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The positive meaning of the use of Interactive Simulation eduMedia in the subject of Light Waves in Secondary School in Morocco

Adil Hamamous
Corresponding author, Faculty of Sciences Dhar Mahraz, Sidi Mohammed Ben Abdellah University, Fez, Morocco, *adil.hamamous@usmba.ac.ma*

Nadia Benjelloun
Faculty of Sciences Dhar Mahraz, Sidi Mohammed Ben Abdellah University, Fez, Morocco, *nadia.benjelloun@usmba.ac.ma*

This work aims to study the impact of the use of the interactive simulation eduMedia, on the understanding and learning of Moroccan students in the qualifying secondary of the second year of the scientific baccalaureate option physical sciences at the high school Abdellah Laroui of the city of Fez. Using the pre-test and post-test methodology with a simulation group (24 students) and an experiment group (24 students) during the school year 2021-2022, the data were then analyzed using the IBM SPSS 21 statistical analysis program, for the analysis of quantitative data, Mann-Whitney U tests of independent samples were used. The results of the descriptive statistics show that the use of interactive simulation and laboratory experiments achieve similar objectives in the study of light waves. At the end of the session, we invited the students of the simulation group to answer the survey questions, moreover, the qualitative data were processed by the SPHINX v5 software. In addition, through interviews, we asked the six teachers to give their opinions on the use of simulation in learning, the results obtained showed a considerable improvement in some other indicators such as motivation and interaction between students compared to the classical method. The results of this research aim to better understand the opinion of teachers and students on the integration of interactive simulations in the school curriculum and may encourage the authorities of the Ministry of National Education, Vocational Training to adopt the interactive simulation program.

Keywords: eduMedia, light waves, learning, motivation, interaction, simulation

INTRODUCTION

Nowadays, the use of information and communication technology (ICT) is becoming more widespread (Prestridge, 2012). ICT can be employed in science education because it bridges the gap between teaching and learning (Waight & Abd-El-Khalick, 2007), information and communication technologies (ICT) have provided innovative tools

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(Tarman & Dev, 2018; Salas-Pilco & Law, 2018). One promising technology that facilitates learning is computer simulation in physics or interactive simulation is a very powerful tool for student learning. The integration of simulation in the classroom can be useful in addressing the need to create a framework for building scientific understanding. Interactive simulations also allow the effect of learning to be transferred to other situations and applied to similar situations in professional life (Perkins et al., 2012). Furthermore, as compared to practical laboratories, interactive simulations save time and effort when doing research (Roschelle et al., 2000). Using PhET interactive simulation to improve scientific creativity based on motivation theory, cognitive psychology theory, and social constructivism learning theory (Astutik et al., 2018), PhET interactive simulation is a scientific approach designed to improve problem-solving skills (Yuliati et al., 2018). According to studies related to computer-assisted instruction, computers and other computer-related instructional materials improve student performance (Waight & Abd-El-Khalick, 2007).

The use of computer simulations facilitates students' conceptual understanding (Jimoyiannis & Komis, 2001; Zacharia, 2007). In addition, they can positively influence student satisfaction, participation, and initiative (Duran et al., 2007). Another potential benefit of computer simulations is enhanced motivation and creativity and creating a stimulating learning environment that improves teacher instruction and facilitates learner engagement (Gill et al., 2014; Karamustafaoğlu, 2012; Adams et al., 2008). Simulations for institutional learning, or distance education, are considered the most promising tools in teaching (Yehya et al., 2018; Taher & Khan, 2015; Trundle & Bell, 2010). Chemikova et al. (2020) demonstrated that simulation-based learning allowed students to practice complex skills in instruction and eliminated the limitations of real-world learning, simulation had a positive effect on learning and was an effective tool for facilitating the learning of complex skills. Alessi & Trollip (2001) classify simulations into four parts: physical simulations, repetitive simulations, procedural simulations, and situational simulations.

In this work, a learning and teaching sequence was carried out using the interactive simulation eduMedia allows students to perform virtual experiments, adapted to their designs, on the topics of light waves (Figure 1). The use of the interactive simulation is simple as the students can manipulate the activities by themselves, eduMedia uses Flash or Java technology, runs smoothly under all major operating systems and there is the possibility to interact directly with the physical concepts and the virtual devices.

