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Effectiveness of animation-based instruction on university students' achievement in cell biology

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Abstract

The purpose of this research was to investigate how students' academic achievement in cell biology can be improved using animation-based instruction. The research adopted a pre-test, post-test and control group quasi-experimental design. The treatment group was taught using a lecture aided by video animation, while the control group utilised the traditional lecture method. The results show that students in the treatment group obtained a significantly higher achievement level compared to the control group. The items for which the achievements are superior are those relating to the structure of the cell membrane and membrane transport. These two items are considered among the most difficult for students to understand because they deal with dynamic and complex processes. This study implies that the lecture based-animation improves the learning of abstract concepts and complex processes that poses many understanding problems among students such as those in cell biology.

Keywords: Animation-based instruction,cell biology,learning,achievement,university students.

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1. Introduction

Today, interest in using Information and Communication Technology (ICT) in education is well established. ICTs have become essential in the mobilisation and development of 21st-century skills in learners, including autonomy, communication, collaboration, argumentation etc. These technological tools also occupy a central place in society, and students will no doubt be confronted with them in their futurelives(Almira Salsabila Majid & Usman, 2021; Guri-Rosenblit, 2019; Nogerbek et al., 2022; Rafeeq & Muhammad Qasim, 2021),hence the need to train students in digital technology at school in each school discipline.

At the university, the integration of ICT is happening more and more quickly. Thus, we are witnessing changes in the teaching and learning process moving from a classic paradigm centred on the transmission of knowledge towards an active paradigm where the learner is responsible for the construction of his knowledge(Guri-Rosenblit, 2019; Qureshi et al., 2021; Saputri et al., 2018; Uygarer & Uzunboylu, 2017). The term ICT brings together a large number of tools designed to use digital documents for teaching and learning purposes, and include in particular audiovisuals, such as videos, documentaries and computing. Computer resources include a whole range of activities such as the use of simulation or animation software that promotes the understanding of various concepts (Castro-Alonso et al., 2016; Ploetzner et al., 2020).

The teaching of biology lends itself easily to the use of ICT (Torkar, 2021). There are thus many didactic aids, including animations, that allow visualising phenomena that are not possible to observe because they occur at the cellular or molecular scale (O'Day, 2006).

1.1. Related research

1.1.1. Peculiarities in teaching cell biology

Cell biology is a growing discipline whose boundaries are becoming more blurred due to the explosion of scientific knowledge. One of the learning difficulties of this discipline is linked to the many concepts and processes that are related to many levels of integration of the complexity between the molecular and subcellular levels up to the level of the cell (Akif Haşiloğlu & Eminoğlu, 2017; Fuchs et al., 2021). As a result, the teaching of cell biology is not adapted to the reductionist approach which consists in explaining the structures and functioning of each level of integration in an isolated way. Cell biology must be taught using an approach that takes into account the complexity of the different levels of integration of cellular structures and processes and this by building bridges between these structures (Verhoeff et al., 2008). In addition, the teaching of cell biology constitutes the basis of subsequent teaching in the other disciplines of biology, such as animal biology, plant biology, physiology, genetics, immunology etc.

Furthermore, several studies have identified several difficulties in learning the basic concepts of cell biology among students (Akif Haşiloğlu & Eminoğlu, 2017; Fuchs et al., 2021; Hala et al., 2018; Suwono et al., 2021).

To improve the teaching of cell biology, multiple teaching approaches had been explored; these approaches are based on putting students in situations that allow them to be active learners(Ploetzner et al., 2021; Verhoeff et al., 2008). In this sense, ICT is an opportunity to improve the teaching of cell biology; it makes it possible to change the student from a passive learner to an active learner, from a dependent learner to an autonomous learner and from a solitary learner to a collaborative learner (Moghavvemi et al., 2018; Ploetzner et al., 2021; Saputri et al., 2018).

Due to the complexity of cellular structures and the underlying molecular processes, teachers should present these processes through the use of appropriate didactic resources (animations, simulation etc.) rather than with static illustration as this allows them to highlight the characteristics of the plasma membrane (fluidity, movement, cell transport etc.) as well as its constituents. For this purpose, the use of animations seems to enable students to better understand the different levels of interactions between molecules crossing the plasma membrane and the different constituents of this membrane.

