seek reasons and evidence, (b) providing some explanations to guide students' thought processes during explorations, (c) providing social-learning environments to allow students to see other points of view, (d) designing predictive activities, and (e) provide enough wait-time for students to reflect when responding to inquiries.

Self-regulation is the control we have over our thoughts, feelings, and actions. The concept of self-regulation includes the ability to concentrate, become involved in group activities, restrain disruptive and impulsive behavior and work autonomously (Duckworth et al, 2009). Engaging students in challenging and collaborative learning experiences, making their own decisions, interacting with more knowledgeable peers, and giving the words to describe the problem they are facing and how to resolve it, are some of the strategies for improving self-regulation through the ISLEC. According to Mumford (1986), metacognition refers to learner's automatic awareness of their own knowledge and their ability to understand, control and manipulate their own cognitive processes. With other words, metacognition is thinking about thinking and developing the process of solving problems and answering questions (Fisher, 2006). Self-regulated learners demonstrate a wide range of metacognitive skills such as asking questions, planning, monitoring, checking, evaluating, discussing, cooperating, revising, self-testing, connecting how information to prior knowledge, and involving the social mediation of thinking by others. These skills are provided by the ISLEC.

Inquiry skills providing by the ISLEC are: exploring, predicting, experimenting, interpreting data, and communicating.

The inference is the heart of the comprehension process. Inferences are explanations or interpretations that follow from the observations. Inference skills enable us to draw conclusions from reasons and evidence. Asking students questions about their observations we can encourage the students to think about the meaning of the observations. Thinking about making inferences in this way should remind us that inferences link what has been observed together with what is already known from previous experiences. We use our past experiences to help us interpret our observations. When students are trying to make inferences, they will often need to go back and make additional observations to become more confident in their inferences. In science, inferences about how things work are continually constructed, modified, and even rejected based on new observations (Brotherton & Preece, 1999). In the ISLEC, students allowed to go back and make additional observations to draw conclusions more confident because simulations are given to them that can run as many times as they wish and repeat some measurements that may be incorrect.

Predictions based on our inferences or hypotheses about events give us a way to test those inferences or hypotheses. If the prediction turns out to be correct, then we have greater confidence in our inference/hypothesis.

Natural curiosity enhances the creativity of students. Natural curiosity in the ISLEC is fostered by thought-provoking questions, hypothesizing through discussion and brainstorming, and learning through active exploration and discovery.

Decision making in contexts of uncertainty relies on inductive reasoning. The reasoning is the process of using existing knowledge to draw conclusions, make predictions, or construct explanations. Inductive reasoning begins with observations that are specific and limited in scope and proceeds to a generalized conclusion that is likely, but not certain, in light of accumulated evidence. We use inductive reasoning skills when we draw inferences about what we think must probably be true based on analogies, case studies, prior experience, statistical analyses, simulations, hypothetical, and making generalizations (Knox, 2016).

In the ISLEC, the students' inductive reasoning skills promoted when they draw inferences based on prior experiences obtained from previous activities, and on observations in simulations.

In this interactive scenario adopted the group problem-solving because (Heller & Hollabaugh, 1992):

1) trainees are given an opportunity to practice a strategy until it becomes more practical;
2) complex problems can be solved by groups rather than by each student;
3) trainees trained through the development and use of the language of physics;
4) through the discussion, learners have to deal with and overcome their misconceptions. Conflicts sometimes arise during cooperation as learners disagree on their interpretations or approaches. When trainees solve a problem together, they co-construct common knowledge and understanding by completing and constructing one with the ideas of the other (Tao & Gunstone, 1999);
5) when solving a problem through brainstorming, trainees are less reluctant because they are not questioned as individuals but as a group. In addition, cooperative problem solving positively affects learner behavior and performance in physics lessons, as well as incentives for their success (Gök, 2010).

Moreover, student engagement enhanced and better learning accomplished where groups of learners immersed in authentic, real-world problems (Herrington, et al., 2010). The presented scenario framework begins with exploratory activities on simple electrical circuits and finishes with an open-ended problem-solving activity. The framework of each activity in the ISLEC has a similar structure with the following:

Step 1: The learners use simulations containing both comparing circuits (see Fig. 1). The circuit on the left is the circuit which the learners studied in the previous section. The circuit on the right is the new circuit that the learners asked to discover its principles.