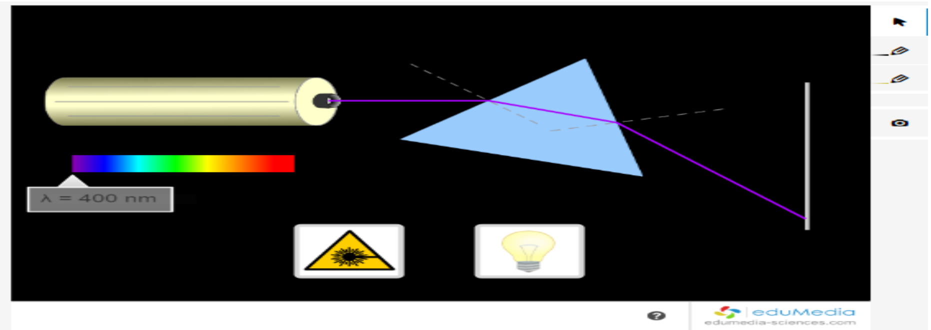

Figure 1
The eduMedia interactive simulation window

The purpose of this task is to compare the impact of the interactive simulation on student comprehension with the qualitative method, as well as its effect on student motivation, inter-student relationships, and student-teacher interactions during learning with the qualitative method. A simulation is used to make the students happy and to motivate them to improve their learning capacity by making the activities more interesting, motivating, and effective. Through this work, we will try to answer the following questions:

- Are there any significant differences between using interactive simulation and traditional teaching?
- Does the pedagogical integration of the interactive simulation have a positive impact on student achievement in high school?
- What are students' perceptions of the role of the interactive simulation in developing comprehension?
- Does the interactive simulation reduce the difficulties in acquiring physical concepts related to light waves in high school students?
- Does the pedagogical use of the interactive simulation have a positive effect on student motivation and interaction?

The importance of this study is to push the Ministry of National Education and Vocational Training to adopt the interactive simulation program in case of a lack of experimental equipment in the laboratory.

METHOD

To make the student active in the learning process, the teacher must use different teaching methods. The experimental method is defined as the statement of a problematic situation that allows the student to think and activate his knowledge to solve the problem, verify the hypotheses using the experiment, collect the results and give the conclusions (Jameau et al., 2015). This method is the most used to teach the course of progressive mechanical waves because of the experimental device available in the laboratory. In this part of the study, we compare two sessions of teaching traveling mechanical waves, one using real equipment and the other using an interactive eduMedia simulation. This does not mean that we are trying to find an alternative to the use of real experience in the teaching and learning process, as we know the satisfying potential provided by real experimentation. We only want to highlight the potentials that interactive simulation technology can provide, so that the teacher can use it as an alternative in the absence of the possibility to perform a real experiment. This study used a quantitative experimental approach of pre-testing and post-testing to examine the difference between the use of an eduMedia interactive simulation and real experiment hands-on activities on concept learning, and a qualitative approach by processing the results of an interview survey.

From a sample of 48 Moroccan students newly enrolled in the second year of the scientific baccalaureate option physical sciences (PC) at the high school Abdellah Laroui of the city of Fez, who have an average age of 17 years; it was conducted using two groups representing two different classes of the same institution during the academic year 2021-2022. The real experiment group is composed of 24 students, and the simulation group contains 24 students. In the multimedia room, we divide the students in the simulation group into groups of three or four students by a computer, we use a laptop to accompany the students during the learning process. After completing the proposed instructional activity, we invited both groups to answer the pre-test and post-test questions in a paper-and-pencil format to compare their answers. The collected data were then analyzed with IBM SPSS 21 (statistical analysis software), the non-parametric Mann-Whitney U test (McKnight *et al.*, 2010; Nachar, 2008) was used to compare the groups of two independent samples, an alpha level of 0.05 was used throughout the analysis of the results. Descriptive statistics were used to summarize the data, including percentages, mean, and standard deviation. In addition, the statistical theory was used to test for a significant difference between the participating groups regarding the usefulness of the computer simulation.

Pre-test[1]

A pre-test (Appendix 1) was used with both groups to ensure equivalence and to assess the degree of mastery of the pre-learned skills. This test consists of nine multiple-choice questions and one open-ended exercise. This instrument was developed and piloted with 24 students, and its reliability was estimated using Cronbach's alpha internal consistency coefficient. The reliability score was found to be 0.71, indicating an acceptable reliability coefficient.

Post-test[2]

The post-test is based on an assessment model designed to test the comprehension and application skills that we have tried to develop in students through the integration of an

1 Dimitrov, D. M., & Rumrill Jr, P. D. (2003). Pretest-posttest designs and measurement of change. *Work*, *20*(2), 159-165.

2 Dimitrov, D. M., & Rumrill Jr, P. D. (2003). Pretest-posttest designs and measurement of change. *Work*, *20*(2), 159-165.

interactive eduMedia simulation. The detailed formulation of the post-test is given in Appendix 1. The post-test contains nine multiple-choice questions (MCQs) and an application exercise in the form of open-ended questions. This instrument was piloted with 24 students, and its reliability measured using Cronbach's alpha was satisfactory (Cronbach's α=0.73). The multiple-choice questions (MCQ) and the exercise consist of the following concepts[3]:

- Propagation of light in transparent media and vacuum
- Demonstration of the phenomenon of light dispersion by a prism.
- Know and exploit the relationship $\lambda = c/v$.
- Define monochromatic light and polychromatic light.
- Know the limits of the wavelengths in the vacuum of the visible spectrum and the corresponding colors.
- To understand that when monochromatic radiation goes through a transparent medium, its frequency does not change.
- Know that transparent media are dispersive.
- Know and use the relation $n= c/v$.
- For a given frequency, calculate the refractive index of a clear medium.