1.1.2. Use of animation in biology education

One of the specificities of teaching cell biology consists in highlighting, simultaneously, the microscopic aspect of the different constituents of the cell, the dynamicity of their interactions and the molecular aspect (Akif Haşiloğlu & Eminoğlu, 2017; Fuchs et al., 2021).

Video animations are potential tools to facilitate teaching and make it possible to understand dynamic processes in cell biology such as exchanges across the plasma membrane, cell division, respiration, and photosynthesis. However, even if this type of tool allows for a better understanding of the problem of the dynamism of microscopic and molecular processes, they remain a representation of reality; one can then ask if this new tool is effective for the teaching of biology (Verhoeff et al., 2008).

On the other hand, researchers are not unanimous about the benefits of these tools for biology education. This divergence in research may be due to the diversity of these tools, their content, the scope of their use and how they are designed (Berney et al., 2015).

The researchers who support the use of these tools in teaching argue that the animations are better than the static pictures used in scientific books or for illustration in cell biology courses, that they are a way to illustrate the teacher's explanations during a course, that they can facilitate the synthesis of the biological phenomena studied or their ability to develop self-learning skills in students (Azizah & Widiartin, 2019; Berney et al., 2015; Kiat et al., 2020; Roehling, 2018; Xiu et al., 2019; Yang et al., 2019). Other researchers have mentioned the fact that the use of these video animations increases students' motivation and their cognitive and emotional engagement (Ekberg & Gao, 2018; Qaddumi et al., 2021; Steiner & Mendelovitch, 2016) and makes learners active(Geri et al., 2017; Ramsay & Terras, 2015).On the other hand, researchers who disagree with the use of video animations in teaching argue that these animations can generate a cognitive load for young learners, especially if the speed of these animations is fast (Berney et al., 2015) or if they greatly simplify the phenomenon being studied (Stith, 2004). Some researchers also criticise the weak impact of these animations on the memorisation of the subject studied by the students and suggest in this sense that these animations be made available to the students so that they can be viewed several times(Lowe & Schnotz, 2008).

Thus, despite the divergence of the researchers' points of view, the use of video animations by the teachers remains interesting, especially if their use is made according to an adequate didactic scenario that incites the students to interact with them and to learn alone (Starbek et al., 2010).

1.2. Purpose of the research

This research aims to study the effect of the use of animation-based instruction on students' learning in cell biology (treatment group). The results of this impact are compared with those of a traditional lecture (control group). The students' scores are obtained by administering a questionnaire before (pre-test) and after the intervention (post-test).

The study is centred on the following four research questions:

- Is there a statistically significant difference between the students' pre-test achievement scores of the treatment and the control groups?
- Is there a significant difference between the students' pre- and post-test achievement scores of the control group?
- Is there a significant difference between the students' pre- and post-test achievement scores of the treatment group?

- Is there a significant difference between the students' post-test achievement scores of the treatment and the control groups?

2. Method

2.1. Research design

Quasi-experimental methods testing causal hypotheses were applied in this study to understand whether the implementation of the animation-based instruction approaches affects the students' learning efficiency of cell biology. The use of animation-based instruction is considered an 'intervention' which consists in evaluating a predefined set of indicators (the items of the questionnaires) and the capacity of a 'treatment' (animation-based instruction) to improve students' learning achievement in cell biology.The quasi-experiment design was preferred also because the study concerns limited sample size and randomisation of the sample; it also allows for generalised findings (Mnguni &Moyo, 2021). This quasi-experimental design adopted a pre-test and post-test equivalent group design (Dimitrov & Rumrill, 2003). In this design, two groups are formed from the total available students. One of the two groups is treated as an experimental group (animation-based lecture) and the other as a control group (traditional lecture) (Leavy, 2017). The achievement mean scores (MSs) of the treatment and control groups were compared to assess if changes from the pre-test and post-test are statistically significant.

2.2. Sample and treatment

This research aims to investigate the effectiveness of animation-based instruction on students' achievement in cell biology. For this, we conducted an experiment method of teaching cell biology among students enrolled in a cell and molecular biology course at a large university. A total of 52first-year master's students were involved in the research. The students were randomly divided into 2 groups of 26 students each: the control group and the treatment group.