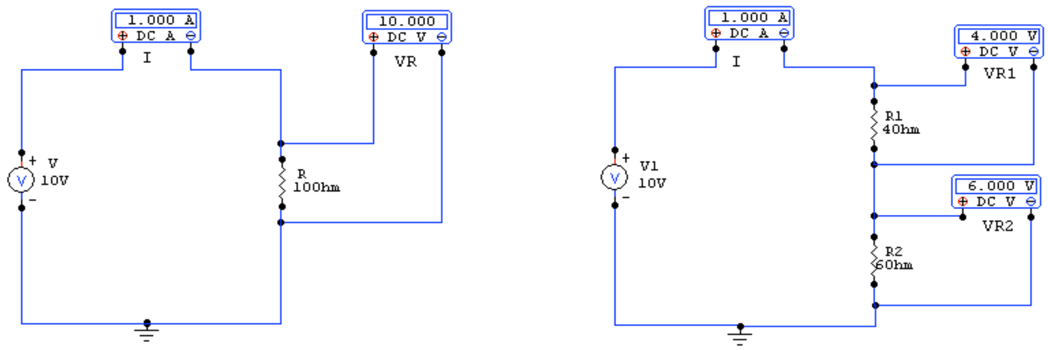

Figure 1. Simulations containing both comparing circuits

Step2: The learners make predictions about all the values of voltages and currents of the circuit to the right comparing it with the circuit to the left in order to recognize similarities and differences.

Step 3: The learners alter the price trend on both sources of circuits from 0 to 10 volt with step 2, complete a table, and answer the following exploratory questions:

Indicative Exploratory Questions

1) For the same voltage of both sources of the two circuits A and B, do you observe the same total current, respectively? If yes, what can we conclude about the total (or equivalent) resistance of the circuit B? Which is the formula to determine the total resistance in the circuit B?
2) Use inductive reasoning to generalize the formula of the total resistance in circuits with more than two resistors.
3) For each value of the circuit B source, which is the sum of the voltage drop across each resistor? What can we conclude about the relationship between the value of the circuit B source and the sum of the values all along each resistive voltage drop?
4) Use inductive reasoning to generalize the formula connecting the voltage of the circuit B source with all the voltage drops across the resistors in similar circuits with more than two resistors.
5) Compare the relationship between the results of the flowing current in each resistor that multiplied by each resistor, and the voltage drop across each resistor. What can we conclude about this comparison? Write down the formula calculating the voltage drop across each resistor.
6) Use inductive reasoning to generalize the formula calculating the voltage drop across each resistor in circuits with more than two resistors.

Moreover, the last activity of the interactive scenario uses an authentic, real-world problem about electrical circuits and it is described below. This activity would be better to be taught using the brainstorming technique.
The problem definition: In how many ways can we connect the resistances R1 = 2 Ohm, R2 = 3 Ohm, and R3 = 6 Ohm?

Problem constraints: To limit the number of solutions to the problem, we need to modify the problem to give the lowest solution limit. In your view, which of the following modifications can help you limit the number of solutions to the problem at the bottom?

a) In how many ways can we connect the resistances R1 = 2Ohm, R2 = 3Ohm and R3 = 6Ohm so each of the possible connections will give the same total resistance?

b) In how many ways can we connect the resistances R1 = 2Ohm, R2 = 3Ohm, and R3 = 6Ohm so each of the possible connections will give different total resistance?

c) In how many ways can we connect the resistances R1 = 2Ohm, R2 = 3Ohm, and R3 = 6Ohm so each of the possible connections will give a single value to the total resistance?

Breaking the problem into sub-problems: For the case (b) of the above modifications, divide the problem into four sub-problems. For example, a sub-problem should consider the solutions of series circuits. In this case, you should find out the possible solutions before and after the constraints.

Decision making and criteria judging the best solutions: In the case of (b) the above changes to the original problem, the criteria for judging which solutions are best to solve the problem are:

Sub-problem1: For serial resistances, it should be possible to provide a single solution between equivalent possible solutions (weight = 25%).

Sub-problem2: For parallel resistances, it might be possible to provide a single solution between equivalent possible solutions (weight = 25%).

Sub-problem3: For two resistors in series and parallel to the third, it might be possible to provide three solutions between equivalent possible solutions (weight = 25%).

Sub-problem4: For two parallel resistances and in series with the third, it might be possible to provide three solutions between equivalent possible solutions (weight = 25%).

The idea with the highest score will better solve the problem. But you should keep a record of all your best ideas and their results if your best idea proves to be impossible.

In Figure 2 we can see a snapshot of a section in the ISLEC.

4. Evaluation of the ISLEC

4.1. Methodology

Evaluation of an educational tool is important and it must be ensured that the appropriate methods are used. Thus, ISLEC evaluated by students of the Higher School of Pedagogical and Technological Education, Athens, Greece in order to exploit their views on improving the effectiveness of the interactive scenario, which mainly concerns its pedagogical and learning aspects. The methodology used to evaluate ISLEC is a case study.

The objective of the research was to explore students' views on the pedagogical and learning aspects offered by the interactive scenario. Students' views were also sought on the usefulness and usability of the ISLEC.

4.2 Participants

The research conducted at the Department of Civil Engineering, Higher School of Pedagogical and Technological Education, Athens, Greece. Fifteen (15) students participated in the research. There were nine males and six females. Their average age was 21 years. They studied in the fourth semester of their studies where they trained in technical and pedagogical subjects to teach in secondary technical and vocational education schools in Greece. Thus, the basic pedagogical and technological knowledge of the students they acquired up to that time was sufficient enough in evaluating the ISLEC.

