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How Pre-service Teachers Learn Microbiology using Lecture, Animations, and Laboratory Activities at one Private University in Rwanda

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Abstract. Observing classroom practices and checking the effect of instructional methods on academic achievement are crucial in the teaching and learning process. The present study was aimed at discovering the dominating pre-service biology teachers' and instructors' activities in microbiology classes and their respective effects when animations–based instructions and small-group laboratory activities are used. An equivalent time-series design was applied using a small group of participants in year two biology education (N=30, 16 female and 14 males), and a pre-test was used as a pre-intervention comparison test, while a post-test alternated with interventions. Classroom Observation Protocol for Undergraduate STEM (COPUS) was used to record classroom activities. Before using its inter-rater agreement reached 80%. Pre-service Biology Teachers Achievement Test (PBTAT) with a Pearson's r reliability of .51 served to measure instructional methods' effect on academic achievement. It was found that the main teaching methods were activities, lectures and animation classes, while group work and instructors moving among the students and guiding them characterized small-group laboratory activity classes. All interventions improved pre-service biology teachers' academic achievement; however, a statistically significant difference (df=28, *p*<.05) existed between interventions where small group laboratory activities proved a considerable effect size (d=3.86). No statistically significant difference (df=1, $p>.05$) was found regarding gender after interventions. However, females scored better than males after the lecture and laboratory methods, while the opposite happened after animation-based instruction. Therefore, we recommend using small-group laboratory activities that promote active learning through student small-group work to improve pre-service biology teachers' academic achievement in biology.

Keywords: pre-service teachers; microbiology; lecture; animations; laboratory activities; Rwanda

1. Introduction

Biology is a course in life sciences found in all nations' educational curricula and is taught to most students, including pre-service teachers, in preparation for becoming secondary school biology teachers (Wibowo & Sadikin, 2019). In developing countries, the teaching of biology has been dominated by conventional instructions and limited to concepts like a description of a structure or function of selected living organisms, presenting others with similar features (Younès & Vohra, 2000). Microbiology is one of the introductory biology courses that informs about common infectious diseases, their prevention, and treatment measures (Au et al., 2008). In higher education, teaching microbiology is found most successful when motivating instructional methods are used, like those promoting critical thinking skills, and hands-on and mind-on methods, such as workshops, group work, and game-based methods (Efthimiou & Tucker, 2021). Microbiology, due to its structure, requires instructional methods that promote students' active classroom practice rather than presented theory to enable concepts fixation and understanding.

Classroom practices are described as teachers' and students' behaviours during the teaching and learning process. These behaviours occur one after another or in parallel, depending on the instructional strategies applied (Stains et al., 2018). Classroom practices are large in diversity, and investigating their educational context may inform instructional staff about factors contributing to students' subject achievement and student learning engagements (Lan et al., 2009). Smith et al. (2013), with the intention to develop a Classroom Observation Protocol for Undergraduate Science, Technology, Engineering, and Mathematics (STEM) (COPUS), classified classroom practice into, "What students are doing" and "What instructor is doing" during the teaching and learning process. This classification permits one to check what is done in a two-minute time interval, and with this the variability of students' engagement and its influencing practices may be recorded. Among the instructors' and students' classroom practices, studies report that lecturing and posing questions are dominant instructor practices, while listening and anwering instructors' questions are most students' common classroom practices (Stains et al., 2018; Byusa et al., 2020). Therefore, an imperative need exists for knowledge of students' and teachers' classroom practices at every level of education to inform teachers about how students learn when different instructional methods are implemented and about their contribution to students' learning engagement and academic achievement.

Instructional methods have different effects on students' learning outcomes, especially their academic achievements. Studies proved that the contribution of traditional methods to pre-service science teachers' academic achievement is much less than that of active instructional methods (Bektaşli, 2013; Dirlikli & Akgün, 2017; Selçuk, 2010; Agoro & Akinsola, 2013; Calik-Uzun, et al., 2019; Taşlidere, 2015). This is a call to pre-service science teachers, and, especially, pre-service biology teachers' trainers, to adopt active and innovative instructional methods like those incorporating instructional resources such as animations and laboratory resources to improve pre-service biology teachers' academic achievements.

