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The Role of Biology Curricula in Promoting Sustainable Development Concepts Among Secondary School Students from Teachers' Perspectives

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Abstract: This study reviews how the secondary school biology curriculum in Al-Kharj region of Saudi Arabia is relevant to sustainable development through the lens of educators. A validated questionnaire of five dimensions cognitive, economic, technological, social and environmental is used in surveying 142 randomly chosen biology teachers using a descriptive-analytical methodology. The results show that the level of applying the concepts of sustainable development is low with the average score of 1.45. The least important are the social factors, and the most important are the aspects related to technology. Teachers have pointed out that sustainability issues are inadequately addressed and rarely align with curriculum and teaching goals. The results indicate that the existing curriculum does not encourage the ability to think sustainably or prepare students with the necessary competencies, which may become an obstacle to achieving Saudi Vision 2030 and the global development goals. The report suggests updating the biology curriculum to explicitly inculcate the concepts of sustainability in all the realms, to equip the students with the ability to play their part in the social and environmental development.

Keywords: Curriculum Reform, Ecological Literacy, Teacher Perspectives, Instructional Design, Education Policy.

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1. Introduction

The economy has swiftly developed, which creates serious ecological imbalances because of the industrialization (Hu et al., 2025). Sustainable development has therefore become a conclusive global paradigm, which is a combination of economic, social, and environmental goals to curtail the soaring environmental challenge. Sustainability embraces inequality and degradation; it was the action agenda of the whole world that was set several decades ago at the 1972 Stockholm conference and the 1987 Brundtland Report. The magnitude has been more evident with nations facing the problems of climatic changes, pollution, and depletion of natural resources.

Education for Sustainable Development (ESD) imparts knowledge, skills, and values to address environmental and social problems, thus creating ecological awareness, ethical decision-making, and problem-solving by promoting curriculum development. In addition, ESD upholds multidisciplinary and lifelong learning and active citizenship, enabling the student to be an active participant in the making of innovative, equitable, and resilient communities that can solve the global sustainability issues of our times.

Through a combination of cognitive, environmental, and ethical aspects, the evolution and ecology of sustainable development analyzes the special position of biology in the process of sustainable development. It is an interdisciplinary subject with a high transmission rate, easy to apply in practical uses, and encourages interdisciplinary learning and improves environmental literacy, civic responsibility, and sustainability (Usta, Doğan, & Abdurrezzak, 2025).

Despite these developments around the world, there is still a gap in knowledge as far as the implementation of sustainability principles in secondary school biology curriculum is concerned. There is much theoretical argumentation, and the real-life experience of the teachers in the classroom is usually left out (Prasetyo et al., 2025). Not many studies have been focused on understanding the concept of sustainable development and its conceptualization and implementation in the curriculum by biology teachers. In this study, the authors combine the views of teachers to discuss these dynamics and answer the following question: How do teachers view the role of the biology curriculum in helping develop sustainable growth among students? This is a gap that should be bridged in order to come up with better curriculum strategies and teacher education programs.

The purpose of the present study is to examine the opinions of secondary school biology teachers on the quality of the curriculum that will contribute to sustainable development and also analyze its merits, flaws, and possible improvements. It builds on both theoretical and empirical writings that guide curriculum design, teacher education, and education policy.

1.1. Problem Statement

The world has been overrun with developmental, environmental, and economic challenges, which are severe threats to the welfare of the society. In that respect, education is becoming more and more acknowledged as one of the major sources of sustainable thinking and the driving force behind progress. In keeping with the Vision 2030, Saudi Arabia is incorporating education reform in the national agenda, where the focus lies in improving lifestyle and advancing the sustainable development goals. The major concern is the redesign of school curriculum to ensure sustainability and provide the students with the skills required to solve real-life challenges they have to face today.