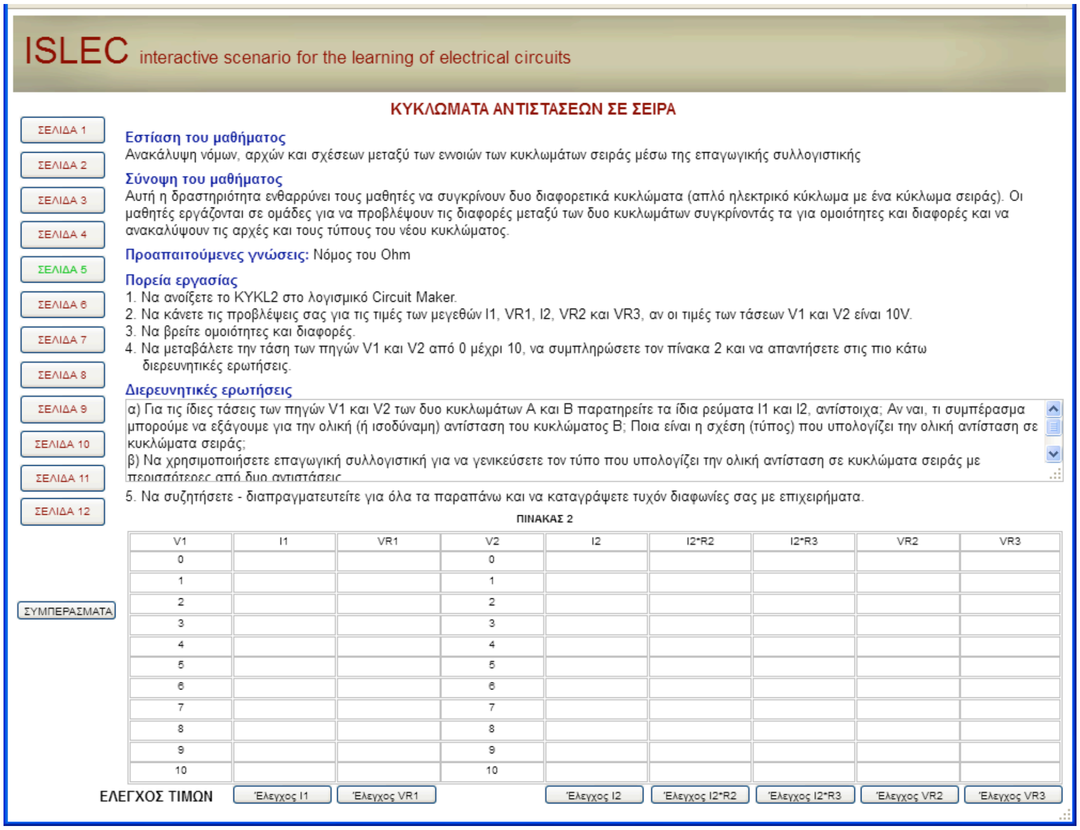

Figure 2. A snapshot of a section in the ISLEC

4.3 Materials

As materials, the ISLEC in conjunction with the CircuitMaker software were used for supporting of simulations.

4.4 Method of Collecting Data

The method used to collect data is the questionnaire. The questionnaire designed by the author and is given to more experienced colleagues to express their views about it. Their views were taken seriously into account and the questionnaire improved. The main goal of the questionnaire given to the participants was to investigate and record their views on the ISLEC. It consists of eighteen questions labeled on Likert's scale. The Likert's scale consists of five categories as follows: not satisfied at all, slightly dissatisfied, fairly satisfied, very satisfied, and extremely satisfied. The characterization "not satisfied at all" is coded to 1, the characterization "slightly satisfied" is coded to 2, the characterization "fairly satisfied" is coded to 3, the characterization "very satisfied" is coded to 4, and the characterization "extremely satisfied" is coded to 5.

4.5 Experimental Procedure

The evaluation of the ISLEC was done by the students of Civil Engineering, Higher School of Pedagogical and Technological Education, Athens, Greece, in the frame of the discipline "Pedagogical Applications with Computers". It was given as individual work to the participants, and it graded with 10% of the total grade of their performance. The students were initially informed about the pedagogical and learning aspects of the ISLEC in detail, and then studied the ISLEC in detail, followed by an extensive discussion; explanations were given, and then they completed the evaluation questionnaire.

4.6 Data Collection

The data collection was done with the evaluation questionnaire completed by all the participants. Table 1 presents students' views on the pedagogical and learning aspects of the interactive scenario and its usefulness and usability.

