Can Serious Games Reduce Electric Current Misconceptions among 10th Grade Moroccan Science Pupils?

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***Abstract*—This study examined the effectiveness of serious games in reducing misconceptions held by 10th grade Moroccan learners regarding the electric current concept. The sample comprised 42 learners from a secondary public school. All categories of misconceptions were probed by means of a diagnostic instrument. The items consisted of twelve qualitative conceptual questions. The analysis of data collected through SPSS software showed a significant difference in terms of learning achievement between the pre-test and post-test, with pupils performing significantly better on the post-test. It was also found from a deeper analysis that the integration of serious games as alternative didactic tools reduces, to a certain extent, the pupils' misconceptions. The results from this study are in accordance with previous related studies, and suggest that serious games can replace the usual instructional tools in specific situations in helping teachers to create a meaningful conceptual change for pupils.**

***Keywords*—learning achievement, serious games, electric current, misconceptions, diagnostic instrument**

I. Introduction

Electricity misconceptions have long posed significant challenges in science education. Since the 1970s, numerous educational researchers have examined these misconceptions to understand their root causes and develop strategies to correct them [1–4]. Despite advancements in teaching strategies, these misconceptions, particularly about fundamental electricity concepts like electric current, continue to persist [5]. While traditional instructional methods, which are usually teacher-centered, may impart factual knowledge, they often fail to promote the deep conceptual understanding necessary for meaningful learning [6, 7]. Research has showed that achieving such learning requires not only the acquisition of knowledge but also the elimination of incorrect preconceptions and replacing them with scientifically accurate explanations [8].

Students struggle to comprehend electricity-related concepts due to the abstract nature of these topics, compounded by misconceptions that are largely derived from everyday experiences or incomplete explanations [9, 10]. For instance, many students misunderstand the behavior of electric current, frequently seeing it as water flowing through a canal. These misconceptions act as barriers to learning, preventing students from fully grasping the principles that underlie electricity [11, 12]. Even when students are exposed to formal scientific explanations, their deep preconceptions can cause them to reject or misinterpret the new information, perpetuating a cycle of misunderstanding [11].

Moreover, misconceptions are not exclusive to pupils. Research reveals that high school students, teachers, and even practitioners frequently exhibit misunderstandings about abstract scientific concepts [13, 14]. Recent studies [15, 16], further suggest that these misconceptions are consistent across various educational levels, making it clear that misconceptions form a substantial barrier to academic progress in science. It is, therefore, essential for science curricula to be designed not just to impart factual knowledge but to engage students actively in identifying and correcting their misconceptions [13].

In recent years, educational technology has emerged as a powerful tool to assist in this endeavor. The use of technology-driven learning solutions, such as simulations and serious games, has been identified as a promising approach for actively engaging students in the learning process [17, 18]. A recent study [19] has suggested that serious games, in particular, provide dynamic and interactive learning environments that allow students to experiment with scientific phenomena in an immersive setting without risk. These tools help to bridge the gap between students' misconceptions and their scientific understanding of science concepts by providing visual and experiential representations of abstract phenomena, thereby supporting conceptual change [20].

In addition, serious games not only enhance the understanding of abstract scientific concepts but also foster higher-order thinking and problem-solving skills [21]. Unlike traditional teaching methods, which often focus on rote memorization, serious games require students to apply their knowledge to real-world scenarios, reinforcing scientific concepts through experiential learning. By providing an engaging platform for learners to test their hypotheses, confront their misconceptions, and receive immediate feedback, serious games create an environment conducive to meaningful conceptual change [22, 23].

Therefore, similar to other approaches and techniques that were previously used to dispel pupils' misconceptions such as Inquiry-Based Learning [9] and educational simulation [18], this study aims to highlight the educational potential of serious games and whether they are an effective tool in helping pupils develop a scientific understanding of the electric current concept.

A. Context of the Study

In the Moroccan educational system, 10th grade students frequently struggle with misconceptions about

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electricity [24], particularly when it comes to understanding concepts such as electric current. Traditional teaching methods often rely on textbooks and teacher-centered experiments, which may not fully engage students or address these misconceptions effectively. In contrast, serious games offer a dynamic, interactive learning environment that promotes active participation and immediate feedback [25]. Unlike traditional methods, serious games allow students to experiment with concepts in real-time, confront their misunderstandings directly, and apply their knowledge in practical scenarios [26]. This makes serious games a promising tool for enhancing conceptual understanding and overcoming persistent misconceptions in the electricity topic.

B. *The Aim of the Study*

The aim of this study is to examine whether serious games are effective in improving students' academic performance and reducing misconceptions about electric current among 10th grade Moroccan Physical Sciences pupils. Specifically, the study explores how the interactive and engaging nature of serious games can help students better grasp abstract concepts in electricity and challenge their pre-existing misconceptions, potentially leading to deeper understanding and improved learning outcomes.

Overall, this research seeks to address the following questions:

1) Do serious games significantly contribute to learning achievement in electrical circuit concepts among 10th grade pupils?
2) To what extent do serious games reduce misconceptions about electric current among 10th grade pupils?