Instructional ~~resources~~ create professional critical thinking skills, and hands-on and minds-on skills in pre-service biology teachers, which assist them to be competent future biology teachers (Mukagihana et al., 2020). Furthermore, instructional resources link instructional methods to the learning theories that emphasize students' involvement in classroom activities and the construction of knowledge. Besides, instructional resources make instructions meaningful, especially when promoting students' cognitive development through collaborative and practical learning (Hung, 2001). Laboratory activities, for example, have been proven to improve the learning of students in Rwandan schools (Uwamahoro et al., 2021). Similarly, multimedia such as you-tube videos, PhET simulations, and animations were found to positively affect students' performance (Ndihokubwayo et al., 2020a). Therefore, the present study aimed to test how pre-service biology teachers learn when instructional resources such as animations and laboratory resources, support instructions that are guided by didactic transposition theory (Chevallard, 1989).

Didactic transposition theory states that what can be observed in class is a teacher-student relationship (Chevallard, 1989). In other words, the teacher-student relationship during the teaching and learning process is described by what the teacher and students do. In the lab and classroom environments one can easily detect the student-teacher relationship by recording in which activities students are involved, and what teachers are doing.

Studies have been conducted on the effect of instructional resources on pre-service science teachers' academic achievement. However, few studies highlighted the impact of animation-based instructions and small group laboratory activities on pre-service biology teachers' academic achievement at private universities using a time series design. Also, few studies highlighted the link between classroom practices and the respective effects of instructional resources used. Researchers and universities were highly interested in detecting what was happening in STEM courses by measuring the students' and teachers' practices when an specific instructional method was applied (Lund et al., 2015), but few engaged in measuring instructional practices when training pre-service biology teachers with different instructional methods. Therefore, the present study aimed to throw light on how pre-service biology teachers learn when animations and small-group laboratory activities are used in class, specifically by establishing the effect of animations and small-group laboratory activities on pre-service biology teachers' academic achievement.

The study contributes to the literature. It provides valuable information on how pre-service biology teachers teach by illustrating the most relevant activities in microbiology classes in a series of lecturing methods, animation-based instructions, and laboratory methods using small-group laboratory activities. The study provides results regarding the effect of these instructional methods on pre-service biology teachers' academic achievements. This information may serve as a guide that shows teachers what their role in class should be; thus, pre-service biology teachers will gain pedagogical content knowledge that they can use as secondary school biology teachers to improve students' academic achievement.

Specifically, through the study we wanted to determine the effect of animations and small-group laboratory activities on pre-service biology teachers' academic achievement. Therefore, this study aimed to answer the following research questions:

1) Which teaching and learning activities are dominating microbiology classes for pre-service biology teachers at private universities when resource-based instructions are used?
2) Is there any statistically significant difference between mean scores of pre-service biology teachers when traditional and resource-based instructions are used on time series?
3) Is there any significant difference between academic achievement mean scores of males and females when resource-based instructions are used on time series?

We then **hypothesized** that:
$H0_1$: There is no statistically significant difference in pre-service biology teachers' mean scores when traditional and resource-based instructions, such as animation-based instruction and small group laboratory activities are used on time series.

$H0_2$: There is no statistically significant difference between male and female pre-service biology teachers' mean scores when traditional and resource-based instructions such as animation-based instruction and small-group laboratory activities are used.

2. Methodology
2.1 Research design
In the study a time series design was used which is a modified form of a typical pre-test and post-test design. This design involves implementing a group of pre-tests and post-tests by repeated observational changes in dependent variables over time before and after a teaching intervention. The design permitted the authors to measure the effect of the instructional method as an independent variable at three levels, namely traditional methods of teaching (lecture), animation-based instruction, and laboratory-based instruction through small-group laboratory activities on pre-service biology teachers' academic achievement dependent variables. A time-series design does not require the use of a large number of participants, and only one group can sufficiently serve a study (Creswell, 2012). This design was suitable for this study, in which a small number of participants were divided into control and experimental groups. During

implementation the researchers used a time-series design in its variation as an equivalent time series that allowed the researchers to alternate an intervention or treatment with post-test observations. Table 1 presents the way the design was implemented in the study.

