agriCHEMture: An Innovative Approach in Enhancing Students' General Chemistry Achievement Through Remote Urban Gardening-Themed Laboratory Work

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Abstract

Urban gardening has been used as a practical theme for science education. However, limited research exists on the use of this theme for remote delivery of laboratory education during the COVID-19 pandemic. Thus, this study aimed to investigate the effects of introducing *agriCHEMture*—a home-based, urban gardening-themed science laboratory e-learning material—on students' general chemistry achievement within a remote learning environment. A quasi-experimental one-group pre-test and post-test research design was utilised. Fifty-one senior high school general chemistry students participated in the study. The agriCHEMture was provided to students as an intervention material between the pre-test and post-test. The two-tailed paired-samples t-test ($p < 0.001$, $\alpha = 0.05$) showed a significant difference between pre-test and post-test scores, while the one-tailed paired-samples t-test confirmed that post-test scores were significantly higher ($p < 0.001$, $\alpha = 0.05$). Both statistical tests reveal a significant increase in students' general chemistry achievement. Overall, the study highlights the effectiveness of the agriCHEMture e-learning material in a remote learning setting. It also informs science educators of an innovative approach to teaching remote science laboratory education. The study recommends conducting research using various experimental setups to compare the results with current findings.

Introduction

Due to school closures brought about by the COVID-19 pandemic, students worldwide missed an average of 68 percent of school-based face-to-face education in 2020 (Evans et al., 2021). As the pandemic severely disrupted the education sector, educational institutions around the globe acted rapidly to redress the harm caused to schoolchildren. They were forced to switch to remote learning, whether in the form of pure online, pure modular, or a combination of both (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2021).

The interruption of face-to-face instruction in academic institutions during the pandemic has escalated concerns about students' learning consequences (Engzell et al., 2021). One of these concerns is the delivery of "wet laboratory" practical education, mainly conducted in standard science laboratories (Kelley, 2021; Klein et al., 2021; Radzikowski et al., 2021). According to Patterson (2000), adjusting to a remote format is incredibly demanding for classes with a laboratory element. Changing standard procedures, finding alternative materials, and minimizing hazards are some of the top concerns of science educators in making laboratory work doable at home.

Concerning innovations in the delivery of laboratory education, urban gardening, a trending recreational activity that bloomed during the pandemic, is seen as a potential theme for laboratory education (Aratini, 2021). Urban gardening has been used as an academic tool in providing experiential learning and teaching scientific concepts to students. Its inclusion in science education results from multiple studies conducted about its positive effects on students' academic achievement (Acharya et al., 2020; DeMarco et al., 1999; Klemmer et al.; 2005; Okiror et al., 2011; Pigg et al.; 2006; Williams & Dickson, 2013). Academic achievement generally refers to the extent to which a student attains short- or long-term educational goals, such as knowledge and skills development, often assessed through test scores (Bolt, 2011).

Thus, this study investigated the effects of agriCHEMture on students' general chemistry achievement in a remote learning environment. AgriCHEMture is an expert-validated and pilot-tested e-learning material that is composed of urban gardening-themed laboratory activities. These activities were specifically designed to meet the selected Most Essential Learning Competencies (MELCs) for General Chemistry I and II subjects (Department of Education, 2020) introduced by the Philippine Department of Education during the COVID-19 pandemic.

Purpose of the Study

Numerous studies describe the adaptation of standard school science laboratory activities for home-based learning during the COVID-19 pandemic. These activities are generally discipline-specific and focused on particular topics. However, there is limited research on the use of practical laboratory themes, such as urban gardening, for home-based laboratory activities. Additionally, few studies examine the effects of home-based laboratory activities on students' academic achievement during the pandemic. This gap highlights the need to investigate the effectiveness of practical home-based science laboratory activities in enhancing academic achievement in remote learning environments.

This study aimed to investigate the effects of agriCHEMture on students' general chemistry achievement. Specifically, the study answered the following research question:

1. *How does the agriCHEMture e-learning material affect students' general chemistry achievement in a remote learning environment?*

Hypothesis

This research seeks to determine whether the agriCHEMture e-learning material, delivered remotely, has a measurable effect on students' general chemistry achievement.

Null Hypothesis: The remote delivery of the AgriCHEMture has no effect on increasing students' general chemistry achievement.

Alternative Hypothesis: The remote delivery of agriCHEMture increases students' general chemistry achievement.