II. Literature Review Framework

The study of electrical concepts represents a fundamental component of science education, introduced early in natural science courses and continuing through advanced physics curricula. Despite its widespread presence in our daily activities, students often struggle to grasp electrical concepts accurately. Research has shown that learners frequently develop their own mental models and explanations about electricity that deviate significantly from accepted scientific principles. Extensive studies have examined how students understand electrical phenomena, with particular focus on circuit behavior. These investigations have revealed persistent misconceptions about key concepts including electrical current flow, voltage, and resistance. The scientific literature has documented several common alternative understandings that students typically hold when learning about basic electrical circuits, specifically:

- Sink or Unipolar Model: Students commonly visualize electricity as simply flowing downward from the power source to the device, similar to water flowing through a pipe. This oversimplified understanding fails to capture the true nature of electrical circuits [27, 28].
- Clashing Current Model: A prevalent misconception where students envision two types of electricity traveling from opposite terminals and meeting at the device to create power, rather than understanding the actual flow of electrical current [28, 29].
- Attenuation Model: Students often incorrectly believe that electric current progressively decreases along a circuit as devices "consume" it, rather than understanding current conservation [2, 4].
- Sharing Current Model: There's a common misunderstanding that devices in a circuit receive equal amounts of current, with a reduced amount returning to the power source [2, 27].
- Local Reasoning Model: Students frequently focus only on the specific location of a circuit modification, failing to comprehend how changes affect the entire circuit system [3, 30].
- Empirical rule Model: A mistaken belief that the brightness of a bulb directly correlates with its physical distance from the battery [31].
- Power Supply as a Constant Current Source Model: Students often incorrectly view batteries as devices that provide constant current rather than understanding their role as constant voltage sources [2, 29].
- Sequential Reasoning Model: When analyzing circuit changes, students often incorrectly think about current flow in terms of "before" and "after" passing a particular point, rather than understanding simultaneous effects [4, 32].
- Short Circuit Model: Students frequently and incorrectly dismiss the role of connecting wires when no devices are attached, failing to understand the concept of short circuits [3].
- Parallel Circuit Misconception: Students commonly make an incorrect assumption about parallel circuits, believing that adding more resistors in parallel increases the overall resistance. In reality, the opposite is true - parallel resistance combinations actually decrease the total circuit resistance. This fundamental misunderstanding affects how students analyze parallel circuit behavior [3, 31].
- Current Flow as Water Flow: A widespread oversimplification occurs when students equate electrical current flow to water movement through pipes. While this analogy might seem helpful initially, it leads to incorrect assumptions about how electricity actually moves through conductors. Students need to understand that electrical current flow involves more complex mechanisms than simple fluid dynamics [27, 28].

The investigation of research questions is framed by this cognitive tool framework to clearly explain the extent to which this study can address these common misconceptions.

III. Methodology

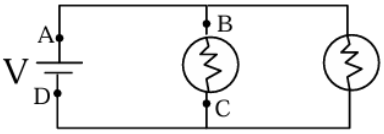
The participants consisted of 42 science pupils (20 females and 22 males) from a 10th grade Moroccan public high school, with a mean age of 15 years old. The pupils had previously studied electricity concepts as part of their standard science curriculum and therefore possessed prior knowledge regarding these concepts. All participants came from middle socioeconomic backgrounds.

This study followed an experimental research design with the objective of "investigating the extent to which an educational intervention using serious games can reduce pupils' misconceptions [33]". This research design involved conducting a study with the same participants throughout all experimental phases (pretest-intervention-posttest). The research design was considered experimental because the sample was randomly selected from among the science pupils, meaning each participant had an equal chance of receiving the treatment [33]. In this respect, we randomly selected 42 pupils from this pool using a random number generator based on the pupil identification lists.

IV. Data Collection and Analysis

The diagnostic instrument used in this research was the Electric Circuit Conceptual Evaluation (ECCE) [34], it was an adaptive instrument to evaluate cognitive gains for pupils when using the microcomputer based physical circuit laboratories [35]. The ECCE was developed by David Sokoloff [35], and has been proven to be a valid tool for measuring conceptual knowledge of electrical concepts. For this study, the ECCE was translated into French without any modifications and was reviewed by a panel of two physics educators to ensure that the items aligned with the Moroccan curriculum and could be easily understood by pupils. The test consisted of twelve conceptual questions that covered the principal DC circuit concepts (See Appendix). Each item exhibited circuit patterns that clearly conveyed the real sense without biasing it, as shown in this example.

Compare the current at A now to the current at A before with only one bulb.



A. The current at point A has now doubled.
B. The current at point A is greater than before but less than double.
C. The current at point A remains unchanged.
D. The current at point A is now reduced to half of its previous value.
E. The current at point A has decreased but is more than half of the previous value.

The purpose of this diagnostic test was to reveal the pupils' misconceptions that they had brought as background knowledge to the science classroom in the formal educational setting. The pretest was conducted one week before the implementation of serious games. The intervention process was described through the integration of this interactive educational technology. The participants were also invited to respond on the post-test questions to examine whether serious games can help pupils reduce their misconceptions, which concluded in the diminishing number of misconceptions and therefore contributed to a conceptual change regarding the electric current concept. The percentage of correct answers corresponding to each item was calculated in both the pre-test and the post-test. Subsequently, the pre- and post-test outcomes were analyzed to assess whether the integration of serious games in the Physical sciences classroom can effectively reduce the identified misconceptions about the electric current concept. It is important to indicate that the order of appearance of the items in posttest as well as the order of appearance of the correct responses to each item, was rearranged to avoid any influence that could be produced by the pupil's memorization of their decisions in the pretest.

Due to the high consistency of the questions' objectives for the Electric Circuits Concept Evaluation [34] with the Simple Electric Circuit Diagnostic Test [28], the taxonomy of misconceptions probed by the inventory of Eryılmaz [28] guided the processes of selecting the misconceptions and helped us to determine which category of misconception was exhibited by each response.