In the control group, the teacher uses the traditional lecture which consists of presenting content, describing and explaining concepts; he uses the PowerPoint presentation as a didactic tool to facilitate learning.

The treatment group was exposed to animation-based instruction which consists of a lecture using animations as a teaching and learning resource. These animations were used to visualise the structure of organelles, plasma membrane and process of transport through the cell membrane. In this case, the teaching approach used includes the following steps:

- Integrating animations in lesson planning according to a specific pedagogical scenario that combines activities carried out by the teacher and the students;

- Carrying out the lesson with the ICT tool. Teaching activities are based on individual and group work. The students were put in an activity; the teacher asked them to note the important points during the broadcast of the animation video sequences. The students' responses were shared and discussed collectively after the broadcast of the animation. The focus was on the relationship between the processes analysed and the structure of the plasma membrane. The role of the teacher is to explain the tasks to be carried out by the students, regulate the discussions and correct possible misconceptions identified among the students. The students have the video animations to view more than once.

The topic of instruction was selected from the syllabus of the master's level. Accordingly, the chapter dealing with 'Plasma membrane structure and cell transport' was chosen because students considered the subject difficult to understand and the understanding of cell transport requires a prior understanding of many physical processes, such as diffusion and osmosis. In this chapter, cell types, structures and functions (plasma membrane); cell transport (diffusion, passive transport and active transport) parts and their functions were thoroughly presented. The topic was taught for a week with seven contact hours for each of the control and treatment groups.

2.3.Assessment and measures

For the collection of data relating to the evaluation of the achievements of the students in cell biology, an achievement test was used to measure students' conceptual understanding of cell biology. For this, we used two multiple-choice questionnaires which were developed using student's misconceptions identified in the literature (Akif Haşiloğlu & Eminoğlu, 2017; Fuchs et al., 2021; Loertscher et al., 2014; Suwono et al., 2021) and based on the content of the curriculum of cell biology at university in Morocco. Each of the 2 questionnaires includes 25 items that were grouped into 5 topics (Table 1).

Table 1: *Cell Biology Topics Included in the Questionnaire*

	Cell characteristics	Organelles	Plasma membrane	Membrane transport	Chemical constituents
Pre-test	Pr 1–5	Pr 6–10	Pr 11–15	Pr 16–20	Pr 21–25
Post-test	Po 1–5	Po 6–10	Po 11–15	Po 16–20	Po 21–25

A questionnaire was administered as a pre-test to all 52 students; it included questions that focused on students' basic understanding of a variety of cell biology concepts. The second questionnaire was administrated as a post-test to students in the control and treatment groups (a week after treatment). The two questionnaires have some common items but are differently formulated. The content validity of the pre-test and post-test was validated through a panel of four experts in the field of cell biology education and didactics of biology. Similarly, Cronbach'salpha was used to establish the internal consistency of the instruments (using Statistical Package for the Social Sciences [SPSS] version 26). In this study, the computed Cronbach alpha coefficient was 0.74 for the pre-test and 0.81 for the post-test, knowing that a coefficient above 0.7 is considered acceptable (Nitko, 2004).

2.4. Data analysis

The means, standard deviations and differences in the achievement MSs for each group (control and treatment) were computed using SPSS version 26. The significance of differences between the MSs on the pre-test and post-test of the treatment and control groups were tested at a 0.05 alpha level.

3. Results

3.1. Normality test

The achievement main scores from both groups were subjected to a normality test before applying the appropriate statistical analysis. Concerning the pre-test, we can deduce that the study population seems to have not a normal distribution (p-value<0.05) for both the Kolmogorov–Smirnov test and the Shapiro–Wilk test, which is considered in this analysis, because the sample size is small (Table 2). On the contrary, concerning the post-test data, we can conclude that the population of study has a normal distribution (p-value>0.05) for both the Kolmogorov–Smirnov test and the Shapiro–Wilk test (Table 2).

Table 2: *Normality Test in Pre-test and Post-test*

Kolmogorov–Smirnov[a]			Shapiro–Wilk		
Statistics	ddl	Sig.	Statistics	ddl	Sig.