Table 1: Equivalent time series design

Time	**Three weeks interval**						
	Interventions						
One group participants	Pre-test	Traditional methods	Post-test	Animation-based instruction	Post-test	Small-group lab activities	Post -test

2.2 Participants

The study was carried out at the University of Technology and Arts of Byumba (UTAB), a private university that trains pre-service biology teachers. As Mukagihana et al. (2020) described, the university was one of three selected private universities to participate in this study. Unfortunately, due to Covid 19 issues, twouniversities closed before data collection was performed (February to April 2021). Therefore, it remained the only private university offering biology education programmes that could participate in the study. The participants consisted of a small population of 50 pre-service biology teachers enrolled in year two in the Faculty of Education, Department of Education in Sciences. Among them, only 37 were available on the first day of the intervention. They formed a single group that participated in a pre-test and alternating interventions, and post-test measures using lecturing as teaching method, animation-based instruction, and laboratory methods through small-group laboratory activities. One research assistant participated in the study by observing and recording the student and instructor activities during interventions.

2.3 Data collection instruments and their reliability

Two instruments were used to collect the data. One was a Pre-service Biology Teachers' Achievement Test (PBTAT) developed by the researchers. This achievement test comprised twenty items/questions related to the concepts of microbiology, taken from a biology module purposively selected for intervention (please see Appendix 1). The internal validity and reliability of the instrument were checked by subjecting the instrument to microbiology experts at the Public University of Rwanda College of Education. After the pilot study, Pearson's r reliability test was calculated using SPSS 23, and the coefficient of .51 was found. Thus the instrument was found to be reliable and used.

The Classroom Observation Protocol for Undergraduate STEM (COPUS) was used to establish which teaching and learning activities dominated microbiology classes for pre-service biology teachers at private universities when resource-based instructions were used. The protocol was designed to help faculty members who did not have a classroom observation protocol to record the activities of undergraduate students and lecturers at university level at two 2-minute time intervals during the teaching and learning process (Smith et al., 2013). Therefore, COPUS was suitable for this study to identify pre-service biology teachers' activities in the microbiology class when traditional methods of teaching, animations–based instruction, and small group laboratory activities were used.

Before using the COPUS STEM, the first author and one research assistant were trained by Kizito Ndihokubwayo, one of the experts who documented and wrote on collecting and analysing data using COPUS (Ndihokubwayo et al., 2020b, 2021). During training, the trainer introduced COPUS by explaining its codes and when to code. After this session, the trainer played a video the researcher and assistant had to observe and they were asked to record the activities carried out by students and teachers in the video every two minutes. The training session lasted for two hours, and then agreement between the two raters reached 80%, indicating that the author and research assistant were ready to apply the protocol optimally.

2.3.1 Data collection procedures

The teaching intervention was carried out on a single group of pre-service biology teachers by implementing an equivalent time-series design described in Table 1. Before the intervention, the group of 37 pre-service biology teachers who were present received a pre-test of 40 minutes and after that they underwente three consecutive treatments, starting with the traditional method of teaching (lecture method), followed by animations-based instruction, and finally, the pre-service biology teachers learned in pairs by means of experimental activities in the laboratory.

A post-test of 40 minutes alternated with treatments thus followed the implementation of each instructional method. During interventions, participants' attendance increased day by day, and after the lecture class, the post-test was taken by 42 pre-service biology teachers. In contrast, after animation and small-group laboratory activities, the class post-test was done respectively by 43 and 45 pre-service biology teachers. In the data filtering 30 pre-service biology teachers' data were used for the analysis. These were those who completed both the pre-intervention test and all the post-tests. The post-test was similar to the pre-test and was not changed during the intervention. The time interval between treatments was three weeks, and the whole process of the time series lasted for nine weeks, starting in February and lasting till April 2021. The intervention focused on three concepts of microbiology (introduction to microbiology, gram stain by differentiating between gram-positive and gram-negative bacteria, and methods of pure culture isolation).

2.3.2 Data collection using Classroom Observation Protocol for Undergraduate STEM (COPUS)

To record the activities done during each instructional method, a trained research assistant was present in the class with the first author, who acted as an instructor during the interventions and recorded each activity done every two minutes, using the blank sheet for COPUS practice observation. The observation was done on printed sheets, and scores were recorded in Excel sheets during the analysing phase.