The paired-samples t-test as well as McNemar's test were used to compare statistically the means of the pre- and post-test for the same sample of pupils to investigate whether there was a significant difference between these means.

In the processing phase, the categorical data were converted to a binary format (1 for misconception, 0 for no misconception) for identified misconception. The dichotomous outcomes were then analyzed using McNemar's test in SPSS to assess the magnitude of changes between pretest and posttest misconceptions. The findings were represented both graphically and in tabular form.

V. The Intervention

By analyzing the results obtained from the previous diagnostic (pre-test), an appropriate serious game was selected, called "Kirchhoff's Revenge". We chose to make the pedagogical intervention through this digital game for two reasons: first, because of its open access property, and second, the potential of this tool was previously recommended by Kortemeyer *et al.* [36] as an effective educational game to address electric current conceptual difficulties. In addition, the learning strategy from the environment provides learners with high curiosity to discover macroscopically the nature of current. Indeed, moving "charges" are indicated, so, as opposed to real circuit elements, currents are visible. In terms of implementation, this application was installed on each laptop from its official website, and the instructions to be followed were also delivered in additional videos. The experimentation was organized with the orientation of the teacher when students used the serious games in a cooperative learning setting. In this sense, the principal rule for the teacher focused on how to effectively incorporate serious games in the learning-teaching process. A trial run was carried out to resolve any potential issues and ensure that the process would proceed smoothly without unexpected complications. The interaction with the serious game environment is presented in Fig. 1.

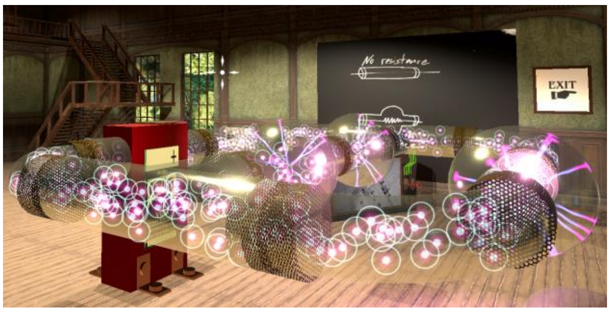


Fig. 1. Screen shot of serious game "Kirchhoff's Revenge" used.

The above serious game was used by the teacher to correct misconceptions that were previously identified from the ECCE instrument. This serious game was well referenced Kortemeyer *et al.* [36] as a prominent tool in overcoming obstacles related to the misunderstanding of electric current. Pupils conceive that when more than one bulb is added in a parallel pattern their brightness decreases because the intensity of electric current in each bulb decreases by half. In addressing this significant misconception, we helped pupils use the appropriate serious game to create conceptual change towards a better assimilation of the behavior of electric current. Before the experimental sessions, all participants first benefited for a trial workshop that provided the opportunity for them to become more familiar with the control options of the serious game, and required them to construct various circuit patterns, including principally the series and parallel circuits. Thereafter, the teacher allowed the pupils to begin completing all-game tasks step by step. Through interaction with the game environment, they observed, without taking any measurements**,** how the electric current flowed and how the brightness of the bulbs varied when additional bulbs were added either in series or in parallel circuits.

VI. Results

Table 1 provides a summary of the descriptive statistics for both the pre-test and post-test results.

Table 1. Descriptive statistics for each test

Test Type	N	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Pre-Test	42	0.00	8.00	4.0238	0.28204	1.82781	3.341
Post-Test	42	2.00	10.00	5.6190	0.27254	1.76625	3.120
Valid N (listwise)	42						

The mean result for the pre-test was equal to M = 4.02, while the result of the post-test reached M = 5.62. Therefore, the mean for the post-test score was higher than the mean score for the pre-test. There was a difference between the means of the posttest and pretest of 1.6, which demonstrated that the serious game enhanced the scientific understanding of pupils.

To determine whether this difference was significant, the paired sample t-test was adopted in this second analysis.

Table 2. Paired samples test

Pair 1	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Post-Pretest	1.59524	2.30651	0.35590	0.87648	2.31400	4.482	41	0.000

The test indicated a significant difference in scores between the pre- and post-test (t (41) = 4.482, p(two-tailed) < 0.05), with pupils performing higher on the post-test compared with the pre-test. It can be concluded from this analysis that the use of the serious game led pupils to perform significantly better on the diagnostic test related to the DC circuit concepts. In addition, this approach demonstrated practicality through supplementary analysis which showed its effectiveness in reducing learning difficulties. The results revealed a large effect size through Cohen's d analysis which equal 0.69 at α = 0.05 with an observed power of 0.98, suggesting that serious games serve as an effective tool for conceptual change. In other words, they had a substantial impact on reducing misconceptions about electric current.

The comparative performance that was obtained using the diagnostic instrument was analyzed in detail, with item by item, as presented in Fig. 2.

The findings have revealed that there was a remarkable increase in the percentage of correct answers from the pre to the post-test for the following items: (1), (5), (7), (8), (9), (10), (11) and (12). The correct responses increased by a mean percentage of 41%. For items (2), (3), (4) and (6), there was a minor decrease in the percentage of correct answers. From these findings, it can be concluded that the use of serious games as an educational tool produced a significant conceptual change, resulting in diminished certain kinds of misconceptions, as a considerable number of pupils chose the correct answers.

