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Instructors and Students' Practices and Behaviours during a Quantum Physics class at the University of Rwanda: Exploring the Usage of Multimedia

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Abstract. This study was aimed at exploring the usage of multimedia during a quantum physics class. Five instructors and 385 undergraduate students at the University of Rwanda, College of Education (UR-CE) were observed and surveyed. Thus, the study employed experimental and survey designs. A standardized classroom observation protocol for undergraduate STEM (COPUS) and a validated online survey were used. Classroom observation data were analysed quantitatively using an M.S. Excel spreadsheet, and interpreted descriptively. Likewise, survey data were analysed qualitatively using a note-pencil, and interpreted narratively. The class in which a multimedia method was used, showed more active learning compared to one in which lecturing was used. The findings indicated that instructors (lecturers) were guiding students, and the students were working in the multimedia class. In the lectured class, instructors were found presenting the content to students and students received information passively. Instructors identified the mathematical

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background as the trigger to students' negative attitude towards learning quantum physics when they were encouraged to learn through animations, PhET simulations, and YouTube videos. The study recommends the use of multimedia technologies in teaching quantum physics-related concepts.

Keywords: Classroom practices; multimedia tools; quantum physics; instructor perceptions; university students' perceptions.

1. Introduction

1.1 Background to the study

The educational system in Rwanda strives to improve quality education by ensuring inclusiveness and equitable education, promoting education for all, and lifelong learning in a country led by a knowledge-based economy (Ministry of Education [MINEDUC], 2018). To achieve quality education, a key strategy such as the use of information and communication technology (ICT) in teaching and learning by augmenting smart classrooms and ICT devices, implementing the new competency-based curriculum (CBC), and promoting Science, Technology, Engineering, and Mathematics (STEM) across all educational levels is in place (Republic of Rwanda, 2017).

Multimedia and a variety of instructional tools play a significant role in teaching and learning physics. For that reason these tools should be well-designed to enhance students' retention of physics concepts (Ndihokubwayo et al., 2020a). Studies conducted by Nzaramyimana et al. (2021) and Oliveira and Oliveira (2013) showed that students' performance increased when they started learning independently through dynamic interactive software. In this context, the use of multimedia in teaching and learning positively impacts students' performance. Thus, students understand more when multimedia, such as audio and visual representations, are used (Kareem, 2018).

Observing classroom practices to assess the effect of instructional methods on students' academic achievement is vital in teaching and learning (Mukagihana et al., 2021). The way sciences, in general, and physics, in particular, are taught do not motivate students to learn actively. As a result, students perform poorly in physics subjects due to inadequate practical skills (Ndihokubwayo et al., 2022). In Rwanda, secondary school teachers mastered applying adequate interactive teaching approaches whereby they integrate exciting activities, a variety of events, and relevant visualizations that boost learners' confidence to express their ideas and link learning content to real-life experiences (Nyirahagenimana et al., 2022). Indeed, Nkurikiyimana et al. (2022) argue that students are motivated and are able to understand physics concepts when strong interactive activities and multimedia are used. However, Ndihokubwayo et al. (2020b) found that teachers do not fully exploit the use of PhET simulations and YouTube videos which are likely to sustain students' interest in learning. Hence, it was recommended that teachers incorporated these instructional tools since they contribute effectively to teaching and learning some physics concepts.

Due to the policy of having sufficient human capital in the workforce, many undergraduate students were enrolled in STEM subjects to complete undergraduate majors in these subjects. However, during their studies, students experienced uninspiring introductions to these courses, as teaching in these subjects still is dominated by traditional lecturing (Akiha et al., 2018). While conducting a campus-wide investigation of clicker implementation emphasizing peer discussion in STEM classes, for example, Lewin et al. (2016) observed that instructors used clicker demonstrations but did not allow peer discussions following clicker questions. The authors argued that failure to use peer discussions might affect students' reasoning, collaboration, and ability to share thoughts among group members. Similarly, at the University of Maine, Smith et al. (2014) did not manage to classify lecturers either into traditional lecturers or instructors who teach interactively since lecturers exhibited a variety of instructional behaviours on the continuum between these two classifications. This is explained by the fact that even if instructors with large classes are likely to lecture, some instructors were observed using interactive teaching methods in STEM courses. However, in a study conducted at the University of Technology and Arts of Byumba (UTAB), Rwanda, Mukagihana et al. (2021) found that lecturing and animation-based instructions dominated, together with small-group laboratory activities that promoted learner-centredness and achievement.