3. Data Analysis and Results

To answer the research questions, we analysd the classroom observation data by relative abundance (percentage of activities), as in Ndihokubwayo et al. (2021). Our implemented intervention was done thrice on a series basis; we presented the results for each intervention separately (see Table 2). Three lessons—one lasting 50 minutes and two of 80minutes—were observed in the lecture class. The total two-minute intervals of students' activities were 129, and the activities of the lecturer counted 185. In the animation class, five lessons—one of 50 minutes, one of 60 minutes, two of 80 minutes, and one of 90 minutes—were observed. Of these, about 201 were activities from the side of students, while 206 were activities from the lecturer's side. Four lessons of 80 minutes each were observed during laboratory classes, where 206 activities of students appeared, and 170 activities of the lecturer were found. The sum of activities was calculated using an MS Excel visualization sheet (see Ndihokubwayo et al., 2021). All scores for each code were counted and summed up to generate totals of all the times that each code was observed. For instance, 103 listening scores appeared out of 129 during the 13 activities from the side of students during a lecture class. The relative percentage was calculated and was found to be 80% (Table 2). Classroom practices were found to vary depending on the intervention given. For instance, for listening (L), the activity appeared 80% in the lecture class, 77% appeared in the animation class, while only 20% appeared in the laboratory class. Lecturing (Lec) occurred 52% in the lecturing class, 2% lecturing occurred in the animation class, while only 3% happened in the lab class (Table 1). A passive attitude characterized the lecturing class as shown by the amount of listening (80%) and lecturing (52%); a teacher-centred attitude characterized the animation class as students listening to the instructor took 77% of the time, and activities and demonstration by the instructor took 69%; however, only the lab class showed a learner centredness and an active learning attitude, as the promoting agent was group work, which gained 57% (52% for working group [WG] and 5% for 'other group' [OG]) of other student activities, while posing question (PQ) and follow-up (Fup) gained 10% and 6% respectively, of the instructor activities (see Table 2).

Table 2: Classroom practices in lecture, animation, and lab classes

	Classroom practices	Lecture class	Animation class	Lab class
Students	Listening (L)	80%	77%	20%
	Answering (AnQ)	5%	0%	6%
	Asking (SQ)	7%	11%	5%
	Whole Class (WC)	0%	5%	4%
	Presentation (SP)	0%	2%	1%
	Thinking (Ind)	3%	2%	1%
	Clicker Discussion (CG)	0%	0%	2%
	Working Group (WG)	0%	0%	52%
	Other Group (OG)	0%	0%	5%
	Prediction (Prd)	0%	0%	0%

	Test/Quiz (T/Q)	5%	0%	0%
	Waiting (W)	0%	1%	0%
	Other (O)	0%	0%	2%
Instructor	Lecturing (Lec)	52%	2%	3%
	Writing (RtW)	34%	0%	0%
	Demo/Video (D/V)	2%	69%	6%
	Follow-up (Fup)	4%	1%	6%
	Posing Questions (PQ)	3%	12%	10%
	Clicker Questions (CQ)	0%	0%	1%
	Answering Question (AnQ)	5%	14%	10%
	Moving (MG)	0%	0%	55%
	One-on-One (1o1)	0%	0%	3%
	Administration (Adm)	0%	1%	2%
	Waiting (W)	0%	0%	0%
	Other (O)	1%	1%	4%

Specifically, after collapsing codes, as Smith et al. (2013) suggested, 88% of lecturer presenting and 80% of students receiving were found in a lecture class, 71% of presenting and 77% of receiving were found in the animation class, while these practices did not occur to the same extent in the lab class. About 61% of students were working, and 85% of the lecturer's time was spent on guiding in the lab class. This shows that lab activities encourage student engagement, among other interventions (Figure 1).