Based on the recent literature that served as a cognitive tool framework for this study [3, 4, 27–29, 31, 32], we were able to identify several types of misconceptions in both the pretest and the posttest results. From the findings of the pre-test, eight common misconceptions were identified. Meanwhile, the posttest analysis revealed only seven misconceptions.

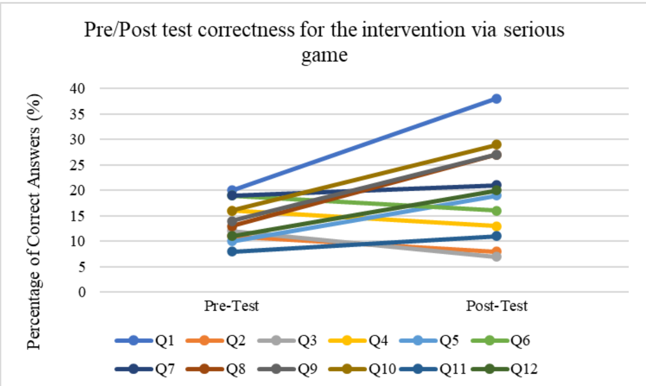


Fig. 2. Percentages of correct responses for each item in the pre-test and post-test.

It can be seen from Fig. 3 that almost all identified misconceptions decreased from the pretest to the posttest by a mean percentage of 31%, only the "Power supply as a constant current source model" and "Parallel circuit misconception" slightly increased among the participants after they used serious games. These results demonstrate that some misconceptions persisted after the intervention to a certain extent. Jaakkola & Nurmi [37], Ronen & Eliahu [38] and Treagust & Duit [39] previously reported the difficulty of removing the pupil misconceptions in an absolute manner, even when using appropriate technological tools designed for this purpose.

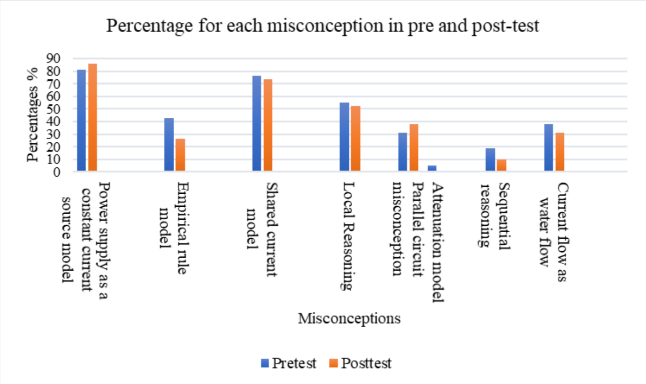


Fig. 3. Represents the percentage of pupils who held the misconceptions in the pre and post-test.

To discover which misconceptions identified by the ECCE instrument were significantly reduced after the intervention via serious games, we used a McNemar's test [40], a non-parametric test appropriate for nominal data. The McNemar test aimed to determine whether there are differences on a dichotomous dependent variable between two paired groups. It can be considered to be similar to the paired-samples t-test, but for a dichotomous rather than a continuous dependent variable. From the statistical analysis, the attenuation model misconception was significantly addressed by means of a serious game, as justified by a p-value no higher than 0.05 (p = 0.002). Consequently, the serious game succeeded in diminishing the pupils' misconceptions, though not as significantly as expected.

VII. Discussion

This research used a diagnostic instrument (ECCE) [34] to identify the possible misconceptions that 10th grade Moroccan pupils experienced in the electricity topic, specifically regarding DC simple circuits. It then examined the effectiveness of serious games in eradicating certain misconceptions. The considerable increase in correct responses implicitly indicates that the Kirchhoff's Revenge game is able to reduce certain misconceptions and therefore has a positive impact on learning electricity concepts. In terms of statistical analysis, the data collected for both pre and posttest showed that serious games produced a significant enhancement in test performance (See Table 2). This signifies that the use of serious games in science disciplines where the electricity as a main topic can reduce the common misconceptions held by pupils to a certain extent. The findings align with previous studies that proved serious games to be a potential platform for changing pupils' misconceptions in areas like Mechanics [41], Chemistry [20] and Biology [42–44]. These studies all revealed that the use of serious games was effective in reducing pupils' misconceptions of scientific concepts. It should be noted that each related study found a specific result in terms of the serious games' effectiveness. In this case, Kirchhoff's Revenge game did not significantly reduce the pupil misconceptions, even though this game provides for users a virtual laboratory that macroscopically incorporates electric charge.

The Moroccan educational system has adopted inappropriate approach to assessing the pupils' conceptual understanding, which is primarily based on quantitative methods. This methodology lacks sufficient diagnostic elements, making it difficult to identify the possible misconceptions held by pupils in the science classroom. This lack of detail undermines whether pupils scientifically understand DC circuit concepts. Additionally, the content-laden curriculum creates pressure for teachers to cover all topics [45]. Therefore, learners do not have the time to effectively assimilate each concept in turn, and teachers still find it difficult to remedy the misconceptions encountered among pupils. Especially when most pupils claim to be demotivated to continue learning through the usual instructional methods [46]. The innovative pedagogical approach based on the use of serious games to eliminate misconceptions is a practicable means by which instructors under these challenging obstacles can reduce pupil misconceptions in an enjoyable setting and support pupils in achieving conceptual change.

However, it can be concluded that some misconceptions are resistant and difficult to eliminate, and there is no single pedagogical intervention that can address the educational challenges related to science misconceptions [47]. In fact, there are other pedagogical methods that have proved feasible for eradicating certain misconceptions, such as educational simulations [18, 47, 48], and methods based on concept cartoons worksheets [49].