Table 1. Students' views on pedagogical and learning aspects offered by the interactive scenario as well as on its usefulness and usability

Questions The ISLEC:	not satisfied at all	slightly dissatisfied	fairly satisfied	very satisfied	extremely satisfied
supports reflection	0	0	4	3	8
supports self-regulation	0	0	4	5	6
fosters natural curiosity	0	0	4	6	5
promotes a deeper understanding	0	0	0	7	8
promotes inquiry skills	1	0	3	4	7
promotes meta-cognitive skills	0	2	5	4	4
assists in the discovery of knowledge	0	0	1	6	8
supports problem-solving	0	0	4	6	5
covers all learning pace	0	4	4	5	2
encourages students' cooperation	0	4	4	2	5
promotes observational skills	0	0	2	6	7
leading to increased learner motivation	0	0	1	8	6
promotes inference skills	0	2	3	4	6
promotes inductive reasoning skills	0	1	4	3	7
activates pre-existing knowledge of the learner	0	2	2	5	6
promotes critical and creative thinking skills	0	1	2	8	4
is usable	0	0	4	4	7
is useful	0	0	1	3	11

4.7 Data Analysis and Results

In Table 2, the results of the quantitative data analysis are presented. The answers of the participants about the closed-ended questions of the Likert's scale were grouped into two categories, as follows: "Dissatisfaction" (not at all satisfied, and slightly dissatisfied), and "Satisfaction" (fairly satisfied, very satisfied, and extremely satisfied). For the data analysis the mean, standard deviation, and the Yates' chi-square statistic method were used. The null hypothesis (H0) was that the amounts of the students belonging to the two categories (Dissatisfaction, Satisfaction) were equal (have no statistically significant relationship) for all the research questions.

4.8 Conclusions

Before making any conclusions from the measurements made, it would be advisable to discuss the limitations of research and how they were overcome. There is a methodological limitation of the research which is the sample size of 15 students. The reason is that this sample used the computer workshop taught by the author: it was difficult to find a larger sample. The sample was divided into two groups so that to give more reliable results by using the chi-square and Cramer's V statistical methods (Gingrich, 2004; Healey, 2010).

The chi-square test is sensitive to sample size. The size of the calculated chi-square is directly proportional to the size of the sample, independent of the strength of the relationship between the variables. The sensitivity of chi-square to sample size may make a weak relationship statistically significant if the sample is large enough. However, we need to use tests of significance like chi-square together with measures of association like Cramer's V to guide us in deciding whether a relationship is important and worth pursuing. Cramer's V is a chi-square–based measure which takes into account the sample size. Chi-square says that there is a significant relationship between variables, but it does not say just how significant and important this is (Gingrich, 2004). Cramer's V is a post-test to give this additional information. Cramer's V varies between 0 and 1. Close to 0 it shows a little association between variables. Close to 1, it indicates a strong association. According to Healey (2010), if the value is less than 0.10 the strength of the relationship is weak. If the value is between 0.11 and 0.30 the strength of the relationship is moderate, and if the value is greater than 0.30 the strength of the relationship is strong. As a rule of thumb, there is no substantial dependence if $V < 0.10$.

As Gingrich (2004) supports, the Cramer's V test shows the reliability of the results. Tables which have a larger value for Cramer's V can be considered to have a strong relationship between the variables, with a smaller value for V indicating a weaker relationship.

According to the results of Table 2, the null hypothesis, in which the amounts of the students belonging to the two categories (Dissatisfaction, Satisfaction) was assumed as equal, is rejected (all the p values are less than 0.05 and $V>=0.73$) except in the following cases: (a) The ISLEC covers all learning paces ($p=0.0707>0.05$, $V=0.46$), and (b) The ISLEC encourages students' cooperation ($p=0.0707>0.05$, $V=0.46$).

More specifically the evaluation showed that the ISLEC:

1) supports reflection ($p=0.0001<0.05$, $V=1$)
2) supports self-regulation ($p=0.0001<0.05$, $V=1$);
3) fosters natural curiosity ($p=0.0001<0.05$, $V=1$);
4) promotes deeper understanding ($p=0.0001<0.05$, $V=1$);
5) promotes inquiry skills ($p=0.0008<0.05$, $V=0.86$);
6) promotes meta-cognitive skills ($p=0.0045<0.05$, $V=0.73$);
7) assists in discovery of knowledge ($p=0.0001<0.05$, $V=1$);
8) supports problem-solving ($p=0.0001<0.05$, $V=1$);
9) promotes observational skills ($p=0.0001<0.05$, $V=1$);
10) leading to increased learner motivation ($p<0.0001<0.05$, $V=1$);
11) promotes inference skills ($p=0.0045<0.05$, $V=0.73$);
12) promotes inductive reasoning skills ($p=0.0008<0.05$, $V=0.86$);
13) activates pre-existing knowledge of the learner ($p=0.0045<0.05$, $V=0.73$);
14) promotes critical and creative thinking skills ($p=0.008<0.05$, $V=0.86$); and
15) is usable ($p=0.0001<0.05$, $V=1$) and useful ($p=0.0001<0.05$, $V=1$);

All sixteen cases above were accepted because p is less than 0.05 and there is a strong relationship between the variables. So, the results are believed to be reliable ($V>=0.73$).