Pre-test	0.128	52	0.034	0.950	52	0.029
Post-test	0.110	52	0.162	0.982	52	0.635

[a] Correction de signification de Lilliefors.

Even if the study population has a normal distribution in the post-test, we used non-parametric tests to test the significance of the differences between the achievement MSs obtained in the pre-test and the post-test for the control and the treatment group; this is due to the small sample size (less than 30 for each group).

3.2. Analysis of pre-test and post-test achievement MSs

Table 3 shows the achievement MS and the standard deviations in the pre-test and post-test. According to Table 2, we can see that the pre-test achievement MSs of the control group (MS=10.42) and the treatment group (MS=10.54) do not differ much in the pre-test (difference = 0.12), but there are quite large differences between them in the post-test (difference = 2.27). However, it is necessary to test whether these differences are statistically significant or not.

Table 3: *The Achievement MSs of Treatment and Control Groups in Post-Test*

	N Statistics	MS Statistics	Standard deviation Statistics
Control pre-test	26	10.42	1.983
Treatment pre-test	26	10.54	1.964
Control post-test	26	13.73	2.442
Treatment post-test	26	16.00	2.298

3.3. Comparison of pre-test and post-test achievement MSs of the control group

For the control group, it can be inferred from Table 4 that the differences in the students' achievement MSs obtained in the pre-test and post-test are significant (p-value = 0.000<0.05), i.e., the student's performance was improved by the traditional teaching method.

Table 4: *Comparison of Pre-test and Post-Test Achievement MSs*

	Tests for equality of means[a]	
	Control post-test – control pre-test	Treatment post-test – treatment pre-test
Z	−4.537[b]	−4.502[b]
Sig. asymptotique (bilatérale)	0.000	0.000

[a] Wilcoxon's test.

[b] Based on the negative ranks.

3.4. Comparison of the pre-test and post-test achievement MSs of the treatment group?

For the treatment group, it can be deduced from Table 4 that the differences in the students'MSs obtained in the pre-test and post-test are statistically significant (p-value = 0.000), i.e., the student's performances were improved by the teaching sequence using video animation.

3.5. Comparison of the pre-test achievement MSs of the treatment group and the control group

Figure 1 shows that there is a slight difference between the achievement MSs of the two groups in the pre-test.

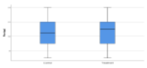

Figure 1: *Comparison of Pre-test MSs Between the Control and Treatment Groups*

According to Table 5, concerning the pre-test, the *p*-value is equal to 0.810 and therefore higher than the 5% threshold, which means that the differences in cell biology between the achievementMSs of the control and the treatment groups in pre-test are not statistically significant (Figure 1); in other words, students in the control and treatment groups have the same level of knowledge before the study.

Table 5

Comparison of Control and Treatment Achievement MSs

	Pre-test	Post-test
U de Mann–Whitney	325.000	174.500
W de Wilcoxon	676.000	525.500
Z	−0.240	−3.017
Sig. asymptotique (bilatérale)	0.810	0.003

Variable: Control and treatment.

3.6. Comparison of the post-test achievement MSs of the treatment group and the control group

Figure 2 shows that there is an important difference between the achievement MSs of the control and treatment groups in the post-test.