Although there has been an increased understanding of the importance of sustainability in education, as demonstrated by events like the Riyadh Investment Conference and the UNESCO Learning Cities Conference, little has been done to incorporate sustainable development in school curricula. According to prior studies, a majority of curricula are still out of date and do not indicate technological and industrial improvements. This is more important in secondary schools as students are ready to enter higher learning institutions, work, or even become citizens. Olalekan, Ayoola and Ogundeji (2025) argue that a teacher can have the concept of sustainability as a learning goal, but they have no ability to bring this concept into practice because of time and resource limitations.

More sustainability goals can be better supported by biology, which is based

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on ecological and empirical research. The unification of the different aspects of sustainability—the cognitive, economic, technological, social, and environmental—is not well placed in the secondary biology syllabus. Subsequently, the lack of knowledge thus interferes with the understanding of students about the consequences of their behaviors as regards to both societal and environmental spheres, consequently limiting evidence-based decision-making and engagement in sustainable lifestyles that are critical in driving the national growth. Purwianingsih, Novidsa and Riandi (2022) claim that teacher-preparation programs often do not include much sustainability-focused content, which results in poorly elaborated lesson plans and a minimal amount of classroom discussions on sustainability-related topics.

Despite the fact that educators play a pivotal role in the implementation of the curriculum, they are rarely consulted during the development stages of the curriculum despite being the direct contact with the curriculum material and students. They do not just posit values and behaviors that are consistent with the sustainability imperatives, but they also instill knowledge in the audience. Interest in the views of instructors can fill the gap that exists between theory and practice. According to Yanuarto et al. (2025), biology teacher educators are looking forward to integrating sustainability into their curriculum; although, this program is hampered by structural constraints and lack of institutional backing.

The problem here is the poor incorporation of ideas of sustainable development into the secondary biology curriculum. This research problem focuses on how much the curriculum can improve the knowledge of the sustainability of students, and it also explores the opinion of biology teachers. Through the analysis of their experiences and contributions, one can consider the real effect the curriculum has on the work of teachers as well as determine the ways to improve it. The following research question will be the guiding question of this study: To what extent does the present-day biology curriculum enable the acquisition of sustainable behaviors by learners, and how can the educators be better positioned in the way of incorporating sustainability into their teaching activities?

1.2. Research Objectives

1. To examine how scientific courses can improve on the cognitive aspect of sustainable development among the students of the secondary schools in the eyes of teachers.
2. To explore the views of teachers regarding the role of science programs in the economic aspect of sustainable development among the students of secondary schools.
3. To explore how scientific curricula impact the teachers on their perception of enhancing the technological aspect of sustainable development among the secondary school students.
4. To investigate the perception of teachers on the relevance of science programs in the social dimension of sustainable development within secondary schools.
5. To determine the extent to which science curriculum facilitates the dissemination of the environmental dimension of sustainable development among secondary school students, as perceived by educators.

1.4 Research Questions

1. From the perspective of educators, what is the function of science curricula in advancing the cognitive aspect of sustainable development concepts among secondary school students?

2. From the perspective of educators, what are the contributions of science curricula to the economic dimension of sustainable development concepts among secondary school students?
3. What is the function of science curricula in promoting sustainable development concepts that enhance the technical competencies of secondary school students as per the perspective of teachers?
4. What is the contribution of the science curriculum to shaping the social dimension of sustainable development concepts among secondary school learners as per teachers' perspective?
5. What are the contributions of science curricula to promoting the environmental aspect of sustainable development among secondary school students from the perspective of teachers?

1.3. Research Scopes

1.3.1. Objective Scope

This article seeks to understand, from the teachers' perspective, how the secondary school biology curriculum will be utilized to support the five pillars of sustainable development. It analyzes the integration or manifestation of cognitive, economic, technical, social, and environmental factors within educational content and activities.

1.3.2. Time Scope

The research is confined to a single academic year in which the activities and biology curriculum were implemented and assessed. This time must ensure the authenticity of the acquired data regarding its relevance to contemporary practices and models of instruction and curriculum in the study.