In general, the evaluation of the ISLEC showed that it satisfies greatly its pedagogical and learning aspects we mentioned above, but it must be improved so as to cover all learning pace and encourage students' cooperation.

4.9 Reliability of the questionnaire

In order to calculate the reliability of the questionnaire, the Cronbach's alpha method used to calculate the reliability of each question in the questionnaire separately. Table 3 shows the results of the reliability of the questionnaire. All the results indicate an excellent reliability (Internal consistency>0.9).

4.9 Validity of the questionnaire

For the validity of the questionnaire, bilateral correlations of the two-tailed Pearson's method were used. All Sig. (2-tails) were found to be less than 0.05. Thus, we can conclude that all questions in the questionnaire are valid.

Table 2. Data analysis

Questions The ISLEC:	**Mean**	**Standard deviation**	x^2	**p**	Cramer's V
supports reflection	4.26	0.22	15	0.0001	1
supports self-regulation	4.13	0.20	15	0.0001	1
fosters natural curiosity	4.06	0.19	15	0.0001	1
promotes a deeper understanding	4.53	0.12	15	0.0001	1
promotes investigative skills	4.06	0.29	11.26	0.0008	0.86
promotes meta-cognitive skills	3.66	0.26	8.06	0.0045	0.73
assists in the discovery of knowledge	4.46	0.15	15	0.0001	1
supports problem-solving	4.06	0.19	15	0.0001	1
covers all learning pace	3.33	0.26	3.26	0.0707	0.46
encourages students' cooperation	3.53	0.31	3.26	0.0707	0.46
promotes observational skills	4.33	0.18	15	0.0001	1
leading to increased learner motivation	4.33	0.15	15	0.0001	1
promotes inference skills	3.93	0.27	8.06	0.0045	0.73
promotes inductive reasoning skills	4.06	0.25	11.26	0.0008	0.86
turns experiences into learning and enables pre-existing knowledge of the learner	4.00	0.26	8.06	0.0045	0.73
promotes critical and creative thinking skills	4.00	0.21	11.26	0.0008	0.86
is usable	4.20	0.21	15	0.0001	1
is useful	4.66	0.15	15	0.0001	1

Table 3. Evaluation of the questionnaire

Questions The ISLEC:	Cronbach's alpha	Change
supports reflection	0.9779	-0.001619
supports self-regulation	0.9770	-0.002548

fosters natural curiosity	0.9775	-0.002049
promotes a deeper understanding	0.9780	-0.001495
promotes inquiry skills	0.9775	-0.002021
promotes meta-cognitive skills	0.9791	-0.0004756
assists in the discovery of knowledge	0.9775	-0.002048
supports problem-solving	0.9775	-0.002049
covers all learning pace	0.9836	0.004061
encourages students' cooperation	0.9817	0.002205
promotes observational skills	0.9771	-0.002471
leading to increased learner motivation	0.9782	-0.001304
promotes inference skills	0.9770	-0.002545
promotes inductive reasoning skills	0.9778	-0.001762
activates pre-existing knowledge of the learner	0.9772	-0.002357
promotes critical and creative thinking skills	0.9792	-0.0002939
is usable	0.9772	-0.002324
is useful	0.9788	-0.0007440

5. Discussion and Future work

This paper describes a scenario framework called ISLEC using inquiry-based simulations. For developing of this framework for the treatment and removal of students' misconceptions were taken into account from the literature mentioned above, the following:

1) Inquiry-based learning with simulations is a promising area for science-based instruction to foster learners' mental interaction with the physical and social world to develop scientific understanding, explanation, and communication among science ideas (Srisawasdi & Panjaburee, 2015).
2) With the help of sufficient scaffolding, or dynamic team support in cooperative environments, provided by inquiry-based computer simulations, an instructor, a more skilled partner, or a more capable peer, will enable concrete operational students to enhance their reasoning skills toward formal thought (Johnson & Johnson, 1989).
3) The students required resolving their cognitive conflict through visualization of physical phenomena via dynamic computer simulation and support in cooperative learning groups (Abdullah & Shariff, 2008).
4) A possible question sequence in the context of inquiry learning with computer simulations is: predict, observe, explain and reflect (Hennessy et al., 2007).
5) High-quality simulation can prepare students for the learning of abstract concepts more effectively than direct field experience (Winn et al., 2005).
6) Inquiry-based simulations have shown promise for helping people understand complex abstract systems phenomena and for learning content knowledge (Linn & Eylon, 2006).