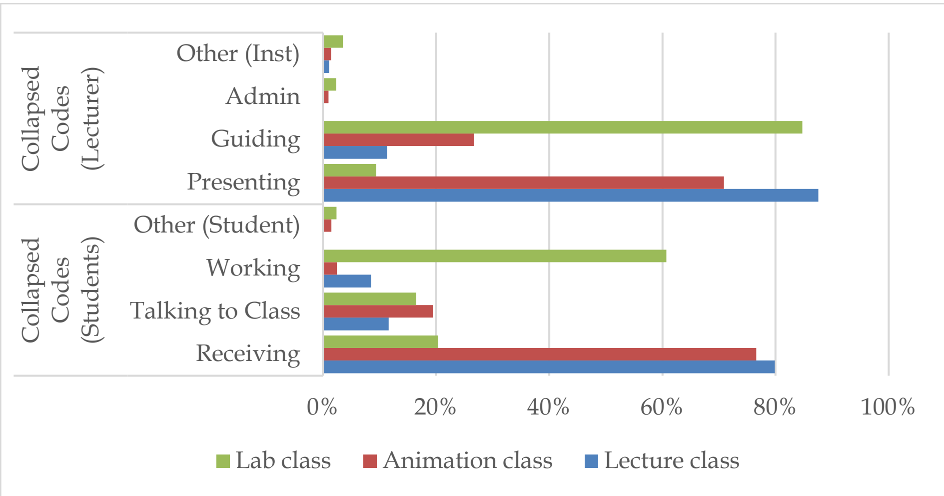

Figure 1: Activity as Percentage of all Codes (Note: Each colour adds to 100%, within rounding error)

The Pearson r coefficient between these intervention classroom practices was found positive. For instance, the medium correlation was found to be 0.54 between lecture and animation methods; the low correlation was found to be 0.05

between lecture and lab methods, while the low correlation was found to be 0.11 between animation and lab methods.

After having analysed the teaching and learning practices, we measured the impact of each intervention given, such as lecture, animation, and lab activities, in the respective series of interventions using SPSS 23. Table 2 displays descriptive statistics from students' scores. Before the intervention, the mean score was 6.70 out of 20 (one score for each of 20 items) (see Table 3). Note that the same students were exposed to all these interventions in equivalent time-series sequences. The potential of such a design is shown in the way the mean scores have upgraded.

Table 3: Descriptive statistics of the test scores among male and female pre-service biology teachers

	Students gender	Mean	Std. Deviation	N
Pre-assessment	Male	6.64	3.10	14
	Female	6.75	2.08	16
	Total	6.70	2.56	30
Lecture Serie	Male	7.21	3.76	14
	Female	8.18	2.07	16
	Total	7.73	2.97	30
Animation Serie	Male	10.92	3.02	14
	Female	10.62	2.47	16
	Total	10.76	2.69	30
Lab Serie	Male	14.42	1.98	14
	Female	14.93	1.12	16
	Total	14.70	1.57	30

A statistically significant difference occurred among the interventions (df=28, p<.05), however, gender did not show this difference (df=1, p>.05). The Cohen effect size (d) after using the lecture method was 0.37, after using the animation method, it increased to 1.54, while after using the lab method, it increased to 3.86.

Using multivariate analysis of variances (MANOVA), male and female students were at the same level at pre-assessment (see Figure 2). Female students showed a better performance than their male counterparts after having been taught with the lecture and lab methods; however, this was the opposite after having been taught by means of the animation method (Figure 2).