Problem statement

Literature shows that methods used in higher education institutions are diverse and include techniques such as real-time data logging, Socratic-guided inquiry, interactive computer simulations, and structured problem-solving. These methods strongly encourage "learning from peers, emphasize rapid feedback, and guide students to express and reflect on their reasoning processes in learning physics" (Meltzer & Thornton, 2012, p. 495). Some years ago, science courses, particularly physics in higher education, faced problems such as lack of motivation and failure, which resulted in some students dropping out. The most mentioned probable reasons were the poor interaction between instructors and students, and poor instructional settings (Oliveira & Oliveira, 2013). Research conducted on the teaching and learning of quantum physics showed that its abstractness was reported to make this content difficult for undergraduate students (Bouchée et al., 2021). While undergraduate courses play a critical role in STEM retention, little is known about the type of instruction students receive after completing their post-secondary STEM courses (Akiha et al., 2018). In addition, instructors still rely more on textbooks and syllabi, which leads to a lack of awareness about multimedia use, such as PhET simulations and YouTube videos in physics classes (Ndihokubwayo et al., 2020b). Most university lecturers still use traditional methods without minding the 21st century innovations. However, the literature shows that multimedia impact students' achievement in physics (Ndihokubwayo et al., 2021; Ugwuanyi & Okeke, 2020). Thus, the current study was worth being conducted to assess the effects of multimedia usage on learners' practices and behaviour in mastering quantum physics.

Theoretical review

Instructors and students value the integration of ICT in their instruction. For instance, Kohnle et al. (2015) reported that students perceived simulation as a helpful tool that enhanced their conceptual understanding and active learning. Similarly, Laosethakul and Leingpibul (2021), while capturing students' perceptions about using these three teaching methods, found that students perceived instruction through video-based tutorials as enhancing their understanding and the ease of following the lesson. The study conducted to assess students' attitudes towards physics in the Nine Year Basic Education in Rwanda showed that many participants had a negative attitude towards learning physics in general (Mbonyiryivuze et al., 2021). Therefore, in this study, we specifically documented university instructors' and students' perceptions of the usage of multimedia during teaching and learning quantum physics to supplement classroom practices.

Traditional instructional methods provided insufficient opportunities for undergraduate students to construct meaning. However, the use of multimedia such as texts, audio-visual and audio content, cartoons, images, and interactive content in teaching and learning physics positively impacts students' learning achievement, (Kareem, 2018). Using multimedia in teaching physics enables lecturers to transmit the content differently to enhance students' environment to be conducive to learning (Ibrahim, 2011). Thus, this study is significant, since the findings of this study will positively affect instructors' practices and behaviour toward students' performance and interests during quantum physics teaching at the University of Rwanda.

This study was based on the cognitive learning theory (Ibrahim, 2011), since multimedia in teaching physics will enable lecturers to transmit the content differently to enhance students' learning. Cognitive learning infers developing students' thinking abilities through interacting with the environment and building on students' prior knowledge. Through this theory, human cognition interacts with oral and nonverbal contents and events since there is a referential connection linking verbal and nonverbal clues (Ibrahim, 2011). Knowledge is easily acquired and stored in memory when it is presented in different forms, such as verbal and visual representations (Wigham, 2012). Thus, this study was aimed at:

- Assessing instructors' and students' classroom practices while using multimedia in quantum physics.
- Exploring instructors' and students' perceptions after multimedia and lecture usage in teaching quantum physics.

2. Methodology

Research design and sampling techniques

In this study both experimental and survey designs were used (Fraenkel et al., 2012). Participants were randomly assigned to two groups, where one group was taught using a multimedia-aided approach, and another group was taught using the lecture method. During these two interventions, both classes were observed and surveyed. The aim was to assess whether the multimedia intervention used met the pre-determined specifications for solving the research problem and to generate recommendations for future work.

The study targeted physicist educators and students from the University of Rwanda College of Education (UR-CE), Department of Mathematics, Science and Physical Education (MSPE). In this department, five physics instructors, teaching quantum physics, and 385 second-year students studying quantum physics modules were purposively selected to participate in the study. The participants, undergraduate students from Mathematics-Physics-Education (MPE), Physics-Chemistry-Education (PCE), and Physics-Geography-Education (PGE), were randomly assigned to a control group (n = 192) or lecture class and an experimental group (n = 193) or multimedia class. Regarding instructors' experience, all lecturers involved in this study were senior lecturers, and they were briefed by the first author on the intervention they needed to deliver. The study was conducted over a period of six weeks between January and March 2022. The control group (lecture class) was instructed by means of PowerPoint slides, a whiteboard, and markers, while in the experimental group (multimedia class) animations, PhET simulations, and YouTube videos were used.

Instruments

Two instruments were used to assess the effect of multimedia usage on teachers' and student practices and behaviour in quantum physics teaching and learning in Rwandan higher education institutions. The first was a classroom observation and the second was a survey. We used a Classroom Observation Protocol for Undergraduate STEM (COPUS) to observe instructors and students in multimedia and lecture classes. Smith et al. (2013) developed the COPUS to describe classroom teaching practices and student behaviour. This protocol is a new instrument to characterize university STEM classroom practices. It was designed to capture the teaching and learning activities done by STEM instructors and learners during each portion of two-minute time intervals after a short 1.5-hour teaching period to reliably characterize how instructors and students spend their time in the classroom (Smith et al., 2013, 2014). COPUS has 28 codes of activities, including 12 for the instructor, 13 for students, and three for student engagement. The validity of the COPUS tool was established during its development process. The Kappa statistics were employed to ensure the agreement between the two rates on this tool. Student codes generated a .652, instructor codes generated a .805, while student engagement codes generated a .625 Kappa value. These are considered very high values regarding interrater reliability.