Through the designed interactive scenario framework, is given the opportunity to students to interacting with inquiry-based simulations, to make and identify predictions, and monitor their effects, to apply their knowledge to other broader contexts, and to solve by themselves complex problems of electricity. Thus, the scenario was designed to assist the students to construct and co-construct their own deep understanding and knowledge of electrical circuits through comparative teaching, inquiry-based simulations, explorations, guided discovery, and communication. The role of these methods is the students to discover principles and laws of the unknown electrical circuits. In the beginning, there is a reference to the learning difficulties and misconceptions of students that they face when learning electricity. Then, inquiry-based learning with simulations is described, and implementations of interactive scenarios in the literature are presented. At the end, an evaluation of the ISLEC is presented.

This article also presents some similar to the ISLEC learning tools offering similar capabilities to compare similarities or differences in different applications that use inquiry-based simulations and interactive scenarios. OsmoBeaker (Meir, et al., 2005) uses simulated laboratories which lead to improved understanding and can help students overcome several common misconceptions about diffusion and osmosis. In SBLi tool the aim is to foster synergies between learner, task, and technology and to create innovative, immersive and authentic problem-based learning environments for student collaboration and interaction on realistic tasks, behaviors and roles. The WISE pedagogical approach is to emphasizing collaborative inquiry engaging students to both self-monitoring and collaborative reflection. Students can develop their inquiry projects through four steps: Prediction, Observation, Explanation, and Reflection. NIELS enables students as young as fifth grade to (a) understand and explain the concepts of electric current and resistance, their relationships, as well as the behavior of novel electrical circuits, (b) alleviate commonly held misconceptions in introductory electricity, and (c) construct scientifically correct explanations of the behavior of electric current as represented in traditional circuit diagrams, as well as physical setups of commonly used electrical circuits.

Some of these systems are aimed at tackling misconceptions that are a serious problem faced by students in learning science and technology. This is also a problem that attempts to address the ISLEC framework. ISLEC seeks and achieves similar pedagogical and learning goals with NIELS and has the same scope which is the electricity. In WISE, students can develop their inquiry projects through four steps: prediction, observation, explanation, and reflection, as the ISLEC attempts through the activities.

In SBLi, the activities within scenarios can be sequenced, partially sequenced, or students can have complete freedom over what they do and when, as the ISLEC attempts through the activities.

In WeSPOT, inquiry-based learning learners take the role of explorers and scientists and are motivated by their personal curiosity, guided by self-reflection, and develop knowledge personal and collaborative sense-making and reasoning, as the ISLEC attempts through the activities.

In Co-Lab, learners express their initial understanding of scientific phenomena in a model sketch, which is then used to predict and explain what will occur in the phenomena being modeled. By testing these hypotheses with the simulation or the remote lab, learners gain the knowledge they can use to refine or extend their model. In WISE and ISLEC the students can develop their inquiry projects through four steps: Prediction, Observation, Explanation, and Reflection.

NIELS and ISLEC relied on the conclusion of Srisawasdi and Panjaburee (2015), that is, inquiry-based learning with simulations is a promising area for science-based instruction to foster learners' mental interaction with the physical and social world to develop scientific understanding, explanation, and communication among science ideas. Moreover, student engagement enhanced and better learning accomplished where groups of learners immersed in authentic, real-world problems (Herrington, et al., 2010). The comparative teaching, using by the ISLEC, which connects the prior knowledge with new knowledge was not used by any other of mentioned-above systems.

Some reflective practice providing by the ISLEC are: (a) prompting students' reflection by asking questions that seek reasons and evidence, (b) providing some explanations to guide students' thought processes during explorations, (c) providing social-learning environments to allow students to see other points of view, (d) designing predictive activities, and (e) provide enough wait-time for students to reflect when responding to inquiries. Engaging students in challenging and collaborative learning experiences, making their own decisions, interacting with more knowledgeable peers, and giving the words to describe the problem they are facing and how to resolve it, are some of the strategies for improving self-regulation through the

ISLEC. ISLEC provides metacognitive skills such as asking questions, planning, monitoring, checking, evaluating, discussing, cooperating, revising, self-testing, connecting how information to prior knowledge, and involving the social mediation of thinking by others. In ISLEC, students are allowed to go back and make additional observations to make their conclusions more confident because simulations are given them that can run as many times as they wish and repeat some measurements that may be incorrect. Natural curiosity in ISLEC is fostered by thought-provoking questions, hypothesizing through discussion and brainstorming, and learning through active exploration and discovery. Moreover, in ISLEC, the students' inductive reasoning skills promoted when they draw inferences based on prior experiences obtained from previous activities, and on observations in simulations.

The evaluation of the interactive scenario by students showed that it: supports reflection, self-regulation, and problem-solving; promotes deeper understanding, investigative skills, meta-cognitive skills, observational skills, inference skills, and inductive reasoning skills; fosters natural curiosity; assists in discovery of knowledge; turns experiences into learning and enables pre-existing knowledge of the learner; and leading to increased learner motivation. Moreover, it is usable and useful. Concerning the development of critical thinking and inquiry skills, the results are the same with the Cakir and Irez (2006) and Ahmed and Parsons (2013) as referred above.