1.3.3. Spatial Scope

The study is limited in terms of geography to the sampled secondary schools within the Saudi National Education system. Such a situation gives a narrow scope of thinking about designing and developing a biology curriculum and its implementation within a given education setting.

1.3.4. Human Scope

The research design focusses on secondary school biology teachers as the major topics, as they are the direct facilitators of curriculum implementation and student involvement. Their comments provide the foundation for understanding the strengths and weaknesses of the curriculum in imparting principles of sustainable development.

1.4. Definitions of Concepts and Terms Used

1.4.1. Education for Sustainable Development (ESD)

ESD provides the information, beliefs, and abilities necessary for learners to address sustainability concerns effectively. All social, environmental, and economic dimensions are integrated; critical thinking and participatory learning are encouraged; Education for Sustainable Development (ESD) aligns with UN Sustainable Development Goal 4.7 and facilitates the realization of scientific concepts (Zhang, Chen, & Xu, 2025).

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1.4.2. Biology in the Curriculum for Sustainability

It aims to incorporate the idea of sustainability that includes climate change and biodiversity in biology courses. This project is supposed to bridge a gap between biological science and the modern global issues through the use of problem-based and interdisciplinary instruction (Jackson et al., 2025). A Pedagogical Content Knowledge in Education for Sustainable Development.

PCK ESD refers to the capacity of educators to incorporate ideas of sustainability with effective teaching practices. It is the integration of subjective knowledge and the strategies through which the students are brought to the level of ethical and systematic thinking. It is expected that this competency will be enhanced by means of training initiatives (WMO, 2025).

1.4.3. Student Sustainability Skills

These include cognitive, affective, and behavioral competencies: critical thinking, empathy, and proactive abilities. They teach the sustainability issues and are the pillars of sustainability education.

1.4.4. Teacher Attitudes Toward Integrating Sustainability

Teaching sustainability depends on the beliefs and thinking of the educators. Although this work has paramount value, it is possible to encounter several factors that make its implementation complicated. The education in school might not be sufficient, and there are not enough tools and resources to help us (United Nations, 2024).

2. Theoretical Framework

Considering the growing crises of climate change, the decrease in biodiversity, and socio-economic inequality, it is urgent to implement Education for Sustainable Development (ESD) in formal education systems on the global level. The scientific field of biology is in a better position to solve these challenges because it is directly related to ecological systems and human-environment interactions. This study focuses on the problem of teaching the concept of sustainable development to students of the second level through the biology curriculum, through the prism of instructors, who mediate between the contents covered in the curriculum and classroom practice. Theoretical frameworks are important because they direct the investigation as well as serve as cognitive tools for comprehending perspectives of teaching, content of the curriculum, and pedagogical methods. They provide an insight into the concept and idea of sustainable development in educational institutions.

The theory developed by Vygotsky allows determining what kinds of socialization support sustainable learning among pupils. As a teacher with the necessary possession of knowledge, the educator promotes the study and interrelation of sustainability with the cultural paradigm in students. This approach focuses on communication and local education as the tools to facilitate sustainable development because the process of knowledge co-construction is seen through mutual experience and dialogues. Teaching and learning in a community through dialogue form is unquestionably important in promoting sustainable development. The creation of knowledge is through exchange of experiences and dialogue.

Meaning is naturally generated by human beings. People always strive to make sense out of the new information, comparing it with their prior knowledge. We assume

that the creation of a mental representation is what we call a schema. We make them of everything that we see and think about. As a result, biodiversity/carbon cycles are not studied in isolation when it comes to biology among students. Their experience is that of developing this new knowledge as a part of their already existing knowledge of the world. Of utmost importance is the way in which teachers plan and present the information on the topics of such problems as sustainability. It can help students to create mental paradigms, and the data will be long-lasting, as specified by the gurus themselves (Robinson et al., 2025).