Interview

To collect the ratings and opinions of the learners in the simulation group, the data collected focuses on learner motivation and interactions between learners, as well as between teacher and learner, in the following process:

Table 1
The interview process

Dimension	Indicator	Data source	Instrument model
Student motivation	- The value of using the interactive simulation - The interactive simulation helps you understand the course better than the traditional method. - The course would be better using another computer simulation - The interactive simulation is more practical than the traditional method	Students in the simulation group	Interview guidance
Student-student and teacher-student interaction	- The interactions between students were very important - Student-teacher interaction was low	Students in the simulation group	Interview guidance

The methodology adopted in this research is also based on interviews with six teachers of physical sciences of the high school Abdellah Laroui of the city of Fez.

3 https://www.bestcours.net/2019/02/blog-post_3.html

The data processing was carried out by the Sphinx v5 software. This made it possible to carry out a presentation of the descriptive statistics for each wording.

The different stages of this process are shown in Figure 1:

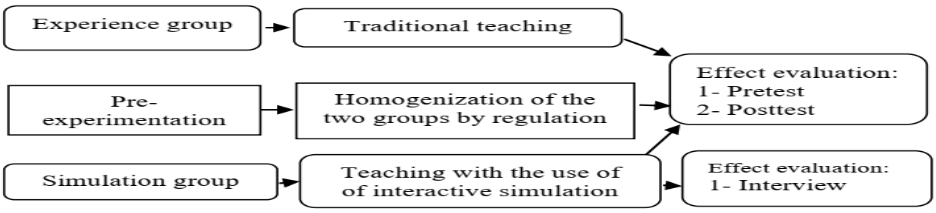

Figure 1
Descriptive diagram of the experiment's approach

Given the limited sample studied and the difficulty of ensuring equivalence between the two groups, we believe that our results and conclusions cannot be generalized, but they can highlight the impact of eduMedia simulations in improving student learning.

FINDINGS

Pre-test results

The results of the pre-test for both groups are shown in Table 2 below:

Table 2
Descriptive statistics (pre-test)

	N	Minimum	Maximum	Mean	Standard deviation
Experience group	24	8,00	18,00	15,0833	2,53526
Simulation group	24	9,00	17,00	14,7500	2,04833

Analyzing these results, the mean of the students in the experiment group at pretest is m = 15.08 while the mean of the students in the simulation group is M = 14.75; the difference is approximately 0.33. To test whether this difference is significant and to reject the null hypothesis (H_0: The difference between the means of students in the experimental group and the simulation group is not significant) that no significant difference existed between the two groups at pretest, we used the Mann-Whitney U test to compare the means of two independent samples, because the distribution of values does not follow the normal distribution, the p-value of Shapiro-Wilk is less than the chosen alpha level 0.05 (Table 3).

Table 3
Normality tests

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistics	ddl	Sig.	Statistics	ddl	Sig.
Experience group	0,195	24	0,019	0,873	24	0,006
Simulation group	0,257	24	0,000	0,863	24	0,004

The results of the comparison are presented in Table 4:

The asymptotic (two-sided) significance of the Mann-Whitney U test above the alpha level is chosen, Asymp. Sig (2-tailed) of 0.408 does not imply the rejection of the null hypothesis; we can thus estimate that there is no significant difference between the tested groups, this shows that both groups have the same level of skills, this result was predictable because both groups received the same course before the pre-test and allow us to validate our experimental model based on a pre-test and a post-test.

Table 4
Mann-Whitney U test

	The groups
Mann-Whitney U	248,500
Wilcoxon W	548,500
Z	-0,828
Asymp. Sig (2-tailed)	0,408

Post-test results

Pedagogical integration impact of the eduMedia interactive simulation on student achievement in high school

The post-test results for both groups are presented in Table 5 below:

Table 5
Descriptive statistics (post-test)

	N	Minimum	Maximum	Mean	Standard deviation
Experience group	24	8,00	18,00	15,2083	2,53633
Simulation group	24	10,00	19,00	15,7917	2,22592

The results show that the mean of the students in the simulation group at the post-test is m = 15.79 while that of the students in the experimental group is M = 15.20; the difference is about 0.59 check if this difference is significant and reject the null hypothesis that the tested educational device did not affect the students' results, we used Mann-Whitney U test (in Table 6, the distribution of values does not follow the normal distribution because the Shapiro-Wilk p-value is less than the selected alpha level 0.05).