The results of this study provide effective support for the use of educational technology in the teaching and learning processes in the science classroom. This innovative tool effectively enhanced the science learning for pupils who had significant weakness regarding electricity topics, as mentioned by Kortemeyer *et al.* [36]. The serious game "MisCoAct" recently showed a great potential as a fruitful way of identifying and overcoming the common misconceptions [20]. Gauthier [50] also reported that Interactive simulations and game-based learning resolved more misconceptions than baseline, which contributes to creating a significant conceptual change, this finding is in concordance with our results. In regard to the Moroccan context, research recently [51] demonstrated that learning through video games produces a shift in the Newtonian concepts misconceptions. It can be said that scientific literature perceived serious games as robust tools in rectifying diverse misconceptions. Although technology is widespread in several areas such as personal lives, and social media remain a principal source of information, the use of ICT has not been extensively adopted in all Moroccan science classrooms [52–55]. The crucial constraint can largely explain this limited prevalence is the poor digital skills of teachers, as has been highlighted in some research [56, 57]. How to effectively incorporate such digital support in science content and determine the appropriate time for its implementation in learning processes undoubtedly play an important role in successfully integrating it into science classrooms. On the whole, this study has shown that if teachers have the necessary technological competencies, the experience of game-based learning can be successfully introduced.

However, it is important to note that this research presents some limitations. Indeed, the experimental study involved a small sample size of 42 science pupils; the findings therefore cannot be generalized to a wider group of pupils or a bigger population. This study lacks a qualitative method that includes additional reasoning from the participants either in the diagnostic test or regarding their views about the serious games experience. In this regard, a mixed-methods approach could provide a more inclusive overview on the effectiveness of serious games for certain aspects.

VIII. Conclusion and Recommendations

The study confirmed that Moroccan pupils have several misconceptions about the electric current concept, which appeared extensively before the pedagogical intervention. To address these misconceptions, the intervention via serious games is still one of the pedagogical solutions, alongside educational simulations that enabled reducing some misconceptions. However, the effectiveness of serious games was not significant, even though the identified misconceptions decreased by a mean percentage of 31%. Nevertheless, serious games succeeded in enhancing the overall performance of pupils in the posttest. Thus, similar to educational simulations, serious games provide an effective platform for science learners to overcome their misconceptions to a certain extent.

Some studies have suggested that the effectiveness of such pedagogical tools depend on factors like age, language and gender [27, 58]. Therefore, it is recommended by this research to investigate in a follow up study whether these aforementioned factors have a significant impact on the effectiveness of serious games in reducing Moroccan students' misconceptions.

In terms of implications, the present study suggested that serious games are needed for an effective design to creating more desired learning for pupils through multiple learning challenges. A wide range of activities should be adjustable according to player skills in which their levels within learner's Zone of Proximal Development [59], the educational policies therefore will be extensively open to educational games as potentially effective tools.

Appendix

A. *Electric Circuit Conceptual Evaluation (ECCE)*

A light bulb and a battery are connected as shown below.

1) Choose the correct answer:

A. The current is highest at A.

B. The current is highest at B.

C. The current is highest at C.

D. The current is highest at D.

E. The current is the same everywhere.

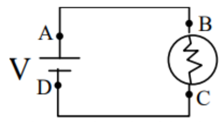
F. The current is the same between A and B and smaller than between C and D.

G. The current is the same between A and B and larger than between C and D.

H. The current is the same everywhere except in the light bulb.

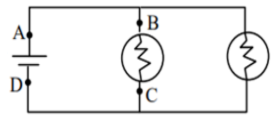
I. The current is the same everywhere except in the battery.

J. None of the above is true".



Circuit 1

For questions 2, 3, 4, and 5, a second identical light bulb is added to the circuit from question 1, as shown below.



Circuit 2

2) Which has the highest electric current intensity?

A. The current intensity at point A in circuit 1

B. The current intensity at point A in circuit 2

C. Neither, they are identical

3) Which has the highest electric current intensity?

A. The current intensity at point B in circuit 1

B. The current intensity at point B in circuit 2

C. Neither, they are identical

4) Now compare the brightness of the light bulb connected between B and C in both circuits.

A. The light bulb located between BC in circuit 1 is brighter.

B. The light bulb located between BC in circuit 2 is brighter.

C. Both light bulbs have the same brightness.

5) Compare the voltage across the light bulb BC between circuit 1 and 2:

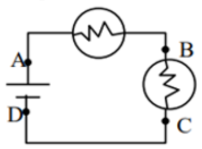
A. The voltage across light bulb BC in circuit 1 is higher

B. The voltage across light bulb BC in circuit 2 is higher

C. The voltage across light bulb BC is the same in both circuits

D. None of these statements is correct.

For questions 6, 7, and 8 a second identical light bulb is added to the circuit from question 1, as shown below.



Circuit 2

6) In which circuit is the current intensity at point A highest?

A. The current intensity at point A in circuit 1

B. The current intensity at point A in circuit 2

C. Neither, they are identical

7) Now compare the brightness of the light bulb connected between B and C in both circuits.

A. The light bulb located between BC in circuit 1 is brighter.

B. The light bulb located between BC in circuit 2 is brighter.

C. Both light bulbs have the same brightness.

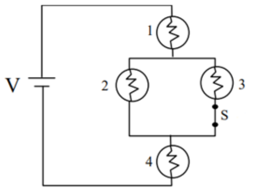
8) Compare the voltage across light bulb BC between circuit 1 and 2.