Technology has actually revolutionized the way of teaching biology. It is now much easier to participate in interactive simulations, to work in electronic laboratories, and to see environmental data in real time. When considering education towards sustainable development (ESD), it is of paramount importance that the educators learn to combine technology, the best teaching methods, and sustainability programs. But the irony of things is that most biology teachers are not ready to use digital resources to teach sustainability. This points at a larger problem with teacher education and our program organization (Xu et al., 2025).

The 21st Century Skills model is a new educational model, which can effectively support the introduction of Education for Sustainable Development (ESD) into the biological classroom. These are methods that refer to key aspects including critical thinking, teamwork, flexibility, and good global citizenship. They are the same as the goals that sustainable development follows. It is not only to prepare students to take tests but also to equip them with competencies to deal with major problems facing the world with the integration of the competencies in our curriculum. In addition, it goes hand in hand with the United Nations Sustainable Development Goals, which is another reason why Education for Sustainable Development has to be included in the science education.

It is also applicable to the social cognitive theory, which are the principles of observational learning and self-efficacy as expounded by Bandura. Teachers as role models have enormous influence on the attitude and behavior of students with regard to the environment. One way that educators can demonstrate their confidence in dealing with sustainability is to model sustainable behavior, thus enhancing confidence among students in their ability to deal with sustainability challenges. Sustainability-related behavior has been successfully modelled and propagated in the secondary school setting.

3. Literature Review

In this section, the previous studies that have used a critical literature review process, where the literature is appraised, thematically grouped, and also critically assessed, will be presented. There are also radical methodological changes, theoretical views, areas of agreement and disagreement, and gaps in the literature that have been outlined in order to establish a holistic and enlightening background to the present study.

3.1. Comprehensive Overview

The idea of the integrated curriculum in improving Education for Sustainable Development (ESD) in secondary biology education is supported by research by Ferrer et al. (2025) and Gui et al. (2025) to be applicable both in international and local settings. They are curriculum directions in relation to SDGs, pedagogy, and teacher competencies. The areas of the research include curricular organization, educator preparation, and

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pedagogy. The theoretical basis of the approach is Pedagogical Content Knowledge (PCK), transformative learning, and GreenComp, which is used in the methodology employed, namely qualitative, quantitative, and mixed-methods design.

3.2. Thematic Analysis

The study is structured into three areas of topics: curricular integration, educator preparation, and pedagogical techniques of support. Curricular Integration: The integration of sustainability, which involves environmental, social, and economic aspects, in the scientific field of biology (Walkowiak et al., 2025). Teacher preparation focuses on the readiness and ability or constraints of the pre-service and in-service teachers to efficiently execute Education in Sustainable Development (ESD). Instructions are comprised of social-scientific problems and experience (UNEP, 2024). These macro factors are connected with each other and contribute to the commitment to policy, curriculum, and pedagogy development and, hence, the achievement of ESD goals.

3.3. Comparative Analysis

Various studies also show that despite the need to teach sustainability, the subject in secondary biology classrooms is poorly addressed in terms of teaching sustainability. Institutional support is also one of the greatest barriers; according to Ogunseitan (2025), it is necessary to refer to innovative pedagogical approaches to reduce the problem. All these observations can be used to emphasize the vital importance of the systemic commitment and the developmental pedagogical strategies, which will enable the incorporation of sustainability in the biology education.

3.4. Advanced Integration

The introduction of conceptual synthesis in sustainability education in biology is based on the opposition of curriculum design, instructor competency, and pedagogical innovation. This paper applies the transformative learning theory (Gómez-Ríos, Gómez-Ríos, & Castellanos-Martínez, 2025) and the empirical evidence provided by Cirkovic and Wood (2025) to explain the concept of sustainability education, recontextualize it, and implement it in different curricular contexts in order to enhance the design of the curriculum and the alignment of the pedagogy in order to ensure sustainability education.