Conceptual Framework

Science educators recognise laboratory work as an effective way to build students' scientific knowledge, skills, and attitudes (Eubanks 2015; Miles and Wells 2020; Neves et al. 2016). Figure 1 shows a framework for studying how the agriCHEMture e-learning material affects students' general chemistry achievement in a remote setting. General chemistry achievement is defined in this study as the extent to which students attain skills and knowledge of general chemistry concepts and principles. This study adapted the Theory of Change (Weiss, 1995) as its foundation. The framework relies on Constructivism, which promotes active knowledge-building through engagement (Bednar et al. 1992; Glasersfeld 1995; Jonassen 1994), and Experiential Learning Theory, which emphasises hands-on, reflective learning (Towns 2001). In this setup, agriCHEMture uses real-world gardening applications to deepen students' understanding and retention of chemistry concepts. It aims to bridge the gap between theory and practice and students' general chemistry achievement.

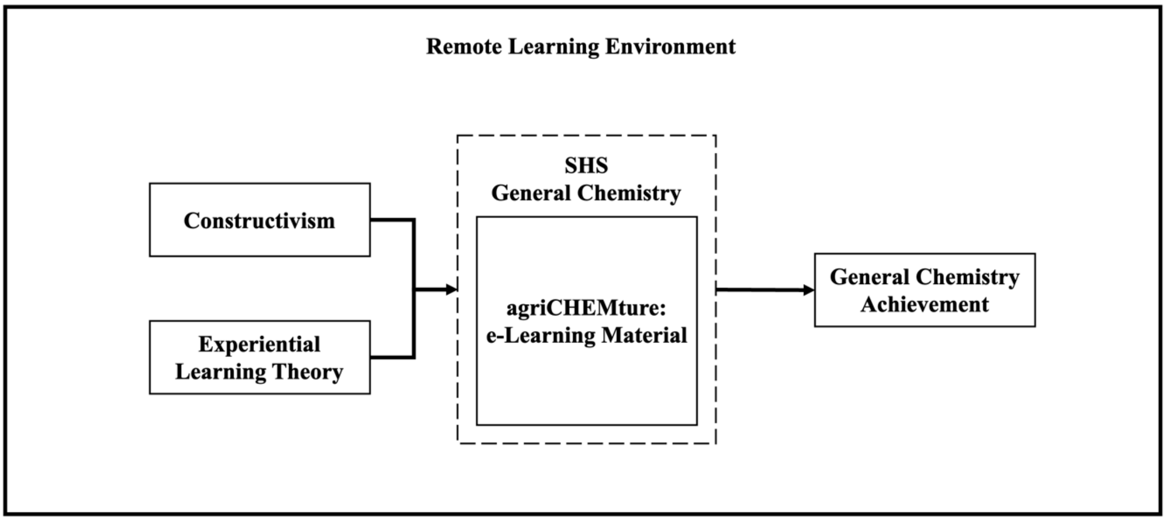

Figure 1. The framework of the study

Review of Related Literature

Urban Gardening

The practice of cultivating plants and crops in cities is called urban gardening (Sklair, 2016). The term urban gardening is often used interchangeably with the term urban agriculture. According to Sklair (2016), urban agriculture generally refers to the larger scale of growing plants and crops. Urban gardening is a sub-discipline of urban agriculture. The concepts of urban gardening started in the 19th century, specifically during the beginning of World War 1, as a response to food insecurity. Currently, urban gardening is a popular activity worldwide and received much attention during the COVID-19 pandemic.

Urban Gardening and Its Beneficial Effects

Urban gardening is beneficial for humans. In the study conducted by Chalmin Pui et al. (2021), frequent engagement in urban gardening activities has significant associations with improved well-being and health. Ambrose et al. (2020) suggest that gardening belongs to the top five activities among measures of emotions, happiness, and meaningfulness. The same study also revealed that urban gardening has no significant difference from other identified leisure activities such as biking, walking, and eating out. Moreover, Schram-Bijkerk et al. (2018) highlight urban gardening's role in enhancing the livability and sustainability of metropolitan areas.

Urban gardening also promotes environmental advancement. Nova et al. (2018) revealed that urban gardening significantly transforms people’s behaviour, including positive outcomes for environmental practices like recycling and influencing friends and relatives to do recycling, composting, and walking. Urban agriculture also helps mitigate the effects of climate change (Kingsley et al., 2021); thus, urban gardening must be given priority in green space management as it may help address challenges brought by urbanization (Schram-Bijkerk et al., 2018).