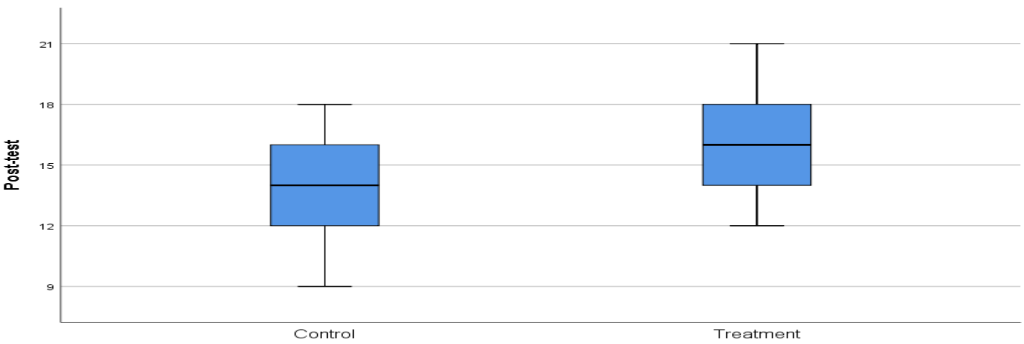

Figure 2

Comparison of Post-Test MSs Between the Control and Treatment Groups

Conversely, concerning the post-test, the *p*-value is equal to 0.003 and therefore less than 0.05, so there is a significant difference between the achievement MSs of the control group and those of the treatment group, which means that there is a positive effect of the teaching method using the video animation on the student's achievement MSs (Table 5).

3.7. Evolution of the average scores for the five cell biology topics

Figure 3 shows the comparison of the achievement MSs of the control and treatment groups obtained in each of the five topics studied (it should be noted that the maximum MS that can be reached in each topic is 5).According to Figure 3, the items for which there is a significant increase in the students' achievements are those relating to the characteristics of the cell, the organelles' structure and the cell chemical constituents, and this is for both the control and treatment groups.

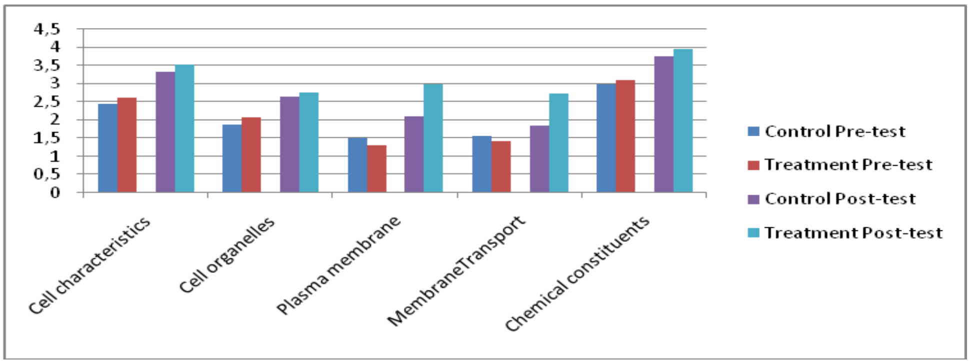

Figure 3

Evolution of the Average Scores for the FiveTopics Studied

On the other hand, the evolution of the average scores of the treatment group is greater than that of the control group in the items relating to the plasma membrane and membrane transport (Figure 3). This is well illustrated by Figure 4 which shows the comparison of the gains in average achievement scores of the control and treatment groups.

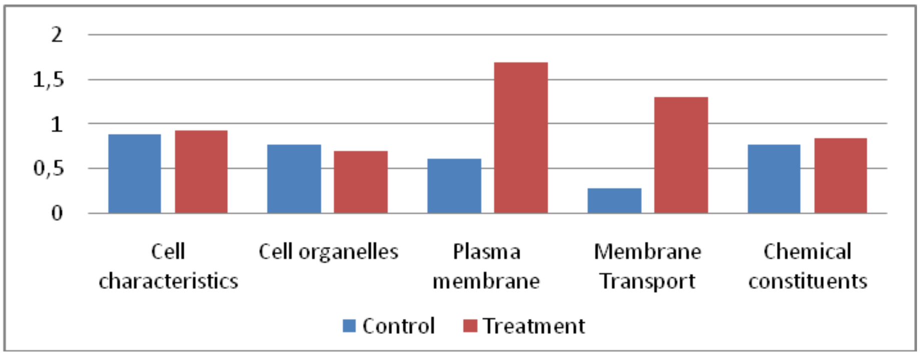

Figure 4*: Comparison of Average Scores Gain in the FiveTopics Studied*

4. Discussion

The finding confirms that the animation-based instruction has led to an improvement in achievements and raised the level of students' knowledge of cell biology (average score gain=5.46 in the treatment group). Similarly, traditional learning had improved the achievements of the control group students but to a lesser degree (average score gain=3.31). Admittedly, the two teaching methods increased students' achievement, but the improvement was more significant in the case of the treatment group ($z = -3.017$; $p<0.05$).