Table 6
Normality tests

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistics	ddl	Sig.	Statistics	ddl	Sig.
Experience group	0,217	24	0,005	0,828	24	0,001
Simulation group	0,204	24	0,011	0,903	24	0,025

The results of the comparison are presented in Table 7:

The asymptotic (two-sided) significance of the Mann-Whitney U test above the alpha level is chosen, Asymp. Sig (2-tailed) of 0.352 does not imply the rejection of the null hypothesis; thus, it can be estimated that there is no significant difference between the tested groups and admit that the use of the interactive simulation eduMedia in the study of light waves, had a similar effect of the study by the laboratory experiment on the students' learning.

This shows that it cannot replace the laboratory experiment with the interactive simulation eduMedia except in the case of the lack of materials the computer simulation has a considerable interest because it allows to realize the inaccessible experiments because of the lack or absence of scientific material in the laboratories and to remedy the problem of the experiments that requires a long time of realization (Chekour, Laafou & Janati-Idrissi, 2015).

Table 7
Mann-Whitney U test

	The groups
Mann-Whitney U	243,500
Wilcoxon W	543,500
Z	-0,931
Asymp. Sig (2-tailed)	0,352

The role of the eduMedia interactive simulation in the development of understanding

To determine the role of the eduMedia interactive simulation in the development of student understanding, we used the Mann-Whitney U test (in this case, the distribution of values does not follow the normal distribution because the Shapiro-Wilk p-value is lower than the chosen alpha level) to compare the results obtained by the students according to the MCQ questions of the post-test. The results are presented in Table 8:

Table 8
Mann-Whitney U test

	Q1 of MCQs	Q2 of MCQs	Q3 of MCQs	Q4 of MCQs	Q5 of MCQs	Q6 of MCQs	Q7 of MCQs	Q8 of MCQs	Q9 of MCQs
Mann-Whitney U	264,00	216,00	264,00	264,00	276,00	252,00	204,00	276,00	216,00
Wilcoxon W	564,00	516,00	564,00	564,00	576,00	552,00	504,00	576,00	516,00
Z	-0,606	-2,110	-0,573	-0,579	-0,288	-0,924	-2,001	-0,292	-1,738
Asymp. Sig (2-tailed)	0,545	0,035	0,566	0,562	0,773	0,355	0,045	0,770	0,082

According to this table, the difference between the groups was not significant ($p > 0.05$) for questions 1, 3, 4, 5, 6, 8, and 9; thus, the simulation used had no added value in terms of knowledge acquisition. In contrast to this finding, in research on the use of simulations in the teaching of Newtonian physics, Joubert et al (2000) found that simulations helped students' knowledge grow and their reasoning become more precise. On the other hand, the difference between the groups was highly significant ($p <0.05$) in favor of the simulation group concerning questions 2 and 7, thus a progression in the level of acquisition of skills related to student's cognitive ability to apply and reason.

We also notice the difference in the rate of correct answers of two groups (Table 9), for question Q1 of the multiple-choice questions (MCQ) which defines the nature of a light wave (8.3 %), MCQ question Q2 which characterizes white light and polychromatic light (25%), MCQ question Q3 which determines the optical index n (4.2%), MCQ question Q4 which exploits the relationship of wavelength, frequency and speed of light in vacuum (11.5%), MCQ question Q5 which defines different wavelengths of the visible spectrum (4.2%), MCQ question Q6 which determines the relationship between colors of lights and wavelengths in vacuum (12.5%), MCQ question Q8 which performs the decomposition of white light using a prism (4.17%), and MCQ question Q9 which analyzes the role of the prism (25%). These results confirm statistical analyses performed using the Mann-Whitney U test ($p > 0.05$ for questions 1, 3, 4, 5, 6, 8, and 9 versus $p < 0.05$ for questions 2 and 7). For these questions, the difference in the rate of correct answers for students in two groups, in general, is almost equal.

Table 9
Correct answers for both groups: Experiment and simulation (post-test)

	The groups	
	Experience group	Simulation group
Q1 of MCQs	62,5%	70,8%
Q2 of MCQs	66,6%	91,6%
Q3 of MCQs	58,3%	54,1%
Q4 of MCQs	62,5%	51%
Q5 of MCQs	54,1%	58,3%
Q6 of MCQs	62,5%	75%
Q7 of MCQs	37,5%	66,6%
Q8 of MCQs	62,5%	58,33%
Q9 of MCQs	29,1%	54,1%

Interview

Student motivation

Student motivation is a major concern for researchers interested in the process of learning through a simulation. Zimmerman (1992) mentions that motivation is a set of factors that drive the student to actively engage in the learning process, adopt attitudes and behaviors that are likely to lead to the achievement of learning goals, and persevere in the face of difficulties. In the same spirit, learner motivation is an essential factor in the development of skills (Audet, 2009; Forget, 2015). Indeed, it is difficult to acquire new concepts, make the link with previous knowledge, and persevere in the appropriation of new concepts.