The role of the student teams is very important for improving of each student's achievement and in the foreseeable future, we will improve the ISLEC in the functions that have low functionality, such as the ability to encourage students' cooperation and cover all learning pace.

References

Abdullah, S. and Shariff, A. (2008). The effects of inquiry-based computer simulation with cooperative learning on scientific thinking and conceptual understanding of gas laws. *Eurasia Journal of Mathematics, Science and Technology Education*, 4(4), 387-398.

Abdi, A. (2014). The effect of Inquiry-Based Learning Method on Students' Academic Achievement in Science Course. *Universal Journal of Educational Research*. 2 (1), 37-41

Ahmed, S., & Parsons, D. (2013). Abductive Science Inquiry Using Mobile Learning Technologies. In Jovanovic, J. and Chiong, R. (Eds.) *Technological and Social Environments for Interactive Learning*, Santa Rosa, California: Informing Science Press. (pp.363-390). Available from: http://www.formatex.org/micte2006/pdf/121

Birchfield, D., Ciufo, T., Minyard, G., Qian, G., Savenye, W., & Sundaram, H. (2006). SMALLab: A mediated platform for education. *Paper presented at the ACM SIGGRAPH*, Boston, MA.

Boud, D., Keogh, R. & Walker, D. (1985). *Reflection: Turning Experience into Learning*. London: Kogan Page.

Brotherton, P.N. & Preece, P. F.W. (1996). Teaching science process skills. *International Journal of Science Education,* 18(1), 65-74

Cakir, M. & Irez, S. (2006). *Creating a Reflective Learning Community: The role of information technology in Genetics learning*. [Online]. [Accessed Feb, 20, 2017].

Carroll M.J. (1999). Five Reasons for Scenario-based Design, *Proceedings of the 32nd Hawaii International Conference on System Sciences*, 3.

Chi M. T. H. (2008). *Three types of conceptual change: Belief revision, mental model transformation, and categorical shift.* In Vosniadou S. (Ed.), Handbook of research on conceptual change (pp. 61-82). Hellsdale, NJ: Lawrence Erlbaum.

Drude, P. (1900). *Zur Elektronentheorie der Metalle*. *Annalen der Physik*. 306 (3): 566.

Fisher, R. (2006). *Teaching, Thinking, and Creativity. Developing creative minds and creative futures. Talking to Think: Why Children Need Philosophical Discussion*. In Jones D. & Hodson P. (eds) Unlocking Speaking and Listening London: Fulton.

Gentner, D. & Markman, A. B. (1994). Structural alignment in comparison: No difference without similarity. *Psychological Science*, 5, 152–158.

Gingrich, P. (2004). *Introductory Statistics for the Social Sciences*. Chapter 11. Department of Sociology and Social Studies. University of Regina.

Gök, T. (2010). A new approach: Computer-assisted problem-solving systems. *Asia-Pacific Forum on Science Learning and Teaching*, 11(2).

Grigoriadou M. & Papanikolaou, K. (2000). Learning Environments on the WEB: The Pedagogical Role of the Educational Material, *Journal Themes in Education*, 1(2), 145-161.

Harlen W. (2013). Inquiry-based learning in science and mathematics. *Review of Science, Mathematics and ICT Education*, 7(2), 9-33.

Healey, J.F. (2010). *The Essentials of Statistics: A Tool for Social Research*. Second Edition. CA: Wadsworth, USA

Heller, P., & Hollabaugh, M., (1992). Teaching Problem-Solving Through Cooperative Teaming. Part 2: Designing problems and structuring teams, *American Journal of Physics*, 60, 637-644.

Hennessy, S., Deaney, R., Ruthven, K. & Winterbottom, M. (2007). Pedagogical strategies for using the interactive whiteboard to foster learner participation in school science. *Learning, Media and Technology*, 32, 283-301.

Herrington,J., Reeves,T. C.,& Oliver, R. (2010). *A Guide to Authentic E-learning*. London and New York: Routledge.

Hung, D. & Chen, D. (2002). Two kinds of scaffolding: The dialectical process within the authenticity-generalizability (A-G) continuum. *Education Technology & Society*, 5(4), 148-153.

Jaakkola T. & Nurmi S. (2004). Academic impact of learning objects: the case of electric circuits. *Paper presented at the British Educational Research Association Annual Conference*, University of Manchester.

Johnson, D. W., Johnson, R.T. (1989). *Cooperation & Competition: Theory and research*. Edina, MN: International Book Company.

Keys, C.W., Bryan, L.A. (2001). Co-Constructing Inquiry-Based Science with Teachers: Essential Research for Lasting Reform. *Journal of Research in Science Teaching,* 38(6), 631-645.