The results also show that the achievements of the students in the treatment group are better than those of the control group for the five items studied. The items for which the achievements are superior are those relating to the structure of the cell membrane and that of membrane transport. These two items are considered among the most difficult for students to understand because they deal with dynamic and complex processes.

These results are consistent with other research that suggests animation supports improved student learning (Kiat et al., 2020; Nesbit & Adesope, 2011). In the same way (Mohapatra, 2013), a study carried out with pre-service teacher trainees found that the use of animation in a lecture led to significant improvement in learning compared to the use of static pictures, especially when it is about teaching complex biological topics such as transport across the cell membrane.

The use of animation-based instruction has many benefits and advantages (Ploetzner et al., 2020, 2021). Animation allows to illustrate the complexity of a system (such as the cell) and this is by showing the transitional states of a process(Berney & Bétrancourt, 2016; Castro-Alonso et al., 2016; Lowe & Schnotz, 2008); animations visualise the dynamic aspects of a system, such as a cell(Berney & Bétrancourt, 2016; Lowe & Schnotz, 2008). Also, animation can convey the causal chain underlying the functioning of dynamic systems (Ramsay & Terras, 2015).The use of animations in teaching cell biology allows fora better understandingof the interactions between the different elements of a system, as well as the relationship between molecular processes and the structure of the cell; this makes it easier to understand the relationship between the function (for example, of an organelle cell) and the corresponding structures (Berney & Bétrancourt, 2016; Ryoo & Linn, 2012).

However, other research shows that the use of animations does not bring any benefit to learning compared to the use of static pictures (Ploetzner et al., 2020). These researches point out several criticisms of the use of animations, the most cited of which are animations impose a large amount of information to process and constitute a learning obstacle for the learner(Geri et al., 2017);animations mean that the learner is forced to extract and process useful transient information gradually, which constitutes a very heavy cognitive load(Berney & Bétrancourt, 2016; Paik & Schraw, 2013; van Merriënboer & Sweller, 2005); animations are much more time-consuming (Berney & Bétrancourt, 2016); and animations may give rise to new and resistant misconceptions(Tasker & Dalton, 2006).

Anyway, even if the content of the static pictures and that of the animation can be identical, this one is advantageous because it is enhanced by motion, which is very important, especially in the learning of the biological phenomena and processes. However, it should be noted that the conceptions acquired by the use of sometimes oversimplified digital tools risk leading to a poor understanding of the complex biological phenomena. In the same way, it is necessary to test the robustness and the perennially of the acquired knowledge of the students who profited from teaching using animated sequences.

5. Conclusion

This study aimed to test the effectiveness of the use of animation-based instruction on the students' learning in cell biology (treatment group). The results of this impact are compared with those of a traditional lecture (control group).

The results allow confirming that both the teaching methods (traditional and animation-based instruction) have led to an improvement inlevel of knowledge of cell biology among students but the improvement is more significant in the case of the treatment group.

The results also show that the achievements of the students in the treatment group are better than those of the control group,especially initems relating to the structure of the cell membrane and membrane transport. These two items are considered among the most difficult for students to understand because they deal with dynamic and complex processes.

The use of animation is especially important in teaching complex concepts and dynamic processes. The cell is a complex system; the use of static pictures cannot make understand the dynamic aspect of the cellular and molecular processes and the interactions between the various elements composing this system. Thereby, learning is best achieved because students are more motivated and are not bored as in the case of a traditional lecture. However, the use of animations can only be beneficial if teachers integrate them into a teaching sequence that makes the learner more active and autonomous in the construction of his learning.

However, it is necessary to specify some limitations of the study and which are the small size of the sample and the fact that we did not evaluate the achievements after a long period to see the effectiveness and the sustainability of the impact of the teaching method tested.

6. Recommendations

Cell biology is a discipline perceived as difficult by students who present many alternative conceptions of it. Hence, the interest in using varied teaching methods that put learners in situations that encourage them to learn individually and in groups, to be aware of the interest of their learningand to think critically about learned knowledge. That is to say,these methods allow inducing a conceptual change from alternative conceptions to scientific ones. This requires the development among learners of skills, such as autonomy, critical thinking etc. Additional research should be conducted to test the effect of the use of animation-based instruction on the development of these skills.

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