According to the theory of self-determination (Ryan & Deci, 2000), the intrinsic motivation of the individual is determined by two main factors: the pleasure of action and the interest it can provide. Based on this psychological idea, we prepared a list of questions to assess the student's motivation:

- Do you think that the interactive simulation helps you understand the course better than the traditional method?
- Do you find the interactive simulation more practical than the traditional method?
- The interactive simulation is a complementary tool to real experiences.
- Do you like to use interactive simulations in physics more often?

The analysis of the data collected from the interview showed that the students are quite motivated to learn using the eduMedia interactive simulation. Most of the students enjoyed the simulation of light waves using the eduMedia interactive simulation. Figure 2 illustrates these results.

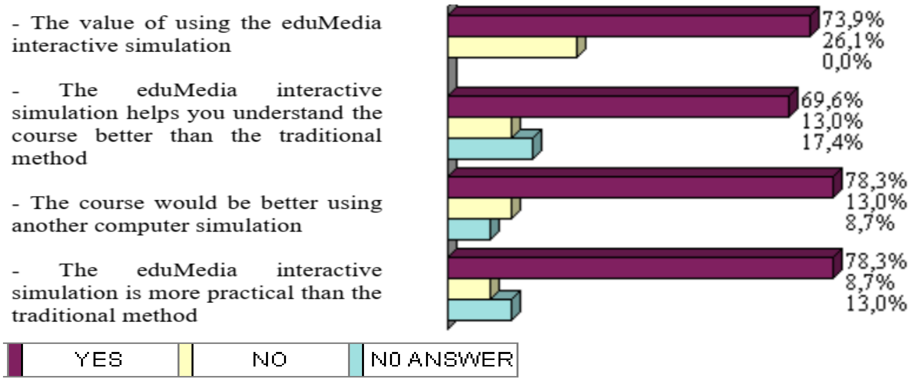

Figure 2
Examining the motivation to use the eduMedia interactive simulation

73% of the students like to use the eduMedia interactive simulation in this course, teaching using the interactive simulation made more convenient according to 78.3% of the students, 69.6% of the learners prefer to use the interactive simulation frequently in the learning process and 78.8% are not interested in learning with another computer simulation. These results once again confirm the students' motivation to learn using the interactive simulation. Furthermore, the results confirm classroom observations and many related studies that have shown that the traditional method has no motivating effect on students (Zheng, 2019). Therefore, the interactive simulation can enhance the educational learning process of light waves with its powerful resources, so that it can generate the required motivation for Moroccan students.

Student-student and teacher-student interaction

Indeed, inter-student interactions promote the learning process and develop communication and argumentation skills. Therefore, classroom teaching and learning aim to improve the effectiveness of this type of interaction, instead of the teacher-student interactions that are normally reduced. Therefore, the evaluation of the interaction is done using two important questions:

- Does the use of the interactive simulation contribute to increased interaction between you and your colleagues, compared to the traditional method?
- Does using the interactive simulation minimize your interactions with the teacher, compared to the traditional method?

The data collected from these two questions are organized and presented in Figure 3; the first glance shows that the results are quite encouraging:

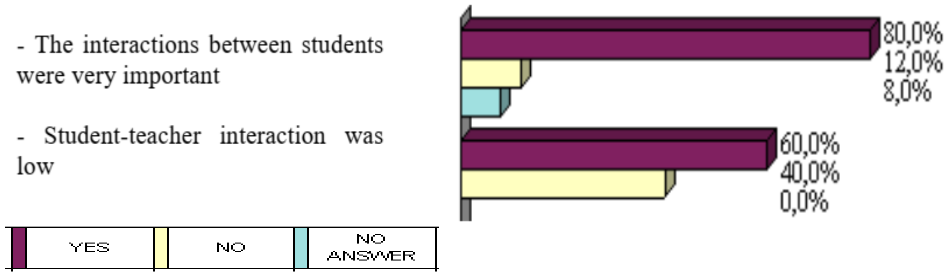

Figure 3
Examination of student-student and teacher-student interactions

The results presented in Figure 2 show that about 60% of the students stated that the use of the eduMedia interactive simulation helped to minimize their interactions with the teacher. On the other hand, 80% of the students stated that the course was rich thanks to the exchange process between the students. In addition, the use of this pedagogical tool helps students to integrate into the social learning environment. Thus, we can confirm that the adoption of the interactive simulation improves the process of interactive exchange among students. In general, students need a tool to interact with each other. In this sense, the use of the interactive simulation in the classroom can be a good tool.