Urban Gardening and Students’ Academic Achievements

Urban gardening has been used as an academic tool to provide experiential learning and teach scientific concepts to students. However, compared to other themes applied in education, studies that investigated the effects of urban gardening on students’ learning and academic achievement are significantly fewer.

DeMarco et al. (1999) reported that school gardening helps their students enhance their learning, garnering 60.6% of votes as very successful. However, 92% of surveyed educators requested more gardening education. Klemmer et al. (2005) found that elementary students with urban gardening in their curriculum got higher achievement test scores than those who did not. Klemmer et al. also pointed out that exposing students to hands-on science activities could result in more scientifically literate adults. However, in the study by Pigg et al. (2006), there is no significant difference in the overall science achievement of the experimental and control groups of students. They argue that urban gardening could be helpful only to some students.

Rahm (2002) showed that urban gardening provides opportunities for students to become environmentally aware, work-conscious, and scientifically literate. Rahm claimed that gardening helps students integrate work, science, and community. Also, engaging students in gardening activities at an early age contributes to students’ environmental relationships and concerns (Cohen & Horm-Wingerd, 1993; Skelly & Zajicek, 1998).

Okiror et al. (2011) also conducted studies that investigated agricultural activities and students’ academic achievement. Their study was conducted in Africa, particularly in Uganda, which is considered a developing country. The study revealed promising results such as pupils having the opportunity to work independently, pupils learning to care for the entire cycle of crop growth/ vegetables, pupils learning new techniques like sterilization of nursery soils & care of nursery beds, and pupils practising what was taught. Since the Philippines is a developing country, these innovations in science education could also provide promising results to Filipino students.

School Gardening and the Philippine Education

In the Philippines, agriculture-related activities for students were introduced during the American occupation as part of industrial education, influenced by John Dewey's concept of progressive education (Papong, 2014). According to Papong, since American education prioritized Industrial Work Education, Filipino schoolchildren were taught farming techniques for earning. During the Japanese occupation in the 1940s, agriculture education was part of vocational education for boys and home economics for girls (Inocian & Nuneza, 2015). In the 1960s, the inclusion of agriculture-related activities in school curricular programs was strengthened due to “Masagana 99”, a program that enhances food production (Agoncillo & Mangahas, 2010). In the 1970s, the “Green Revolution” project of Imelda Marcos supported the Cooperative Work Curriculum in public schools during martial law that required high school students in urban areas to undergo on-the-job training that included farm work. After the Green Revolution Project, agriculture-related activities were formally included in basic education through the subject Home Economics and Livelihood Education (HELE) during the 1980s, Technology and Home Economics (THE) during the 1990s, Makabayan Curriculum and Edukasyong Pantahanan at Pangkabuhayan during the early 2000s, and Technology and Livelihood Education (TLE) during the implementation of K-12 Curriculum in 2012. The main goal of adding farming and urban gardening to the basic education curriculum is to boost food production and reduce poverty, not to improve students' academic performance.

Urban Gardening as Experimental Work

Farmers are thought to have conducted experiments long before the rise of modern science. Hansson (2019) suggests that craftspeople, including farmers, engaged in experimental practices well before formal experimental traditions were established. Today, there is now plenty of literature on farmers’ experiments because of extensive fieldwork performed by anthropologists and agricultural researchers. In the work of Hansson (2019), some of the experiments conducted by farmers that are commonly mentioned include irrigation and watering experiments, pest controls, plant growth techniques, nutrient absorption, soil quality improvements, microorganism management, crop protection, and harvesting methods. These demonstrate that agriculture, particularly farming, is highly experimental in nature. Thus, making experimentation the heart of agricultural practice (Richards, 1989).

Since urban gardening is part of agriculture, it also requires experimentation. In the United States of America, urban gardening has been part of the curriculum of several state departments since the 1990s (Duncan et al. 2016). Duncan et al. (2016) revealed several positive and encouraging impacts regarding their sample of urban middle school youth engaged in the school garden program. They claimed that urban gardening as an experiential learning activity for students was highly valued by students, teachers, and parents alike.