Likewise, a survey was administered online to document instructors' and students' perceptions during multimedia and lecture instruction implementation. Instructors were asked four questions, while students were asked one major question that needed a detailed description (see Table 1). University lecturers validated these items for trustworthiness before data collection.

Table 1. Survey items for instructor and students

Instructor	Students
➢ How were students motivated during quantum physics classes? ➢ What main challenges have you experienced when teaching the quantum physics module? ➢ Have you used any ICT teaching tools in quantum physics lessons? If so, which ICT teaching tools? ➢ What do you think makes the quantum physics module interesting for students?	➢ Do you consider the existing teaching practices (teaching methods used by your lecturer) efficient enough for you to understand quantum physics concepts? o If yes, explain your answer. o If no, explain your answer.

Ethical clearance
The research project successfully passed through URCE (Ethical Committee) by following the established ethical process: (1) presentation of the research proposal, (2) submission of the application and tools to be used for ethical research clearance, and (3) review and approval of the application by the ethical research committee. The researchers also obtained a formal informed consent form approved by the University of Rwanda College of Education Ethical Committee and filled out by each student and instructor participating in the study.

Data collection procedures
Trained research assistants from the African Centre of Excellence for Innovative Teaching and Learning Mathematics and Science (ACEITLMS) collected the data obtained from classroom observation. In this study, the COPUS tool was used to describe the instructor and student actions in the quantum physics class. In order to effectively use this tool, three steps were followed: pre-classroom observation training session, classroom observation practice, and post-classroom observation reflection session.

During pre-classroom observation training, a group of four research assistants (master's students in science education at ACEITLMS) was trained to use the COPUS sheet and on COPUS code description. The training was conducted for two hours, and its purpose was to help observers to understand and become familiar with the code and its descriptions. In the training process, the researchers displayed the student and instructor codes and discussed with the observers what each behaviour typically looks like in the classroom.

For classroom observation practice, all four trained observers were given paper versions of the coding sheet and code descriptions sheet, and noted Down in coding what the students and the instructor did during each portion of two-minute time intervals in the physics classroom. They used cell phones to count the time to keep the observers synchronized and to ensure that they filled out a new row in the observation protocol at identical 2-minute intervals. This exercise was done individually for 40 minutes and in pairs for another 40 minutes.

A post-classroom observation session was conducted with all observers and the first author. First, each observer presented his/her code and then compared his/her codes with partner pairs codes, and then the whole group discussed the student and instructor codes for each of the 2-minute segments of the 40-min period. To select research assistants who conducted classroom observation during our intervention period, we examined the agreement between pairs of observers, and two of them were selected. Their interrater reliability was higher when compared to the rest. Selected observers were appointed to conduct classroom observations; one in a class that was taught quantum physics using multimedia-aided technologies (demonstration using animations, PhET simulations, and YouTube videos), and another one in a class taught quantum physics by using lectures (using PowerPoint or notes slides) over six weeks (from January to February 2022). Each week, four periods of 40 minutes were observed.

Data analysis
Data were analysed descriptively. We used an M.S. Excel spreadsheet to analyse the classroom observation data, and a note and pencil method to analyse the survey data. Results were interpreted descriptively and narratively. For COPUS data, the average of each instructor or student code was summed up, and its average was computed (Ndihokubwayo et al., 2021). Thus, each activity percent contributed to the accumulated percentage. Since COPUS developers advised to collapse or combine some codes for easy visualization and interpretation, we followed their approach to present our results. We analysed the data on paper for survey findings and used a pencil to group thoughts. We presented these findings using a narrative mode (Ndihokubwayo et al., 2019) by describing the respondents' thoughts and depicting some quotes for representation.

3. Results and Findings

Classroom practices

The graphs on this sheet show how frequently a given activity code was marked compared to the sum of all codes marked in all time intervals during the class session, expressed as a percentage. Because a given activity may not occupy the full two minutes of a time interval, and because multiple activities may occur simultaneously (e.g., the instructor might be moving and guiding [M.G.] and having a one-on-one [1o1] interaction at the same time), these percentages do not represent the fraction of time devoted to each activity. Rather, they are the fraction of activities calculated separately for the instructor's and students' activities.