3.5. Study objectives and the research gap

The literature lacks any sustained analysis of the social and ethical aspects of sustainability as well as longitudinal or comparative data concerning the adoption of practices. According to IEA (2024), teachers do not match their classroom activities to their knowledge. The proposed research aims to fill this gap by exploring the ways of making secondary biology teachers interested in sustainability-oriented content, depending on whether it is tied to institutional backgrounds and curriculum freedom. The study will be based on the PCK and GreenComp models of teacher knowledge and practice to analyze teacher agency, instructional decisions, and institutional barriers. This project design helps to produce new theoretical knowledge and practical results that will be used to inform the long-term curricular transformation and teacher education programs.

This study examines available literature on the topic of sustainability in the teaching of biology, indicating methodological heterogeneity, shared goals, and gaps in content and practice as demonstrated by the literature. It recognizes a disregard of social-ethical aspects and institutional limitations. This study is able to fill these gaps and

contribute to the literature directly on the areas that are congruent with sustainability and teacher empowerment.

4. Methodology

4.1. Study Approach

The study adopts a qualitative research methodology that seeks to delve into the perceptions of teachers with respect to the application of sustainable development in biology teaching in secondary schools. The qualitative approach is required due to the interpretative nature of the issue to obtain knowledge, professional experiences, and inexplicable insights.

This study explores the views of the secondary school biology teachers on the aspect of how sustainable development should be integrated into the biology curriculum in Nigeria with the help of a descriptive survey research approach. This framework is the best that can be used to understand collective cognition, behavior, and orientation through clear and systematic surveys. It gathers data in an organized way and maintains the natural environment's integrity.

The researcher has first reviewed the literature and research and developed a questionnaire, which was later reviewed by experts before it was sent to a random sample of English biology teachers in Al-Kharj via email and social media.

Responses were then categorized, organized, and analyzed using SPSS version 26. This software provided simple summaries and complex statistical approaches to analyze the data and respond to the research questions. The approach helped to carry out a comprehensive analysis of how the concept of sustainability could be applied to the realm of biology lessons, thereby providing a strong base towards comprehending and promoting sustainability pedagogy.

4.2. Data Collection

The data was collected using a questionnaire that is specifically designed to collect information in this study. The document included two parts, one of which was a demographic segment, and the other part included 25 questions divided into five areas of sustainability, which are cognition, economy, technology, society, and environment. The materials are designed and revised in accordance with the existing research and are reviewed by specialists in respective spheres. To ensure a high level of reliability and internal consistency, the instrument is pilot tested on 70 educators. The ultimate version is sent to the sample group through email. A three-point Likert scale is used in the questionnaire, and the questions in the questionnaire are targeted at an attempt to quantify teachers' perceptions of the role of the biology curriculum in sustainable development, and this will be clear, valid, and reliable.

4.3. Statistical Tools

Analysis of the data is done by use of SPSS version 26, which provides a wide range of statistical reviews in accordance with the research aims and objectives. The descriptive statistics that were used to describe the demographic picture of the participants as well as clarify the perception that teachers hold about the role of bio-curricula in promoting concepts of sustainable development included frequencies, percentages, means, and standard deviations. Cronbach's alpha coefficient of the

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whole instrument and the subscales was computed to determine the reliability of the instrument. Moreover, Pearson correlation coefficients are used to determine the internal consistency validity by using the items and their respective dimensions. These are statistical techniques that offer strong support to the data interpretation and make the research results more precise, reliable, and valid.

4.4. Sample and Population

The research sample includes the entire population of biology teachers in the secondary schools of Al-Kharj district of education (N=224) in the academic year 1446 AH, including 96 male teachers and 128 female teachers. Calculation of the sample size (N=142) is done by the Richard Geiger equation. The basic random sampling process is used to ensure the representativeness of the sample, which resulted in 61 men and 81 women respondents. Accessibility and volunteering of the sample apply to the selection, and data is collected via the spreading of an electronic survey by utilizing the official communication channels of the schools. This approach provided equal chances of selection, as well as improved the reliability and generalizability of the research results.

Table 1: Distribution of the Research Sample According to Educational Qualification.