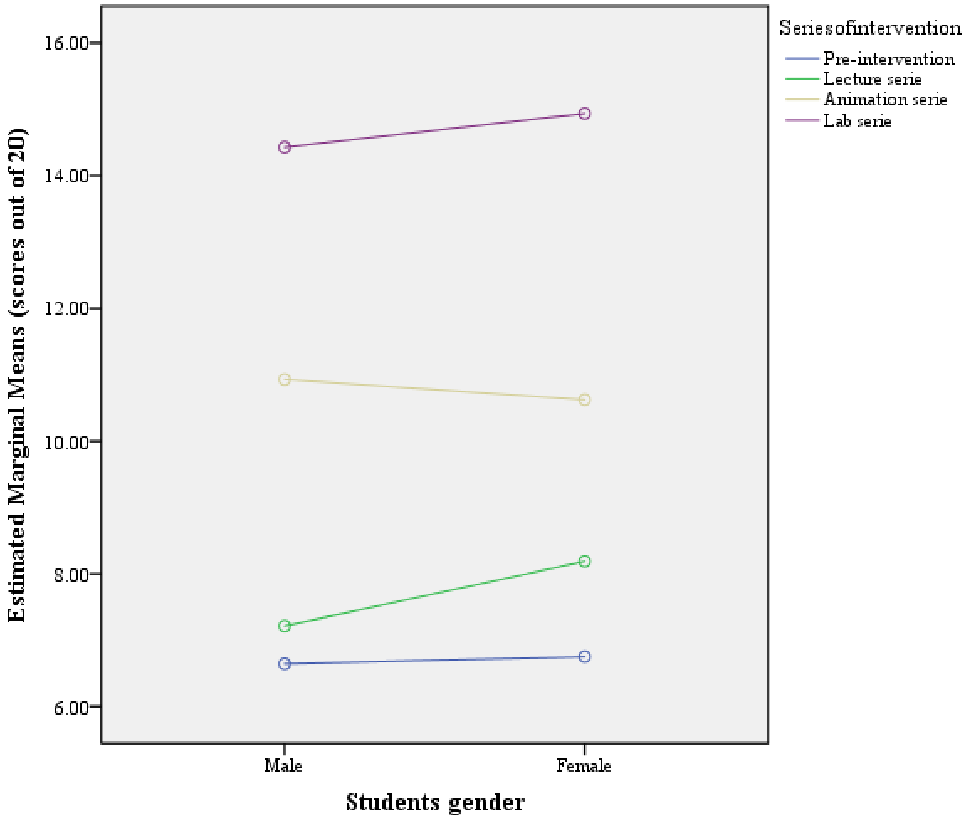

Figure 2: Multivariate analysis of variances between male and female pre-service teachers across three series of teaching interventions

4. Results discussion

The present study identified how pre-service biology teachers learn microbiology at one private university in Rwanda when three different instructional methods were applied in equivalent time series. The results revealed that lecture classes and animation classes were dominated by students listening and instructor lecturing activities, while in the laboratory class, group work, instructor moving and guiding outweighed. Based on those differences, the laboratory method with small-group laboratory activities promoted the active learning environment. At the same time, lectures and animation-based instruction encouraged passivity, though animations were used as an active instructional resource.

The dominance of instructor activities and students' passivity, as shown by their role in the lecture method class, results from the characteristics of traditional methods that rely on teacher-centred teaching methods. The method does not motivate and promote students' active participation in class. These observations prove that, at the undergraduate level too, by using the lecture method, students learn in a passive environment, where their role is merely listening, taking notes, and answering instructors' questions. The findings concur with research findings of Byusa et al. (2020b), Ndihokubwayo et al. (2020a & b), and Stains et al. (2018), who confirmed that instructors presenting and students receiving activities like listening to the teacher, taking notes and answering teachers' questions dominate a traditional classroom environment. In contrast, the findings do not corroborate with other studies that regard facilitating and guiding as part of the instructors' role in computer-assisted instruction (Aiyedun, 2020; Gilakjani & Rahimy, 2019).

Lectures and animation-based instructions promoted pre-service biology teachers' passive learning, as their listening level, 80%, and 77%, respectively proved. The pre-service biology teachers' behaviour in the animation class indicates that teaching and learning by animations require more intervention of both a real instructor and a graphically presented instructor. This happens because of different factors: first, the English language level used in animations may be a barrier to pre-service biology teachers' understanding of concepts. This requires of the instructor to intervene by repeating what was said using 'soft', that is, to the students more understandable, English grammar; thus, a lecturing activity is recoded during observations. This results in animation classes becoming similar to lecture classes in terms of students and teacher activities, even though their motivating and engaging levels differ. The implication is that both lectures and animation classes may look similar based on instructors' and students' roles. The findings are not in consonance with the findings of Ma et al. (2010), who attested that students exposed to animations benefited from it and achieved better than those merely exposed to traditional instructions.

The findings regarding the instructor-guided pre-service biology teachers being instructed in laboratory classes using small-group laboratory activities proved to be contrary to the above-mentioned results. Pre-service biology teachers in the lab class actively participated by working in groups, where small groups of two were formed. Pre-service biology teachers receiving instruction through activities that characterized other types of instruction were reduced in the lab class. All those practices proved that the pre-service biology teachers learned through learner-centred practices in the small-group lab activities in the laboratory. Therefore, the laboratory method using small-group laboratory activities is an instructional method to improve pre-service biology teachers' active learning and learning engagement. These behaviours promote profound subject achievement, resulting in them becoming competent professional biology teachers in future. The findings concur with the findings of Lombard et al. (2021), who asserted that students guided in using instructional resources when learning performed better than their colleagues who learned in the traditional environment.