Table 1 presents the overall results of control and experimental groups in all COPUS codes. On the students' side, listening (L) dominated the class in the control group (with 181 out of 365 counts of responses, or 50% of responses), while multiple activities (such as thinking [Ind], clicker discussion [C.G.], answering questions [AnQ], and other-group [O.G.]) dominated in the multimedia class. Likewise, both lecturing (Lec) and writing (RtW) dominated other instructor activities (with 129 out of 384 counts of responses, or 34% of responses for each activity) in the lecture class. In contrast, multiple activities (such as follow-up [Fup], one-on-one [1o1], clicker questions [C.Q.], and demo/video [D/V]) dominated in the multimedia class.

Table 1: Activity as a percentage of all activities in lecture and multimedia classes (Note: Each colour adds to 100%, within rounding error)

		Lecture Class		Multimedia class	
	Activity	Count of responses	% of Responses	Count of responses	% of Responses
Students	Listening (L)	181	50%	33	10%
	Answering (AnQ)	76	21%	43	14%
	Asking (S.Q.)	23	6%	0	0%
	Whole Class (W.C.)	3	1%	0	0%
	Presentation (S.P.)	5	1%	4	1%
	Thinking (Ind)	26	7%	70	22%
	Clicker Discussion (C.G.)	22	6%	46	14%
	Working Group (W.G.)	2	1%	23	7%
	Other Group (O.G.)	2	1%	41	13%
	Prediction (Prd)	0	0%	32	10%
	Test/Quiz (T/Q)	5	1%	20	6%
	Waiting (W)	5	1%	6	2%
	Other (O)	15	4%	0	0%
	Total Responses:	365		318	
Instructor	Lecturing (Lec)	129	34%	13	4%
	Writing (RtW)	129	34%	37	10%
	Demo/Video (D/V)	6	2%	43	12%
	Follow-up (Fup)	31	8%	102	28%
	Posing Question (P.Q.)	2	1%	0	0%
	Clicker Question (C.Q.)	3	1%	57	15%
	Answering Question (AnQ)	5	1%	29	8%
	Moving (M.G.)	1	0%	19	5%
	One-on-One (1o1)	58	15%	67	18%
	Administration (Adm)	8	2%	2	1%
	Waiting (W)	2	1%	0	0%
	Other (O)	10	3%	0	0%
	Total Responses:	384		369	

By narrowing down visualization and collapsing some codes, we still got a high percentage of receiving (50% of other combined activities) on the side of students in a lecture class. Similarly, the instructor dominating collapsed code was presenting (69% of other combined activities) in lecture class (see Figure 1).