A. The voltage across light bulb BC in circuit 1 is higher

B. The voltage across light bulb BC in circuit 2 is higher

C. The voltage across light bulb BC is the same in both circuits

D. None of these statements is correct.



9) Which of the following correctly ranks the bulbs in brightness?

A. All bulbs are just as bright

B. 1 is brightest, 2 next brightest, 3 next brightest and 4 dimmest

C. 1 is brightest, 2 is just as bright as 3 and both are dimmer than 1. 4 is dimmest.

D. 1 is just as bright as 4. 2 is just as bright as 3 and both are dimmer than 1 and 4.

E. 2 is just as bright as 3. 1 is just as bright as 4 and both are dimmer than 2 and 3.

F. 1 is brightest, 4 is next brightest, 2 is just as bright as 3 and both are dimmer than 4

J. None of these is correct.

10) Which of the following correctly ranks the currents flowing through the bulbs?

A. All bulbs have the same current flowing through them

B. The current through 1 is largest, 2 next largest, 3 next largest and 4 smallest

C. The current through 1 is largest, 2 is just as large as 3, an both are smaller than 1, 4 is smallest

D. The current through 1 is just as large as 4, 2 is just as large as 3 and both are smaller than 1 and 4

E. The current through 2 is just as large as 3, 1 is just as large as 4 and both are smaller than 2 and 3

F. The current through 1 is largest, 4 is next largest, 2 is just as large as 3 and both are smaller than 4

J. None of these is correct

11) What happens to the current through bulb 1 if the switch, S, is opened?

A. It increases

B. It remains the same

C. It decreases

J. Not enough information is given

12) What happens to the current through bulb 2 if the switch, S, is opened?

A. It increases

B. It remains the same

C. It decreases

J. Not enough information is given.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

MA prepared the theoretical basis of the research, conducted experimental research and statistical analysis of data, discussed the findings, and wrote the manuscript; JK analyzed the manuscript, participated in discussions, and supervised our study; AT supervised the preparation of this manuscript. All authors approved the final version.

References

[1] R. Driver and J. Easley, "Pupils and paradigms: A review of literature related to concept development in adolescent science students," *Stud. Sci. Educ.*, vol. 5, no. 1, pp. 61–84, Jan. 1978. doi: 10.1080/03057267808559857

[2] D. Shipstone, "Pupils' understanding of simple electrical circuits. Some implications for instruction," *Phys. Educ.*, vol. 23, no. 2, p. 92, 1988.

[3] P. M. Heller and F. N. Finley, "Variable uses of alternative conceptions: A case study in current electricity," *J. Res. Sci. Teach.*, vol. 29, no. 3, pp. 259–275, Mar. 1992. doi: 10.1002/tea.3660290306

[4] L. C. McDermott and P. S. Shaffer, "Research as a guide for curriculum development: An example from introductory electricity. Part I: Investigation of student understanding," *Am. J. Phys.*, vol. 60, pp. 994–994, 1992.

[5] Y. Zhu, L. Zhang, Y. Leng, R. Pang, and X. Wang, "Event-related potential evidence for persistence of an intuitive misconception about electricity," *Mind Brain Educ.*, vol. 13, no. 2, pp. 80–91, May 2019. doi: 10.1111/mbe.12188

[6] C. H. Crouch and E. Mazur, "Peer instruction: Ten years of experience and results," *Am. J. Phys.*, vol. 69, no. 9, pp. 970–977, 2001.

[7] R. R. Hake, "Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," *Am. J. Phys.*, vol. 66, no. 1, pp. 64–74, 1998.

[8] G. J. Posner, K. A. Strike, P. W. Hewson, and W. A. Gertzog, "Accommodation of a scientific conception: Toward a theory of conceptual change," *Sci. Educ.*, vol. 66, no. 2, pp. 211–227, 1982.

[9] H. D. Assem, M. Owusu, S. Issah, and B. Issah, "Identifying and dispelling students' misconceptions about electricity and magnetism using inquiry-based learning in selected junior high schools," *ASEAN J. Sci. Educ.*, vol. 3, no. 1, pp. 13–32, 2024.

[10] A. Halim and D. Lestari, "Identification of the causes of misconception on the concept of dynamic electricity," in *Proc. Journal of Physics: Conference Series*, IOP Publishing, 2019, p. 052060. https://iopscience.iop.org/article/10.1088/1742-6596/1280/5/052060/meta

[11] N. C. Afra, I. Osta, and W. Zoubeir, "Students' alternative conceptions about electricity and effect of inquiry-based teaching strategies," *Int. J. Sci. Math. Educ.*, vol. 7, no. 1, pp. 103–132, Feb. 2009. doi: 10.1007/s10763-007-9106-7

[12] M. Arnold and R. Millar, "Being constructive: An alternative approach to the teaching of introductory ideas in electricity," *Int. J. Sci. Educ.*, vol. 9, no. 5, pp. 553–563, Oct. 1987. doi: 10.1080/0950069870090505

[13] Z.-J. Kock, R. Taconis, S. Bolhuis, and K. Gravemeijer, "Some key issues in creating inquiry-based instructional practices that aim at the understanding of simple electric circuits," *Res. Sci. Educ.*, vol. 43, pp. 579–597, 2013.