The findings revealed that lecture methods, animation-based instruction, and small-group lab activities improved the pre-service biology teacher's academic achievement. However, there was a statistically significant difference between the interventions (df=28, $p<.05$). Besides, based on the mean scores, the lecture method improved the academic achievement slightly, compared to the mean scores obtained before the intervention. In contrast, animation improved achievement more than lectures, and using small-group lab activities improved pre-service biology teachers' academic achievement more than lectures and animation. The difference is also justified by the difference in Cohen's d effect size, where lectures showed d=0.37, animation-based instruction d=1.54, and small-group lab activities d=3.86. Therefore, we rejected the first null hypothesis that there would not be such a statistical difference. These findings disagree with those of Aiyedun (2020) and Aremu and Sangodoyin (2010) who proved that animations improved students' achievement in biology more than traditional methods. Besides, the findings deviate from what Arıcı & Yılmaz (2020) attested, namely that computer instructions improved students’ academic achievement more than laboratory instructions.

This difference in the effect of those instructional methods on pre-service biology teachers’ academic achievement justifies the significance of treating students in a series of interventions where students' outcome regarding performance after an intervention may be boosted by what was gained from the previous one. Thus, in this study the significant contribution of animation-based instructions was boosted by the lecture intervention before its application. The high contribution of laboratory instruction using small-group laboratory activities resulted from the combination of pre-service biology teachers’ gain from a lecture class, animation class, and small-group lab activities. Besides, these differences in pre-service biology teachers’ scores are explained by the difference in students’ and instructors’ activities that characterized series of interventions in which laboratory classes with small-group activities encouraged the pre-service biology teachers’ involvement in the activities – involvement was proven very high when working in small groups of two (pairs). These findings concur with the findings of Högström et al. (2010), who attested that students gained more when they were allowed to plan for experiments, manipulate outcomes, pose questions, discuss results, and draw conclusions. Therefore, based on the findings, animation-based instruction may improve student academic achievement when applied after traditional methods. Laboratory methods may significantly contribute after teaching the concept by lecture method of instruction or by implementing animation-based instruction or a combination of these instructional methods in a time series. Therefore, we recommend using those instructional methods in a time series to improve pre-service biology teachers’ academic achievement.

The findings revealed no statistically significant difference between males and females after the three interventions had been used; therefore, we rejected the first null hypothesis. However, with each intervention, males and females scored differently, as the lectures and lab methods improved female pre-service biology teachers' academic achievement more than that of males. On the other side, however, this was not the case with animation–based instruction, where males achieved better than females.

This finding indicates that males and females do not enjoy or prefer the same instructional methods. The lower performance of females in animation classes may be because, according to their nature, females were found to respond slower to technological instructional tools than males (McLachlan et al., 2010; Tezci, 2011). More recently, a significant gender difference in the use of digital tools was established by Pal et al. (2020) who found that males' engagement in the use of technological tools for learning was higher than that of females. Therefore, we recommend that in class instructors must be aware of such differences and encourage students of either gender to participate equally in teaching and learning activities when different instructional methods are applied. This will contribute positively to the performance of students in the identical range of scores.

5. Conclusion and recommendations

This study wished to determine how pre-service biology teachers learn microbiology at one of the private universities that train pre-service biology teachers when animations and small-group laboratory activities are applied as resource-based instruction. We used the Classroom Observation Protocol for Undergraduate STEM (COPUS) during an equivalent time series of interventions using the lecturing method, animation-based instruction, and small-group laboratory activities to track the pre-service biology teachers and instructor activities during interventional classes. We observed that the instructor dominated the classes by lecturing in lecture and animation-based classes. Laboratory methods, using small-group laboratory activities promoted learner-centredness and active learning, thus increasing their academic achievement. Therefore, we recommend that animation should be used strategically to improve learning outcomes. It should be oriented to promote more students working actively and being engaged in the teaching-learning process, rather than merely listening, and the process should be based on teachers posing questions and answering questions.