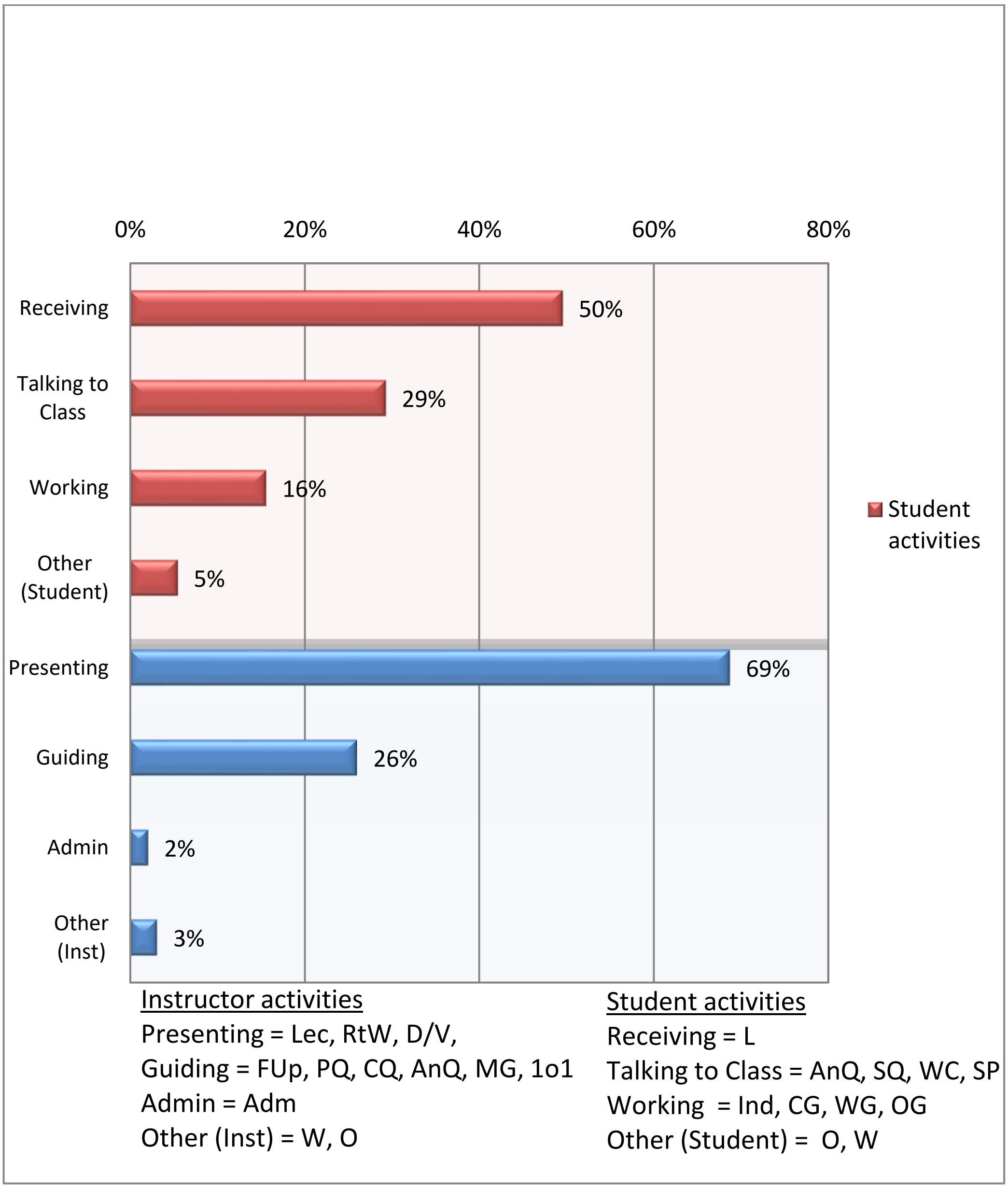

Figure 1: Activity as a percentage of all collapsed codes in lecture class (Note: Each colour adds to 100%, within rounding error)

Despite the instructor-centred mode or passive learning observed in a lecture class, we had a different situation in the multimedia class. Figure 2 shows that working collapsed code was dominant at 73% of other codes on the side of students while guiding dominated (74%) other codes on the instructor's side. It can be seen that multimedia-aided instruction helped students learn in an active learning mode which is conducive to learning, while during the lecture they were passive.