Remote Delivery of Laboratory Work Amidst COVID-19 Pandemic

Science educators rapidly redesigned their classes to instruct, support, and motivate students to a new remote learning environment and quickly adopt new teaching strategies (Youssef et al., 2020), specifically in the remote delivery of laboratory work. Maqsood et al. (2021) revealed that the developed home-based laboratory for enzyme assay in biochemistry class was appreciated by students and showed a general positive acceptance. However, limitations, especially in the data collection, are observable, making the laboratory activity challenging to perform. The studies of Caraballo et al. (2021), Andrews et al. (2020), Radzikowski et al. (2021), and Kelley (2021), which were about the development of home-based laboratory work, gained positive responses from the students. These authors suggest that their home-based laboratory activities be developed further to suit the remote and regular laboratory courses. These studies suggest that home-based laboratory activities are possible to be delivered remotely, but further studies must be made to determine their effects on student's academic success in a remote learning environment. There is also a scarcity of studies that use practical science laboratory themes, such as urban gardening, in delivering laboratory education in a remote learning environment.

Methodology

Research Design
The study utilized a quasi-experimental one-group pre-test and post-test design to investigate the effects of agriCHEMture on students' general chemistry achievement. In this research design, the single group of participants was engaged in a pre-test, followed by the intervention, and then a post-test. The use of this research design determines whether there is a causal relationship between the intervention and the outcome (Rogers & Revesz, 2019). In this study, agriCHEMture is the intervention, and students' post-test scores are the outcomes. The pre-test was also used to ensure the comparability of students' pre-existing knowledge.

Participants and Location of the Study
Fifty-one senior high school general chemistry students from a private school in Caloocan City, Metro Manila, Philippines, participated in the study. Their study began in July 2021 through synchronous and asynchronous online learning. The participants were chosen through convenience sampling. The use of convenience sampling provided valuable data despite the challenges faced during the peak of the COVID-19 pandemic. The selection of participants was influenced by the need to adapt to school restrictions, as many educational institutions prioritized stability in their educational plans and limited face-to-face interactions.

Research Instruments

Pre-test and Post-test
The expert-validated and reliability-assessed pre-test (KR-20 Alpha = 0.704) *(See Appendix A)* and post-test (KR-20 Alpha = 0.708) *(See Appendix B)* developed by Pineda and Guidote (2022) were utilized in this study. Both tests were composed of two (2) parts. The first part of the instruments includes factual data questions to identify the students' basic information. The second part was composed of thirty (30) multiple-choice items covering the selected Most Essential Learning Competencies (MELCs) for general chemistry subjects. The MELCs, developed by the Philippine Department of Education (DepEd), list the general chemistry content standards and skills, which are mandated for use in all DepEd schools nationwide. Tables of Specification (TOS) *(see Appendix C and D)* were made to ensure alignment between MELCs and test items. The pre-test and post-test were designed with a focus on the chemistry of urban gardening. Additionally, they were designed with parallel items. Parallel items mean that they are similar in content, structure, and difficulty level but not identical.

AgriCHEMture e-Learning Material
This study utilized the expert-validated and pilot-tested agriCHEMture e-learning material developed by Pineda and Guidote (2022). AgriCHEMture is a website-based instructional material composed of laboratory activities related to urban gardening. The material also contains video lectures, laboratory manuals, and data sheets needed for laboratory activities. The activities are divided into four (4) categories: soil quality, water quality, plant growth and development, and culminating activity. Table 1 shows the list of the agriCHEMture home-based laboratory activities and the related concepts and skills. The agriCHEMture can be accessed upon sending a request to the developers.

Table 1. List of AgriCHEMture Laboratory Activities

Laboratory Activity No.	Title	Category	Target Chemistry Concepts and Skills
1	I CHEM Grow You!	Plant Growth & Development	• measurements • making observations
2	The pH is Right! – Soil Edition	Soil Quality	• acidity, basicity and alkanity • conducting qualitative soil pH tests
3	The Best Dirt Ever!	Soil Quality	• Compounds and particles sizes • Performing simple qualitative soil texture analyses
4	The pH is Right! – Water Edition	Water Quality	• Acidity, basicity, and alkalinity • Properties of water • Properties of select elements • Performing qualitative water pH tests
5	Test for Water Hardness	Water Quality	• Ions, compounds, and molecules • Chemical equations • Conducting qualitative water hardness test
6	Master Chef	Culminating Activity	• Biomolecules • Creating pechay dish, experimentation

Implementation

Pre-test and Post-test

Students had 40 minutes to complete both the pre-test and post-test. The pre-test was given before the intervention, and the post-test afterward. Both tests were administered via Google Forms during a live Zoom session, where all students were required to open their cameras. Both tests contained 30 items, each worth 1 point, for a maximum score of 30 points.