Teachers' opinion

In this part, we collect data from the teachers of physical sciences of the high school Abdellah Laroui of the city of Fez, who participated in the survey of the open question. From the point of view of the teachers, we observed a fluidity and a significant reduction of the tasks of the teacher compared to the traditional method, since we are not solicited by the groups except in certain specific situations, our role is thus limited to supervising and animating the session. This experience also allows us to record a high level of motivation from the students, as well as a high level of inter-teacher interaction to discuss the simulations and respond to the exercise that we have integrated into the pedagogical scenario. The key to the success of this experiment lies in the facilities offered by the simulations which allow the learner to adopt the learning pace that suits him/her, thus guaranteeing a certain autonomy of learning (El Hajjami et al., 2000). But the disadvantages are that the students only manipulate manually, do not draw the graphs themselves, and do not face measurement errors.

DISCUSSION

In this work, students in the simulation group, who used the eduMedia interactive simulation, generally managed to answer questions 2 and 7 more effectively. The post-test responses confirm that these students from both groups also acquired the same skills regarding light waves, it can be inferred that the use of the interactive simulation and the real experiment had a similar impact on the students' performance and skills. Similarly, Ben Ouahi et al. (2022) who previously tested PhET (Physics Education Technology) Interactive simulation in teaching and learning of students, confirmed that the use of interactive simulations in science education in Morocco can enhance learning activities and help students to understand scientific concepts effectively as the use of real experiment. (Mrani et al., (2020) also showed that PhET simulations have a remarkable effect on the acquisition and application of new knowledge in the lesson on Archimedes' thrust.

Several types of research conducted in experimental disciplines also showed improvement in learners' performance and comprehension. For example, Rutten, Van Joolingen, and Van der Veen (2012), who reviewed 51 articles from 2001 to 2010, that showed classical teaching can be improved by using computer simulations. In the same vein, White and Frederiksen (2000) showed that the use of "Thinker Tools" computer simulation in physics allowed high school students to demonstrate a better understanding and interpretation of forces acting on a moving object than traditionally taught higher education students. Furthermore, Droui, Hajjami, Bouklah, and Zouirech (2013) reported the positive effects of using a simulation of Newtonian laws in a problem-solving context on Newtonian mechanical conceptual understanding. On its side, Zacharia (2007) reports that replacing real experimentation with virtual experimentation during a specific part of the experiment has a positive influence on students' conceptual understanding of electrical circuits. This claim is supported by several types of research, using a simulation can develop students' understanding of physics concepts (Arias et al., 2020; Bozkurt & Ilik, 2010; Sarabando et al., 2014). (Price et al., 2018; Wieman et al., 2008) have also shown that simulation adds value by enabling activities that are not possible with classroom equipment and helps overcome logistical barriers and lack of laboratory equipment. Similarly, Van Riesen et al. (2018) state that experiments can lead students to build their knowledge, help them understand the world around them, and help them eventually solve problems. Participatory learning through computer simulation can significantly improve students' problem-solving and creative thinking skills[4]. Other investigations have indicated that the use of computer simulations was less effective than traditional instruction and hands-on laboratory approaches (Michael, 2001; Marshall, et al., 2006).

In addition, the results obtained in this research showed a considerable improvement in some other indicators such as motivation and interaction between students compared to the classical method, we observed a strong motivation in students who communicated and interacted more and more with each other. This result is supported by Durán, Gallardo, Toral, Martinez-Torres and Barrero (2007), who focused on the cognitive and affective domains to study the effects of a computer simulation on student motivation, interaction, and participation. Gambari, Gbodi, Olakanmi, and Abalaka (2016) found that students using a computer simulation performed better, and they recommended that chemistry teachers use computer simulations to improve

4 Simanjuntak, M. P., Hutahaean, J., Marpaung, N., & Ramadhani, D. (2021). Effectiveness of Problem-Based Learning Combined with Computer Simulation on Students' Problem-Solving and Creative Thinking Skills. *International Journal of Instruction*, *14*(3), 519-534.

their students' performance and motivation in the subject.

On the other hand, Ben Ouahi et al. (2022) also revealed that the lack of technological tools, the lack of in-service training, and the problems related to the pedagogical approaches of the educational system are major obstacles that influence the motivation of Moroccan teachers to use interactive simulations in the classroom. Many previous studies have confirmed that the absence or inadequacy of technological equipment in the science room and the unavailability of computer rooms are huge constraints to the proper use of simulation (Mahdi & Laafou, Mohamed.R, 2018; Taoufik et al, 2016).