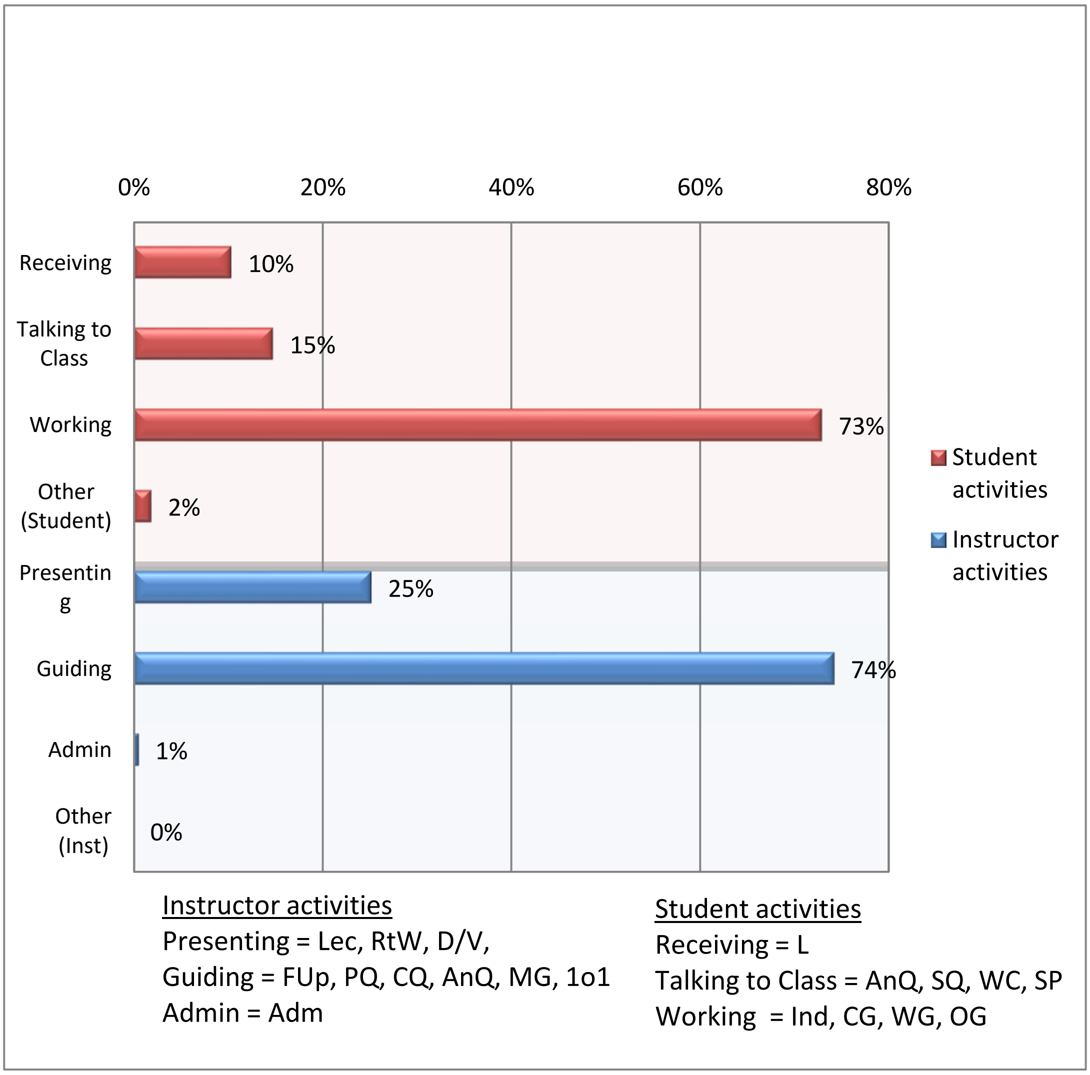

Figure 2: Activity as a percentage of all collapsed codes in the multimedia class (Note: Each colour adds to 100%, within rounding error)

Instructors' and students' perceptions

Instructors' perceptions

Instructors that used multimedia testified that the students were motivated. One instructor from a multimedia class said, "When multimedia is used, students are motivated". However, instructors in lecture classes realized that some students were discouraged by the high level of mathematics in the course. It seemed like multimedia omitted providing mathematical background. However, mathematics was needed in both classes. The main challenges experienced when teaching quantum physics/modern physics modules were outlined by the instructors of both multimedia and lecture classes. One of the lecture class instructors noted that less mathematical background was provided to the students. For instance, he claimed that " ... getting used to Dirac notation was low for students". Another claimed that due to big classes, a lack of experiments or other tools to illustrate quantum physics concepts arose. It seemed that when multimedia were used, the problem of the big classes was resolved.

When asked whether instructors used ICT teaching tools in quantum physics/ modern physics lessons, they all confirmed that they used PowerPoint presentations with a computer and projector. However, those in lecture classes used these tools to present the theoretical content, while those WHO used multimedia, used computers and projectors to manipulate simulations and watch YouTube videos. We finally asked instructors whether they proposed something that could make the quantum physics module more interesting for students. They all agreed that animation and/or simulation could be used. One instructor said, "The use of demonstration and multimedia-aided technology can help students learn well". Strong and accurate mathematical demonstrations, results simulations, and plotting of the orbitals were also articulated as supporting modes to smoothly raise students' interest in learning modern physics.

Students' perceptions

Asked whether they considered the existing teaching practices efficient enough to understand quantum physics concepts, 78% of the students in the multimedia class said "yes" to multimedia instruction, while 45% in the lecture class said "yes" to lecture instruction (see Figure 1).

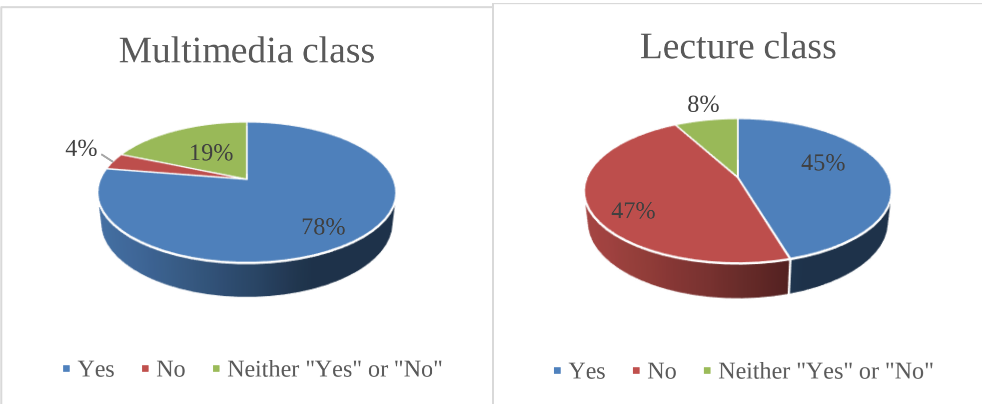

Figure 3: Students' perceptions of a useful teaching method to help them understand quantum physics

Students in multimedia classes: Students testified that multimedia helped them understand abstract concepts in quantum physics. For instance, one student said:

> *Yes, my lecturer used simulation and animations. This helps me better understand quantum physics, especially the photoelectric effect, Compton effect, and black body radiation. It is enough because what she taught us concerned with the thing which cannot be observed using naked eyes (it is microscopic).*

Another student testified that the method helped him to make meaning by observing abstract concepts; therefore, he could understand everything. He confidently mentioned that he now could solve new problems because of that method.

Students took multimedia usage as various events that could bring insights and engage them in learning, while stimulating them to explore real-life environments. For instance, one student said, "Yes, my lecturer used more examples using simulation, demonstration, a different event that helped me to understand quantum physics better and see where it is applied in real-life."