AgriCHEMture e-Learning Material

The delivery of agriCHEMture learning material officially started the day after the pretest administration. A comprehensive orientation about the objectives, content, and delivery of agriCHEMture was provided to all participants. The students accessed the AgriCHEMture website through the link given to them. Each week, students were assigned to perform a specific home-based laboratory activity. The intervention material was delivered remotely and asynchronously, meaning students performed the activity at their own pace, but a deadline had been set. The agriCHEMture implementation lasted for six (6) weeks. Pineda and Guidote's (2022) study outlined the six-week AgriCHEMture implementation, including students' experiences and a detailed discussion of students' insights.

Analysis of Pre-Test and Post-Test Results

The pre-test and post-test results were analysed using a two-tailed paired-samples t-test in *SPSS* and a one-tailed paired-samples t-test in jamovi software. These tests were suitable because the data came from the same group of students before and after the intervention. A 95% significance level was used for the analyses.

Ethical Considerations

The study was granted an Ethics Clearance Certificate (**Protocol ID: SOSEREC_21_006**) from the University Research Ethics Office of Ateneo de Manila University. The methods indicated in this study were to be in accordance with all the ethical requirements of the university and pose no harm to human participants.

Results and Discussion

How does the agriCHEMture e-learning material affect students' general chemistry achievement in a remote learning environment?

The pre-test scores were subjected first to a normality test to attain more valid and reliable paired-samples t-test results. The normality test ensures that the samples were drawn from a normally distributed population (Ghasemi & Zahediasl, 2012). The normal distribution is one of the assumptions in parametric tests in which a paired-samples t-test is included (Kim, 2015). Table 2 displays the results of the normality test for pre-test scores, conducted at a 0.05 significance level. Kolmogorov- Smirnov (K-S) and Shapiro-Wilk (S-W) are the two commonly used tests for normality (Mishra et al., 2019). The null hypothesis for the normality test is that the population is normally distributed (Orcan, 2020). It can be seen from the table that the p-values for K-S and S-W, which are 0.200 and 0.211, respectively, are greater than alpha (α=0.05) and suggest that the population is normally distributed.

Table 2. Normality Test Results for Pre-test Scores

	Kolmogorov-Smirnov			**Shapiro-Wilk**		
	Statistic	df	Sig	Statistic	df	Sig
Pre-test Scores	0.94	51	0.200	0.970	51	0.211

Table 3. Descriptive Statistics of Pre-Test and Post-Test Scores

	Mean	**Standard Deviation**	**Variance**	**Skewness**
Pre-test Scores	18.55	4.095	16.773	-0.329
Post-test Scores	20.75	3.503	12.74	-0.740

Since the pre-test scores were found to be normally distributed, they were compared to post-test scores using the paired-samples t-test. The results of the two-tailed paired-samples t-test using the *SPSS* are shown in Table 4. The findings suggest that at a 95% confidence level, there is a significant difference between the students' pre-test and post-test scores, with a p-value of 0.000014.

Table 4. Two-tailed Paired-samples t-test for Pre-test and Post-test Scores

	Mean	Standard Deviation	t	df	Sig. (2-tailed)
Pre-test Scores - Post-test Scores	-2.196	3.250	-4.826	50	.000014

Another statistical software, *jamovi*, was used to determine if the agriCHEMture e-learning material significantly improved students' using the one-tailed paired-samples t-test. The results of the one-tailed paired-samples t-test are presented in Table 5. The obtained p-value of <0.001 at a 95% significance level reveals that post-test scores are significantly higher than pre-test scores.

Table 5. One-tailed Paired-samples t-test for Pre-test and Post-test Scores

	statistic	df	p-value (1-tailed)
Pre-test Scores - Post-test Scores	-4.826	50	<.001

The results of the 2-tailed and 1-tailed paired samples t-test indicate that students' general chemistry achievement significantly increased.

Table 6 presents the number of participants who scored at least 60% and above the mean. In the post-test, 76.47% of students achieved at least 60% (18 out of 30 points), which is higher than the 52.94% of students recorded in the pre-test. Regarding scores above the mean, 62.75% of students in the post-test surpassed the mean, a notable improvement compared to the pre-test. These results indicate that more students performed better in the post-test.