Qualification	Frequency	Percentage (%)
Bachelor's Degree	127	89.4
Master's Degree	12	8.5
Doctorate (Ph.D.)	3	2.1
Total	**142**	**100**

According to Table 1, the research sample comprises secondary school biology teachers, with the majority having a bachelor's degree (89.4%), with a much smaller percentage having a master's degree (8.5) or a doctorate degree (2.1). The vast majority of educators in Al-Kharj continue to study as undergraduates, and this fact contributes greatly to the development of the teaching community. This creates an implication of few educators with postgraduate degrees and, as a result, inhibits the in-depth investigation of themes and formulation of curriculum when incorporating such intricate issues as sustainable development. These results distinctly prove the benefits of providing professional training and advanced programs. It can be reasonably argued that such measures will raise the ability of our teachers to teach sustainability.

Figure 1: Distribution of the Research Sample by Educational Qualification.

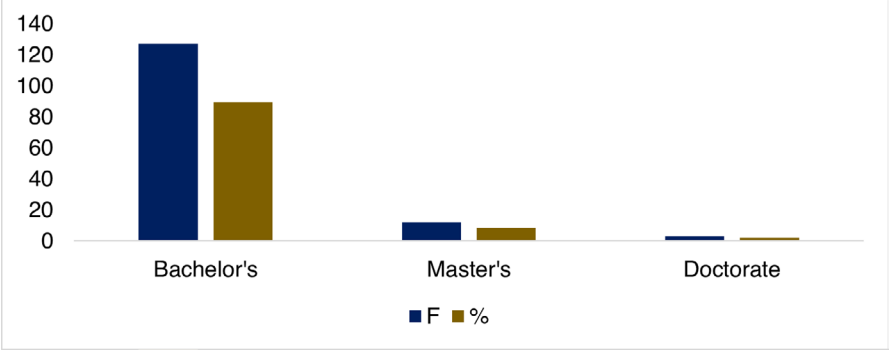


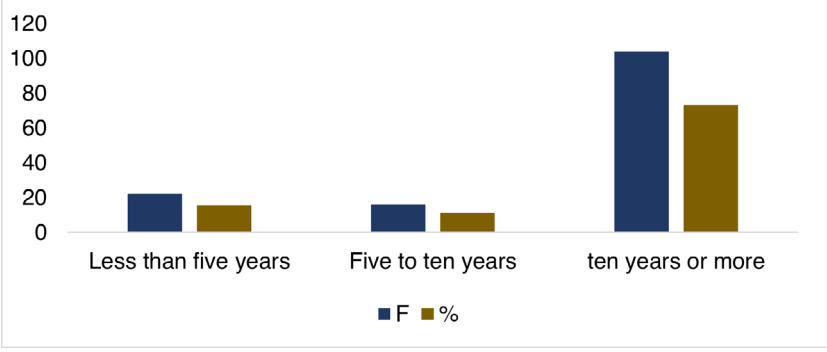
Figure 1 clearly indicates the education levels of the biology teachers in secondary schools that are being studied. It is also clear that nearly 90 percent of them have a BA. On the other hand, few of them have master's or doctorate degrees. The trend can indicate the gap in the development of the teaching professions in Al-Kharj governorate. The teachers who are less qualified might not be exposed to modern pedagogical processes, critical thinking skills, and interdisciplinary incorporation that is necessary to teach concepts such as sustainability.

Table 2: Distribution of the Research Sample According to Years of Teaching Experience.

Years of Teaching Experience	Frequency	Percentage
Less than 5 years	22	15.5%
From 5 to 10 years	16	11.3%
More than 10 years	104	73.2%
Total	**142**	**100%**

Table 2 shows that the most frequent among the biology educators who participated is a large majority of 73.2% who have over 10 years of teaching experience. This implies that Al-Kharj educational district has a well-experienced teaching staff. On the other hand, only 15.5 percent of teachers have less than five years of experience, whereas 11.3 percent of teachers have five to ten years of experience. The level of experienced teachers sampled could also add credibility to the study since they will be in a well-positioned position to provide better information on how the curriculum can be implemented and how it can be changed. Authenticity is important with their experience, which is gained by the years of practical work and the profound knowledge of educational trends.