Knox, D.K. The California Critical Thinking Skills Test. Clemson University. Available at: https://www.clemson.edu/academics/programs/thinks2/documents/scholars/summer_2013/knox_cctst.pdf

Lee, H.S., Linn, M C., Varma, K., & Liu, O.L. (2010). How do technology-enhanced inquiry science units impact classroom learning*? Journal of Research in Science Teaching*, 47(1), 71–90.

Lee, V.S. (1999). Creating a Blueprint for the Constructivist Classroom. *The National Teaching and Learning Forum*, 8(4), 1-4.

Linn, M.C. & Eylon, B-S. (2006). *Science education: Integrating Views of Learning and Instruction*. In P.A. Alexander and P. H. Winne (Eds.), Handbook of Educational Psychology (2nd ed., pp. 511-544). Mahwah, NJ: Lawrence Erlbaum Associates.

Mayer, R.E. (2004). Should There Be a Three-Strike Rule Against Pure Discovery Learning? The Case for Guided Methods of Instruction. *American Psychologist*, 59(1), 14 –19

McDermott, L.C. (1990). Research and Computer-Based Instruction: Opportunity for Interaction, *American Journal of Physics*, 58(5), 452-462.

McDermott, L. & Shaffer, P. (1992). Research as a guide for curriculum development: An example from introductory electricity. *American Journal of physics*, 60(11), 994-1013.

Meir, E., Perry, J., Stal, D., Maruca, S., & Klopfer, E. (2005). How Effective Are Simulated Molecular-Level Experiments for Teaching Diffusion and Osmosis? *Cell Biology Education*, 4(3), 235-248.

Mikroyannidis, A., Okada, A., Scott, P., Keynes, M. Rusman, H. Specht, M., Stefanov, K., Boytchev, P., Protopsaltis, A., Held, P., Hetzner, S., Kikis-Papadakis, K., & Chaimala F. (2013). WeSPOT: A Personal and Social Approach to Inquiry-Based Learning. *Journal of Universal Computer Science*, 19(14), 2093-2111.

Norton, G., Taylor, M., Stewart, T. Blackburn, G., Jinks, A., & Razdar, B. (2012). Designing, developing, and implementing a software tool for scenario based learning. *Australasian Journal of Educational Technology,* 28(7), 1083-1102.

Okada, A. (2013). Scientific Literacy in the Digital Age: Tools, Environments, and Resources for co-inquiry. *European Scientific Journal*, 4, 263–274.

Papadimitriou, A., Grigoriadou, M., & Gyftodimos, G. (2012). MATHEMA: A Learner-Controlled Adaptive Educational Hypermedia System, *Journal of Information Technology and Application in Education (JITAE)*, 1(2), 47-73.

Ronen, M. & Eliahu, M. (2000). Simulation. A Bridge Between Theory and Reality: The case of electric circuits. *Journal of computer assisted learning*, 16(1), 14-26.

Sengupta, P., & Wilensky, U. (2009). Learning Electricity with NIELS: Thinking with electrons and thinking in levels. *International Journal of Computers for Mathematical Learning*, 14(1), 21-50.

Slotta, J.D. (2004).The Web-based Inquiry Science Environment (WISE): Scaffolding Knowledge Integration in the Science Classroom. In M.C. Linn, P. Belland E. & Davis(Eds). *Internet Environments for Science Education*. (pp. 203-232). Lawrence Erlbaum & Associates. http://www.encorewiki.org/download/attachments/11961270/SlottaWISE2004.pdf

Srisawasdi N., Panjaburee, P. (2015). Exploring Effectiveness of Simulation-based Inquiry Learning in Science with Integration of Formative Assessment. *Journal of Computers in Education*, 2(3), 323–352

Srisawasdi, N., & Sornkhatha, P. (2014). The effect of simulation-based inquiry on students' conceptual learning and its potential applications in mobile learning. *International Journal of Mobile Learning and Organisation*, 8(1), 24–49.

Stewart, T.M., & Brown,M.E.(2008). Developing interactive scenarios: The value of good planning, hiteboards and table-based schemas. *Proceedings of ascilite* (pp. 983-990) Melbourne, Australia.

Tao, P-K., & Gunstone, R.F. (1999). Conceptual Change in Science through Cooperative Learning at the Computer. *International Journal of Science Education*. 21(1), 39-57.

Trundle, K. C., & Bell, R. L. (2010). The use of a computer simulation to promote conceptual change: A quasi-experimental study. *Journal of Computers & Education*, 54(4), 1078–1088.

Van Joolingen, W. R., de Jong, T., Lazonder, A. W., Savelsbergh, E. R., & Manlove, S. (2005). Co-Lab: research and development of an online learning environment for collaborative scientific discovery learning. *Computers in Human Behavior*, 21, 671–688

Winn, W. D., Stahr, F., Sarason, C., Fruland, R., Oppenheimer, P. & Lee, Y-L. (2005). Learning oceanography from a computer simulation compared with direct experience at sea. *Journal of Research in Science Teaching*, 43(1), 25–42.