CONCLUSION

The objective of this work is to highlight the effect of using the interactive simulation eduMedia in the study of light waves on the learning of students. The statistical data collected from research among Moroccan students in the second year of the scientific baccalaureate option physical sciences at the high school Abdellah Laroui in the city of Fez, with a simulation group and an experienced group, the methodology pre-test and post-test revealed that there was no significant difference between the two groups in the pre-test. At post-test after using the interactive simulation, also there was no statistically significant difference between the simulation group and the experience group, the use of eduMedia interactive simulation and laboratory experiments can achieve similar goals in the study of light waves, the interactive simulation will be an alternative to do the inaccessible experiments. Furthermore, the findings of this study suggest that students are highly motivated to employ simulation in the learning of wave concepts; nonetheless, simulation cannot substitute laboratory trials. The students interviewed stated that the interactive simulation, compared to the traditional method, improves the learning process, motivates the students during the course, and increases the interaction between the students in the learning process. The teachers also observed a significant fluidity and reduction of teaching tasks compared to the traditional method and the simulation thus guarantees a certain autonomy of learning among the students.

We can see that the use of the interactive simulation is very practical in case of the absence of laboratory materials in high school and it could respond greatly to the anticipations of the Ministry of National Education, Vocational Training in the context of its new orientation towards computerization and digitalization of education.

IMPLICATIONS

Our research can also encourage physical science teachers to use interactive simulations in their classrooms, as many interviewees mentioned that the use of interactive simulations can significantly improve students' skills, certain indicators such as motivation and interaction between students compared to the conventional method. The results of this research can become the precursor of larger-scale research, with the aim of better understanding the opinion of teachers and students on the integration of interactive simulations in the school curriculum and can encourage the authorities of the Ministry of National Education, Vocational Training to adopt the interactive simulation program so that students acquire skills.

LIMITATIONS

This study has some limitations. 48 Moroccan secondary school students qualifying for the second year of the scientific baccalaureate with the option of physical sciences in the high school of Fez, who have an average age of 18 years participated in this study and we conducted this survey with 6 teachers of physical sciences and 24 students, it would be advantageous to conduct similar research in different disciplines (mathematics and life and earth sciences) with many samples.

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APPENDIX 1

Pre-test

MCQS

Choose the correct answer

1.The celerity of a progressive mechanical wave

- [ ] Is constant during the propagation if the medium is homogeneous
- [ ] Decreases during propagation
- [ ] Depending on the propagation medium

2.The wave created on the surface of the water by a stone thrown into a pond is :

- [ ] Longitudinal
- [ ] Transversal

3.Sound is a wave:

- [ ] Longitudinal
- [ ] Transversal

4.The celerity of sound in air, at ordinary temperature and normal pressure, is of the order of:

- [ ] 250 m/s
- [ ] 350 m/s
- [ ] 450 m/s

5.Sound travels at the following speeds in the air:

- [ ] Decreases with increasing temperature
- [ ] Increases with increasing temperature
- [ ] Decreases with increasing pressure

☐ Increases with increasing pressure

6.Generally speaking, the celerity of a wave is:

☐ In a liquid, it is larger than in a solid

☐ In a solid, it is larger than in a liquid

☐ In a gas, it is larger than in a solid

☐ In a solid, it is larger than in a gas

7.Two points separated by an integer number of wavelengths are:

☐ In phase

☐ In phase opposition

8.For a periodic traveling mechanical wave, the relation that relates the wavelength λ, the celerity c, and the period T is:

☐ $\lambda = \frac{c}{T}$.

☐ $\lambda = c + T$.

☐ $\lambda = c.T$.

☐ $\lambda = c.T^2$.

9.When two points A and B of a medium are separated by a distance d, and a wave propagates in this medium at the velocity v, the point B will repeat the movement of point A with a delay that is:

☐ $\frac{\lambda}{v}$.

☐ $\frac{d}{v}$.

☐ $v.d$.

☐ $\frac{v}{d}$.

$\frac{\lambda}{d}$.

Exercise 1:

On a wave tank, square waves are created using a small flat strip of a vibrator set at a frequency N = 50Hz. These waves propagate on the water surface without attenuation and reflection.
Figure 1 shows the appearance of the water surface at a given time, such as d = 15mm.

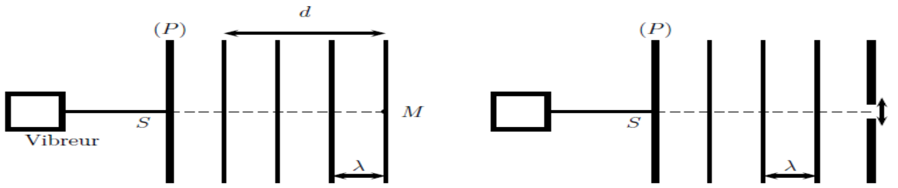


figure 1 figure 2

1. a. Using Figure 1, determine the value of the wavelength λ
   b. Deduce V the propagation speed of the waves on the water surface.
   c. Consider a point M on the propagation surface (Figure 1). Calculate the delay τ of the vibration of point M concerning the source S.
   d. We double the value of the frequency N'= 2N, the wavelength is λ' =3mm. Calculate V' the value of the propagation speed in this case. Is water a medium dispersive? Justify.