[14] N. Wiles and D. Wright, "A hypermedia system to aid teacher understanding of pupil preconceptions," *J. Comput. Assist. Learn.*, vol. 13, no. 1, pp. 26–34, Mar. 1997. doi: 10.1046/j.1365-2729.1997.00004.x

[15] R. Duit and C. V. Rhöneck, "Learning and understanding key concepts of electricity," *Connect. Res. Phys. Educ. Teach. Educ*., vol. 1, pp. 1–6, 1997.

[16] K. S. Taber, T. D. Trafford, and T. Quail, "Conceptual resources for constructing the concepts of electricity: The role of models, analogies and imagination," *Phys. Educ*., vol. 41, no. 2, p. 155, 2006.

[17] M. Achour, J. Khouna, and A. Tahiri, 'The use of serious games in physics: A review of selected empirical studies from 2012 to 2021," *Int. J. Inf. Educ. Technol.*, vol. 13, no. 12, 2023. https://www.ijiet.org/vol13/IJIET-V13N12-2014.pdf

[18] U. Ramnarain and S. Moosa, "The use of simulations in correcting electricity misconceptions of grade 10 South African physical sciences learners," *Int. J. Innov. Sci. Math. Educ.*, vol. 25, no. 5, 2017. https://openjournals.library.sydney.edu.au/CAL/article/view/11580

[19] R. Baker, J. Walonoski, N. Heffernan, I. Roll, A. Corbett, and K. Koedinger, "Why students engage in 'gaming the system' behavior in interactive learning environments," *J. Interact. Learn. Res*., vol. 19, no. 2, pp. 185–224, 2008.

[20] N. Belova and C. Zowada, "Innovating higher education via game-based learning on misconceptions," *Educ. Sci.*, vol. 10, no. 9, p. 221, 2020.

[21] G. Hwang and C. Chen, "Influences of an inquiry-based ubiquitous gaming design on students' learning achievements, motivation, behavioral patterns, and tendency towards critical thinking and problem solving," *Br. J. Educ. Technol*., vol. 48, no. 4, pp. 950–971, Jun. 2017. doi: 10.1111/bjet.12464

[22] M.-T. Cheng, H. -C. She, and L. A. Annetta, "Game immersion experience: Its hierarchical structure and impact on game-based science learning," *J. Comput. Assist. Learn*., vol. 31, no. 3, pp. 232–253, Jun. 2015. doi: 10.1111/jcal.12066

[23] M. S. Gresalfi and J. Barnes, "Designing feedback in an immersive videogame: Supporting student mathematical engagement," *Educ.*

Technol. Res. Dev., vol. 64, no. 1, pp. 65–86, Feb. 2016. doi: 10.1007/s11423-015-9411-8

[24] E. H. Touli, M. Talbi, and M. Radid, "Barriers to learning physics in Moroccan secondary college: The case of student's representations in electricity," *Procedia-Soc. Behav. Sci.*, vol. 197, pp. 278–280, 2015.

[25] W. S. Ravyse, A. S. Blignaut, V. Leendertz, and A. Woolner, "Success factors for serious games to enhance learning: A systematic review," *Virtual Real.*, vol. 21, no. 1, pp. 31–58, Mar. 2017. doi: 10.1007/s10055-016-0298-4

[26] C. Murphy, "Why games work and the science of learning," in *Proc. MODSIM World 2011 Conference and Expo.*, 2012. https://ntrs.nasa.gov/citations/20130008648

[27] S. Sencar and A. Eryilmaz, "Factors mediating the effect of gender on ninth-grade Turkish students' misconceptions concerning electric circuits," *J. Res. Sci. Teach.*, vol. 41, no. 6, pp. 603–616, Aug. 2004. doi: 10.1002/tea.20016

[28] H. Peşman and A. Eryılmaz, "Development of a three-tier test to assess misconceptions about simple electric circuits," *J. Educ. Res.*, vol. 103, no. 3, pp. 208–222, Feb. 2010. doi: 10.1080/00220670903383002

[29] P. V. Engelhardt and R. J. Beichner, "Students' understanding of direct current resistive electrical circuits," *Am. J. Phys.*, vol. 72, no. 1, pp. 98–115, 2004.

[30] R. Cohen, B. Eylon, and U. Ganiel, "Potential difference and current in simple electric circuits: A study of student's concepts," *American Journal of Physics*, pp. 407–412, 1983.

[31] A. T. Borges and J. K. Gilbert, "Mental models of electricity," *Int. J. Sci. Educ.*, vol. 21, no. 1, pp. 95–117, Jan. 1999. doi: 10.1080/095006999290859

[32] S. K. Chambers and T. Andre, "Gender, prior knowledge, interest, and experience in electricity and conceptual change text manipulations in learning about direct current," *J. Res. Sci. Teach.*, vol. 34, no. 2, pp. 107–123, Feb. 1997. doi: 10.1002/(SICI)1098-2736(199702)34:2<107::AID-TEA2>3.0.CO;2-X

[33] C. Baker, "Quantitative research designs: Experimental, quasi-experimental, and descriptive," *Evid.-Based Pract. Integr. Approach Res. Adm. Pract.*, vol. 2, pp. 157–158, 2017.

[34] R. Thornton and D. Sokoloff. (1992). *The Electric Circuits Concept Evaluation (ECCE)*. [Online]. Available: https://physport.org

[35] R. F. Tinker, *Microcomputer-Based Labs: Educational Research and Standards*, Berlin, Heidelberg: Springer Berlin Heidelberg-page, 1996. doi: 10.1007/978-3-642-61189-6.