We also confirmed the effectiveness of time-series design, the use of which ensued in lectures, animation-based instruction, and small-group laboratory activities significantly improving pre-service biology teachers' academic achievement. However, a statistically significant difference was found between interventions. This difference was found to be rooted in the implementation of time series where the achievement in animation classes was based on the knowledge gained from a lecture class and high performance in a small-group lab class resulted from the boosted knowledge constructed from both the lecture method, animation-based instruction, and application of small-group laboratory activities. Therefore, to build pre-service biology teachers' concept understanding in a microbiology class and other related biology modules, using the lecture method before animation-based instruction, and small-group laboratory activities is recommended. There was no observed gender difference after equivalent time series of these instructional methods; however, a difference was observed within interventions. In the lecture and lab, female pre-service biology teachers scored better than males, but, on the contrary, males performed better in animation than females. The difference in performance was caused by the differences in the acceptability of the instructional methods for females and males. Therefore, we recommend that instructors engage females and males equally when an instructional method is applied to help them have the same conceptual understanding and preferences.

Further research is recommended to measure pre-service biology teachers' and trainers' activities in other modules of biology. Researchers are also advised to check the effect of the instructional methods used when applied in equivalent time series.

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Appendix 1: Pre-service Biology Teachers' Achievement Test [Module of microbiology].

Description: Dear pre-service biology teachers, The questions below were prepared for measuring your academic achievements generally in biology considering your performance in the module of microbiology. The types of questions in the test are objective questions (multiple and true or false) and short answer questions.

Identification:

University name:

Reg number:

Gender:

Instructions: Answer all questions. Read each question carefully and provide the correct answer.

Date: ……………………. Duration: 40min

Multiple choice questions:

1. Which of the following is a reason for micro-organisms to be useful in many different research laboratories?

A. They are easy to see and count
B. They have fairly complex structures and are expensive
C. They reproduce quickly and grow in large numbers
D. They live everywhere, so contaminants from the environment are not a problem

2. Prokaryotes do not have which of the following?

A. Cell membrane
B. Nucleus' membrane
C. Cytoplasm
D. Ribosomes

3. The Common basic stains are

A .methylene blue
B. crystal violet
C. safranin
D. malachite green
E. all of the above.

4. Which of the following correlates with the exponential phase?

A. Log phase
B. Rate of growth is constant and also called balanced growth
C. Population is most uniform in terms of chemical and physical properties during this phase.
D. Exponential growth - all cellular components are synthesized at a constant rate.
E. All of the above.

5. Gram-negative bacteria have much of …………., and that is found on their outer membrane

A. Lipopolysaccharides
B. Peptidoglycan
C. Teichoic acid
D. All the above

6. Among the following methods of microbial culture, what is the most common and suitable for isolation of pure culture?

A. Pour plate method
B. Streak Plate method
C. Dilution method
D. None of the above

7. Among the following types of stains, what is used to identify bacteria, and was developed by a Danish physician Hans Christian Gram.

A. Simple staining
B. Differential staining
C. Gram stain
D. All the above

True or False questions:

8. A stain is a chemical that adheres to structures of the micro-organism as dyes so that micro-organisms can be easily seen under a microscope. **True or False?**

9. Staphylococcus and Streptococcus are examples of Gram-positive bacteria. **True or False?**

10. Agar is a complex polysaccharide used as a solidifying agent for culture media preparation. **True or False?**

11. A. Bacteria generation time is simply the time it takes for one cell to divide into two **True or False?**

Short answer questions:

12. The concept that human and animal diseases are caused by microorganisms is called ………….

13. Gram-positive bacteria stain in ……………. Colour

14. A peptidoglycan layer that is very thick is commonly seen in .... Bacteria.

15. Lawn culture is used for different purposes including bacteria antibiotic sensitivity testing? Yes or No

16. Who discovered the fungus Penicillium that produced an antibiotic called penicillin in 1929?

17. Who laid the foundation of aseptic techniques that prevent contamination by unwanted microbes?

18. Who was the first person to use a microscope to observe living cells?

19. Microbial cultures are used to determine the type of organism, its abundance in the sample being tested? Yes or No

20. Aside from peptidoglycan, what other component makes up a large percentage of the gram-positive cell wall?