2. The frequency of the vibrator is again set to 50Hz. An obstacle containing an opening of width is placed in the tank. See figure. Show, justifying the answer, the aspect of the water surface when the waves pass the obstacle in the two cases: a = 4mm and a = 10mm.

Post-test
MCQS

Choose the correct answer

1.Light is a wave:

- Mechanical
- Electromagnetic

2.White light is a polychromatic light.

- True
- False

3.When light passes from one medium to another of different optical index n:

- The light's frequency is changed

☐ The light's color is changed.

☐ The speed of light is sped up or slowed down

4.In water, the wavelength of radiation of frequency 5.09E14 Hz is 442 nm. What is the index of water? (Data: Speed of light in vacuum: c=3. 10^{8}m/s)

○ 0,76

○ 1,1

○ 1,3

○ 1,5

5.The range in wavelengths of the visible spectrum is:

○ From 300 nm to 500 nm

○ From 300 micrometers to 500 micrometers

○ From 400 nm to 800 nm

○ From 400 micrometers to 800 micrometers

6.The link between the colors of light and the wavelengths in the vacuum is:

○ The red corresponds to the long wavelengths, the violet to the small wavelengths

○ The red corresponds to the small wavelengths, the violet to the long wavelengths

7.Ultraviolet rays are radiation:

☐ With a wavelength smaller than violet

☐ Of wavelength greater than violet

☐ Of frequency smaller than the violet

☐ Of frequency greater than the violet

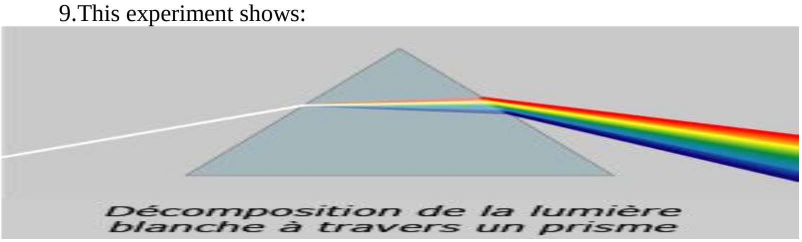
8.When we realize the decomposition of white light using a prism to observe the spectrum of white light:

☐ This experiment involves the phenomenon of refraction

☐ This experiment involves the phenomenon of diffraction

☐ This experiment involves the phenomenon of dispersion

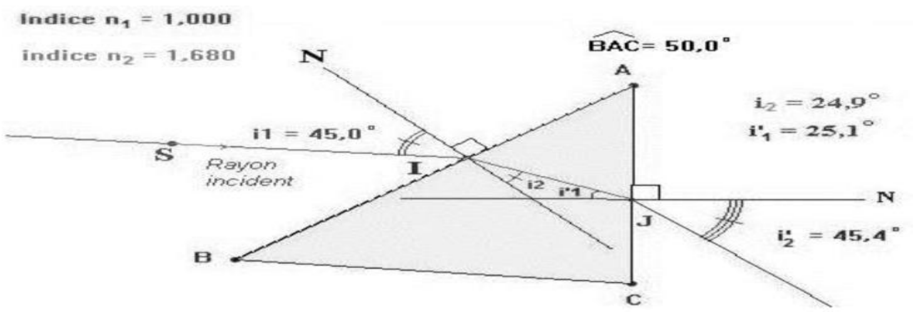
9.This experiment shows:



- ☐ that the prism is dispersive
- ☐ that the prism is dissipative
- ☐ that the prism is directional
- ☐ the white light arriving on the prism is monochromatic

Exercise

We must study the conditions of dispersion of the white light by a prism for which the refraction is 1,680 to 470 nm (blue radiation) and 1,596 nm (red radiation).
The adapted notations for the angles are given in the following diagram.



A thin beam of the white light of index $\boldsymbol{i_1} = \mathbf{45}$ is sent onto a face of the prism of angle Â = 50°.

1- Calculate the angle of refraction $\boldsymbol{i_{2B}}$ for the blue radiation and then the angle of refraction $\boldsymbol{i_{2R}}$ for the red radiation.
2- For both radiations, deduce the deviation due to the first separation surface crossed.
3- In the case of blue radiation, the index angle on the exit face of the prism, $\boldsymbol{i}_{1'}$verifies the relation: Â =$\boldsymbol{i_2}$+$\boldsymbol{i_1}$′. Deduce the numerical value of $\boldsymbol{i_{1'}}$ for each radiation studied.
4- What are the values of the prism exit angles $\boldsymbol{i_{2B}}$ and $\boldsymbol{i_{1R'}}$ for each radiation.
5- Calculate the deflection D experienced by the incident brush as it exits the prism as a function of $\boldsymbol{i_1}$, $\boldsymbol{i_{2'}}$ and A

Deduce the deviations undergone respectively by the blue light and by the red light.