[36] G. Kortemeyer *et al.*, "Using a computer game to teach circuit concepts," *Eur. J. Phys.*, vol. 40, no. 5, 055703, 2019. doi: 10.1088/1361-6404/ab2a1d

[37] T. Jaakkola and S. Nurmi, "Fostering elementary school students' understanding of simple electricity by combining simulation and laboratory activities," *J. Comput. Assist. Learn.*, vol. 24, no. 4, pp. 271–283, Aug. 2008. doi: 10.1111/j.1365-2729.2007.00259.x

[38] M. Ronen and M. Eliahu, "Simulation—A bridge between theory and reality: The case of electric circuits," *J. Comput. Assist. Learn.*, vol. 16, no. 1, pp. 14–26, Mar. 2000. doi: 10.1046/j.1365-2729.2000.00112.x

[39] D. F. Treagust and R. Duit, "Conceptual change: A discussion of theoretical, methodological and practical challenges for science education," *Cult. Stud. Sci. Educ.*, vol. 3, no. 2, pp. 297–328, Jul. 2008. doi: 10.1007/s11422-008-9090-4

[40] M. Q. R. P. Smith and G. D. Ruxton, "Effective use of the McNemar test," *Behav. Ecol. Sociobiol.*, vol. 74, no. 11, p. 133, Nov. 2020. doi: 10.1007/s00265-020-02916-y

[41] H. Back, "Changing misconceptions in Newton's laws of motion through playing computer games and peer interaction," State University of New York at Albany, 1996.

[42] J. C. Adams, "The use of a virtual world to address misconceptions held by students regarding photosynthesis and respiration," PhD Thesis, Citeseer, 1998.

[43] D. Baxter, "Addressing genetics misconceptions with an educational game," PhD Thesis, Citeseer, 2008.

[44] T. Foko and A. Amory, "Social constructivism in games based learning in the South African context," in *Proc. EdMedia+ Innovate Learning, Association for the Advancement of Computing in Education (AACE)*, 2008, pp. 5757–5764. https://www.learntechlib.org/p/29180/

[45] O. Dardary, M. Tridane, and S. Belaaouad, "Constraints related to the integration of information and communication technologies in the teaching of the physical sciences at the level of the Moroccan educational system," *Indian J. Sci. Technol.*, vol. 11, p. 44, 2018.

[46] M. Takase, M. Niitani, T. Imai, and M. Okada, "Students' perceptions of teaching factors that demotivate their learning in lectures and laboratory-based skills practice," *Int. J. Nurs. Sci.*, vol. 6, no. 4, pp. 414–420, 2019.

[47] E. Taşlıdere, "Effect of conceptual change oriented instruction on students' conceptual understanding and decreasing their misconceptions in DC electric circuits," *Creat. Educ.*, vol. 4, no. 4, pp. 273–282, 2013.

[48] A. Kapartzianis and J. Kriek, "Conceptual change activities alleviating misconceptions about electric circuits," *J. Balt. Sci. Educ.*, vol. 13, no. 3, p. 298, 2014.

[49] L. C. Sıong, O. Y. Tyug, F. A. Phang, and J. Pusppanathan, "The use of concept cartoons in overcoming the misconception in electricity concepts," *Particip. Educ. Res.*, vol. 10, no. 1, pp. 310–329, 2023.

[50] A. Gauthier, "game and simulation stimulate conceptual change about molecular emergence in different ways, with potential cultural implications," *Education Sciences*, vol. 14, no. 4, 2024. https://doi.org/10.3390/educsci14040366

[51] T. Bouzid, H. Darhmaoui, and F. Kaddari, "Force and motion misconceptions in Moroccan high school science majors: Insights from video game activity," *Research in Science and Technological Education*, 2024. https://doi.org/10.1080/02635143.2024.2428618

[52] S. Benfaress, M. Zaki, and A. Alami, "Multidimensional analysis of ICT integration factors : A case study through the Moroccan GENIE program," *Eur. Sci. J. ESJ.*, vol. 12, no. 19, p. 164, 2016. (in French)

[53] A. Biaz, A. Bennamara, A. Khyati, and M. Talbi, " Integration of Information and communication technologies in teaching: Current situation and perspectives," *EpiNet Rev. Électronique L'EPI*, vol. 120, 2009. (in French)

[54] A. Maouni, A. Mimet, M. Khaddor, M. Madrane, and M. Moumene, "The integration of ICT in the teaching of life and earth sciences in Morocco: Reality and expectations," *Radisma*, vol. 10, p. 27, 2014.

[55] M. Achour, J. Khouna, and A. Tahiri, "The use of serious games in Moroccan educational context," in *Proc. 2023 7th IEEE Congress on Information Science and Technology (CiSt)*, IEEE, 2023, pp. 415–418. doi: 10.1109/CiSt56084.2023.10410005

[56] Y. A. Hammou and M. Elfatihi, "Barriers to ICT integration in Moroccan secondary school EFL classrooms," *J. Educ. Pract.*, vol. 12, p. 26, 2021.

[57] A. Khaloufi and H. Laabidi, 'An examination of the impact of computer skills on the effective use of ICT in the classroom," *Indones. J. EFL Linguist.*, vol. 2, no. 1, pp. 53–69, 2017.

[58] M. Rollnick, "Current issues and perspectives on second language learning of science," *Stud. Sci. Educ.*, vol. 35, no. 1, pp. 93–121, Jan. 2000. doi: 10.1080/03057260008560156

[59] L. S. Vygotsky, *Mind in Society: The Development of Higher Psychological Processes*, Cambridge: Harvard University Press, 1978.