Students perceived multimedia as a learner-centred approach and a tool that enhanced scientific thinking. They were confident that they could teach quantum-related concepts themselves. For instance, one student said, "The method used includes some video animation, simulation, and some demonstration which make us think scientifically." Another student said, "This is a learner-centred approach, it helped us provide our ideas, and the lecturer acted as facilitator. It was a good method because I now can teach concepts found in this module." Students confirmed that they were attentive and that there was a change in their behaviour because of the interesting method used. They said the method was efficient because they understood the different phenomena used in quantum physics and related experiments better.

Some students who answered "no" to the method, claimed that exercises were insufficient. For instance, one student said, "No, because I try to do some exercises, I try to do well some of them, but I see others are difficult. Our lecturer, please help me to be able to do all questions on quantum physics; thank you." Another student claimed that there was a lack of technology, such as computers for the learners that would help them to practise more and more. He mentioned thatthere should be sufficient computers available so that they could repeat what the instructor had taught them in the classroom.
Some students who neither answered "yes" nor "no" said that the method used was insufficient because this module requires practical work to understand more. He said that although observation through animations is real as it appears; however, fieldwork is necessary for more information.

Students who said "no" to the method, and even those who appreciated it, requesred more exercises and clarification of mathematical expressions. One student said, "Yes, since she was using animation, it was better for me to understand. If possible, she can continue to facilitate me in another part that involves mathematical expression and operators in Schrodinger equations." Another student responded, "Yes, it helps, but more explanations and exercise (in class) are needed."

However, students appreciated how the instructor gave them more assignments and were keen to revise the content themselves. One student said, "In fact, the lecturer used more effort to explain us, but the lesson is too hard to understand where students are also required more effort to revise. It will be helpful if all physics lecturers can teach using ICT as she did."

Students in lecture class: The lecture method was appreciated by some of the students. They said that the method used made them feel comfortable with quantum mechanics; however, most of them suggested that there was a need for improvements. One student said, "Yes, because the lecturer used different methods to explain very well and allowed collaboration with learners, but the teacher may try to give more exercises and corrections to students." Others testified that the methods used by their lecturer were sufficient for them to understand quantum physics concepts. One student provided an example: "Yes, the method he uses helps to develop the questions and the way of solving them, which helps us to think critically and solve the problems very quickly." However, the student recommended that the lecturer should have prepared the lesson on mathematics about Schrodinger before delivering the module, which would have helped them to understand more. He said, "When we were learning, he tried to help us to understand the concept very well, except the Schrodinger equation. It is very difficult because it is mathematics." Other students claimed that the module contained too many chemistry terms. One student said, *"Yes, because it has many chemistry terms and is a mathematics module."*

Students who were against the lecture method, provided many reasons. Some claimed lectures were not efficient enough, because the class was large, the lecturer did not use demonstrations such as simulation and animation, quantum is one of the most difficult modules, during lectures practical demonstrations were not used, a shortage of material existed, the time to cover the module was too short, and the method was teacher-centred. One student said, "No, because I didn't understand quantum physics, the method was not enough for me; if possible, he may use both demonstration and multimedia methods to make it more understandable." Another student said,

> *No, it was not efficient because my lecturer used the lecturer-centered method, and time for doing or showing an example to solve quantum physics was limited, so the lecturer must use many examples and let students do those to get a great understanding.*

Other students claimed they did not get an opportunity to see how things work and were not given a chance to do some research. Therefore, they suggested that they needed more exercises related to the module, and the lecturer should have used concrete examples to explain the content. Others suggested that it would be better if their lecturer showed some related videos or helped them to conduct some experiments.

4. Discussion

Instructors' and students' classroom practices during the application of multimedia in quantum physics

In this study we compared instructor and student activities during lecture and multimedia classes. In general, students' activities were dominated by listening (L) in the lecture class, equivalent to 50% of responses, while the listening (L) activity was reduced to 10% in the multimedia class. The fact that the listening activity was reduced shows how much students were involved in other activities such as answering, thinking, and predicting, which also got high scores. However, the general observation reveals the students' passive learning during the lecture class.

We also found that writing (RtW) dominated instructors' activities, as indicated by 34% of the responses of students in a lecture class, which decreased to 10% in the multimedia class. However, in the lecture class, the instructors' activity was mainly characterized by doing follow-up work, according to 28% of the responses. That instructors did follow-up work s in the multimedia class indicates that instructors facilitated students in their activities. These findings also show how the teaching and learning of quantum physics are dominated by the teacher-and-talk approach, during which students are mainly copying notes from their notebooks.

The general pre-determined results are not different from the results found after merging some of the activities in both lecture and multimedia classes. In the lecture class, students' activities were dominated by the receiving activity (50%), while the instructors' activity was mainly presenting (65%). As discussed previously, this implies a teacher-centred learning pedagogy where it seems that students learn quantum physics passively. However, some changes were noted while merging the lecture class activities with the teacher-centred learning pedagogy, but the students' dominance during activity working was rated at (73%), while the instructor dominated guiding (74%). The implications of these results are that students are actively engaged in learning during the multimedia class as their instructors assist them.