Table 6. Frequencies and Percentage of Students Scoring at least 60% and Above the Mean

Test	Students Scoring at least 60%		Students Scoring above the Mean	
	Frequency	%	Frequency	%
Pre-test	27	52.94	25	49.02
Post-test	39	76.47	32	62.75

Overall, the findings provide valuable information about the effectiveness of the agriCHEMture e-learning material in increasing students' general chemistry academic achievement in a remote learning environment.

External Factors That Might Affect the Results

Remote learning during the COVID-19 pandemic introduced new challenges in the Philippines (Barrot et al., 2021; Reyes et al., 2024), particularly regarding the quality of data collected during learning assessments (Dayagbil et al., 2021). Given the exclusive online administration of the pre-test and post-test, external factors such as the learning environment, student's motivation and mental health, and family support were considered influential ((Kharbat & Daabes, 2021). These factors may have positively or negatively impacted students' academic performance, depending on their home circumstances during the data collection. Although this study followed established guidelines for data collection, the challenges of conducting remote research during the pandemic highlight the need for future studies with more controlled data-gathering procedures. Overall, the data collected effectively highlights key trends and outcomes, serving as a foundation for future research.

Conclusions

With the goal of improving the practice of science teaching during the COVID-19 pandemic, this pioneering study generally investigated the effects of the remote delivery of agriCHEMture e-learning materials on the students' general chemistry achievement. AgriCHEMture includes practical, interdisciplinary, home-based laboratory activities tailored for senior high school general chemistry in a remote setting. This expert-validated and pilot-tested intervention material led to a notable improvement in students' general chemistry scores, as shown by their pre-test and post-test results. These findings show that urban gardening can help improve students' general chemistry academic achievement in a remote learning environment.

Implications to Teaching and Learning

agriCHEMture as a holistic and authentic learning material

The developed agriCHEMture considers all the guidelines of the Philippine Department of Education in developing assessment tools for science subjects, making it a valuable instructional tool for authentically and holistically assessing and evaluating student learning in a remote setting. Moreover, agriCHEMture is designed to be applicable across various learning modalities, including remote learning, hybrid, and in-person settings. For hybrid learning, activities such as measuring and observing can be done at home, while tasks like testing water and soil quality can be conducted in a school-based lab using standard equipment. In an in-person setting, activities such as growing plants can take place in the school garden, while all chemistry lab components can be carried out in a standard science laboratory. This aligns with students' preferences, as they find an in-person activity to provide more meaningful experiences (Andrews et al., 2023).

agriCHEMture as an alternative learning material

Various factors continue to threaten the continuity of onsite and face-to-face instruction, including the potential outbreak of future pandemics ((Madhav et al., 2018), natural disasters (Shipman, 2024), wars, and other unforeseen disruptions. The findings of this study contribute to education by providing an effective alternative learning material that enriches the repository of science laboratory educational resources that can be used during emergencies that will result in school closures and sudden shifts to remote learning.

Additionally, agriCHEMture is designed to be conducted safely at home using widely available materials or inexpensive items if students choose to purchase them. Resource-limited schools, especially those without standard science laboratories, will benefit from this approach, as it makes lab work feasible at home while ensuring that fundamental scientific skills and knowledge are still developed. AgriCHEMture could also be used to promote the field of agriculture, particularly in communities where it is often neglected (Graham, 2021).

Limitations

The study was conducted during the COVID-19 pandemic when nationwide total school closures were implemented. All the data collection processes were conducted online, and interactions with students were also conducted remotely through video calls, emails, chats, and other electronic messaging applications. Additionally, the study focuses only on investigating students' general chemistry achievement through pre-test and post-test scores.

Recommendations

The study recommends the following:

1. *Utilize true experimental research design*. Using a true experimental design and random sampling with a control group could help compare the results of this study and better explain how the agriCHEMture e-learning material affects students' general chemistry achievement.

2. *Implement the agriCHEMture e-Learning Material for students with a modular, hybrid (face-to-face-online), or pure onsite learning set-up.* The learning environment is a crucial component of the learning process; thus, exploring different learning environments contributes to recent findings.

Declaration of AI Tools in Scientific Writing
AI tools (Grammarly QuillBot) were used to correct grammar and rephrase sentences for better language clarity and readability.

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