Figure 2: Distribution of the Research Sample by Years of Teaching Experience.



As shown in Figure 2, most of the professors surveyed are highly recognized geriatrics, and most of them have more than 10 years of experience. This trend is an indication of the presence of a well-trained and consistent pool of teachers. This experience helps to conduct a more comprehensive data collection; the trained educators are in a privileged position, as they could offer valuable and evidence-based information about the implementation of the themes of sustainable development into the biology curriculum and the obstacles that appeared during this procedure. The authority of the study is supported by this number because these two professionals have extensive experience, and their views are valuable.

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4.5. Research Instrument

The data-gathering tool that will be used in this study is the questionnaire. This research aims at determining how biology curriculum can be used to deliver the concept of sustainable development to secondary school students, as it is understood by biology teachers. The designed structured instrument is meant to gather the specified quantitative data that are based on the objectives of the study and thus are subject to statistical analysis.

Its validity and academic rigor are achieved by conducting an extensive review of the available literature on education and sustainability development and how this can be incorporated into the science curriculum. Some of the works that are highly referenced and inform the questionnaire are the studies conducted by the World Bank (2021). These materials give the conceptual and empirical basis for the development of a questionnaire that can indicate contemporary pedagogical work and sustainable development in teaching biology.

The prototype version of the questionnaire has two vital elements. The first section will be reviewed as the collection of demographic data about the respondents, such as gender, highest educational level, and teaching experiences. The second part is composed of 25 items, which are distributed equally in five sustainable development areas: cognitive, economic, technological, social, and environmental. The framework aims at ensuring that the areas of concern are well represented in the study and that the presentation of sustainability in biology courses is well understood.

The validity of the item in the questionnaire is guaranteed by sending the questionnaire to the expert review. Scientific education and scientific curriculum development Products are reviewed by subject matter experts on the basis of the criteria of clarity, scientific rigor, and linguistic appropriateness. The reviewers make the systematic contribution in terms of how well the items are aligned with the specified parameters and conceptual consistency of the tool. Therefore, a number of changes are made to make the terminology more precise, the item location more relevant, and the dimensions more consistent to increase the validity of the instrument and make it more aligned with the objectives of the study.

After the phase of validation, the modified questionnaire is pilot tested with another sample consisting of 70 biology teachers who were not included in the main sample of the research. The instrument's internal consistency and reliability are tested in the pilot research, and then it will be implemented on a large scale. The results of this step will be a guarantee to the researcher that the questionnaire is working as intended in the context of structure, clarity, and response pattern.

To determine the internal consistency validity of the questionnaire, the Pearson correlation coefficient was calculated between each item and the corresponding dimension or between each dimension and the total questionnaire score. Such a statistical method facilitates measurement of the extent to which items of each dimension are related to each other and significantly assess the same underlying construct. Table 3 shows the correlations that were obtained on all five aspects of sustainable development: cognitive, economic, technological, social, and environmental, in accordance with the answers of the teachers.

Table 3 illustrates that all Pearson correlation coefficients between individual items and their respective dimensions are statistically significant, with values that vary from moderate to high ($r = 0.67$ to 0.87). The correlations between each dimension and the overall questionnaire score are robust, ranging from 0.77 to 0.91. These findings

provide robust evidence of internal consistency, demonstrated by the coherence of the items within each dimension and their capacity to measure the intended construct.

Table 3: Pearson Correlation Coefficients for the Questionnaire.