Instructors should be interactive in ways that give students room to learn actively. Within this context, instructors should not spend much time writing notes while students only copy. Instead, students should be allowed to think, work in groups, and present, among other activities. Ndihokubwayo et al. (2022) also found that teachers and learners spent much time lecturing and listening to physics instructions. In addition, Ndihokubwayo et al. (2020b) found that lecturers still relied on using syllabi and textbooks, which resulted in them forgetting about multimedia integration while teaching physics. These observations were not only found in physics instructions, but also in other STEM subjects. For instance, Mukagihana et al. (2021) found that lectures and small-group laboratory-based activities dominated the main teaching of biology more than animations did. While using COPUS in chemistry instruction, Byusa et al. (2020) argued that although teachers put students in groups, students were still learning passively since teachers simply moved around the groups without encouraging the students to complete the given activities.

Instructors' and students' perceptions of multimedia and lecture usage in teaching and learning quantum physics

After exposure to multimedia and lecture teaching methods, we collected instructors' and students' perceptions. Instructors reported on their observation of ways in which observed students perceiving multimedia and lecture-based instruction. Our findings show that students were satisfied with the use of multimedia since they were allowed to interact during PhET simulations and YouTube videos. However, students in the lecture class were discouraged by the numerous mathematical computations that learning quantum physics entails.

The findings of the instructors' responses are not different from those of the students. Both the students in the multimedia and lecture classes were adamant about the effectiveness of these two learning methods since they all were learning collaboratively. However, multimedia potentially may reduce the abstractness of quantum physics, as reported by 76% of students in the multimedia class. This is because students could use simulation and animations and observe some phenomena they could not observe in real situations with the naked eye. In addition, the use of multimedia promotes a learner-centred approach, as was also observed in the physics classroom observation. Indeed, with multimedia, students are exposed to interactive multimedia, whereby the instructors can let them explore to develop their critical thinking. Although students in lecture classes may have gained in learning, they lacked some content clarifications since the instructors did not manage to conduct the demonstrations as clearly as it was displayed by multimedia.

Because quantum physics is more abstract, instructors should integrate multimedia into their teaching through animation, simulation, and watching YouTube videos (Bouchée et al., 2021), which encourage and result in students' conceptual understanding and performance (Ibrahim, 2011). The active learning promoted by being exposed to multimedia would result in students becoming interested in using this technology (Nzaramyimana et al., 2021; Oliveira & Oliveira, 2013). Online videos that are more interactive, containing tasks, questions, and quizzes, which enhance students' active learning, are recommended to support the teaching and learning of quantum physics (Richtberg & Girwidz, 2019).

Students encountering difficulties in calculations are a major issue for some undergraduate students. For instance, Johansson et al. (2018) argue that students do not have the required abilities to be good at quantum physics since they are hampered by the many mathematical calculations that are found in learning quantum physics, and which may result in negative consequences for students who are disinterested in the topic. Thus, a need exists to investigate the way in which students acquire knowledge through different forms of content representation, since knowledge is easily acquired and maintained when presented in different forms, such as text, verbal and visual representations (Wigham, 2012).

The unique finding of this study was attained through the use of classroom observation and student-lecturer surveys to document the extent multimedia plays a role in learning quantum mechanics. This adds knowledge to the existing small quantum study literature, higher learning, and the Rwandan context.

Limitations of the study

This study focused on a public higher education institution. It did not study the situation of learning quantum physics in secondary schools or private higher education institutions. The study only focused on quantum physics. It did not look at other modules to ease the comparison of branches of physics taught at the university level.

5. Conclusion

This study was aimed at exploring university instructors' and their students' classroom practices and perceptions when implementing multimedia and lecture instruction in Rwanda. We had two objectives with the study: The first was to document classroom practices including COPUS, while the second was a survey to determine how participants perceived instruction. Four instructors and 385 students participated in this study, and data collection was done at the beginning of the 2022 academic year at the University of Rwanda College of Education (UR-CE). The study results showed that multimedia classes enhanced students' active learning more than lectures. Also, the observed instructors testified that students were motivated to learn through multimedia, although some students needed a mathematical background. Likewise, students who were taught through multimedia revealed a positive attitude toward learning quantum physics and appreciated the usage of animation, computer simulation, and YouTube videos. Therefore, we recommend that lecturers at UR-CE should use multimedia-related tools in their classes. Although the study employed a sufficient sample, the findings may not be applicable in other modules; therefore, we recommend the same study to be conducted in other modules taught at UR-CE, or other higher learning institutions in Rwanda or abroad.

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Declaration of Interest

The authors declare no competing interest.

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