Dimension 1: Cognitive Development	r	Dimension 2: Economic Development	R
Item 1	0.87**	Item 6	0.71**
Item 2	0.82**	Item 7	0.87**
Item 3	0.78**	Item 8	0.70**
Item 4	0.67**	Item 9	0.82**
Item 5	0.80**	Item 10	0.84**
Correlation of Dimension with Total Questionnaire	0.89**	Correlation of Dimension with Total Questionnaire	0.90**
Dimension 3: Technological Development	**r**	**Dimension 4: Social Development**	**R**
Item 11	0.77**	Item 16	0.80**
Item 12	0.72**	Item 17	0.84**
Item 13	0.71**	Item 18	0.76**
Item 14	0.78**	Item 19	0.70**
Item 15	0.81**	Item 20	0.80**
Correlation of Dimension with Total Questionnaire.	0.77**	Correlation of Dimension with Total Questionnaire.	0.83**

Note: (**) indicates statistical significance at the 0.01 level or lower ($p \leq .01$).

The high internal consistency enhances the content validity of the instrument, which creates a sense of reliability in the accuracy of the questionnaire as a measure of the teacher's attitude towards the application of sustainable development principles in teaching biology. The invariance of the dimensions demonstrates the conceptual clarity and usefulness of the items and the analytical and interpretive potential of the instrument in the educational research.

The internal consistency of the instrument is gauged with the help of the Cronbach alpha coefficient that evaluates the reliability of the questionnaire. Table 4 shows the alpha values, which show the reliability of the given dimensions of the questionnaire.

Table 4: Coefficients of Alpha Reliability of the Questionnaire.

Main Dimension	Cronbach's Alpha (α)
Dimension 1: Cognitive Development	0.94
Dimension 2: Economic Development	0.88
Dimension 3: Technological Development	0.98
Dimension 4: Social Development	0.93
Dimension 5: Environmental Development	0.82
Overall Dimensions	0.96

The validity of the questionnaire was evaluated by establishing the internal consistency of the individual dimension and the instrument as a whole using the Cronbach alpha coefficient. Cronbach's alpha is a statistical fact that shows the degree of interrelatedness between items in a construct and provides a fact of reliability of the scale. Table 4 shows the values of the Cronbach's alpha of the five dimensions—cognitive, economic, technological, social, and environmental—along with the value of the overall reliability. Findings: All dimension reliability coefficients are high, which means that the questionnaire items are successful at measuring the target constructs, and the instrument is likely to assess the teacher views on the principles of sustainable development in the education of biology.

To understand the results of the responses obtained from the mean of the Likert scales, the judgment criteria are used according to the following formula:

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$$Length\ of\ Interval = Number\ of\ LevelsUpper\ Limit - Lower\ Limit = 3 - 1/3 = 0.67$$

This calculation is used in the classification of the levels of consensus or perception and the average scores of the better interpretation in statistical examination. Table 5 shows that the mean values between 2.35 and 3.00 would represent the high level of availability/agreement, mean values between 1.68 and 2.34 would represent the medium level of availability/agreement, and mean values between 1.00 and 1.67 would represent the low level of availability/agreement. These standards offer a standardized and objective basis on which the questionnaire results can be interpreted on all aspects.

Table 5: Criteria for Interpreting the Questionnaire Results.

Level of Availability	Upper Limit	Lower Limit
High	3.00	2.35
Medium	2.34	1.68
Low	1.67	1.00

5. Results

This section presents the research findings based on data collected among the biology teaching professionals in Al-Kharj educational region. The analysis aims to explore the views of educators on the role played by the biology curricula in facilitating principles of sustainable development. The frequency, percentage, means, and standard deviations are provided to describe the demographic profile of the study participants and their response to the study questionnaire items. Moreover, Pearson correlation coefficient and Cronbach's alpha have been used to determine the internal consistency and reliability of the study tool. The findings were grouped by the objectives and dimensions of the study to give a detailed description of the concept of sustainable development among biology curriculums today in the view of educators.

Results of the first research question: "From the perspective of educators, what is the function of science curricula in advancing the cognitive aspect of sustainable development concepts among secondary school students?" Frequencies, percentages, means, and standard deviations as descriptive statistics are calculated according to the responses of the participants to the items that measure the cognitive aspect of the questionnaire. All the results are provided in Table 6.

Table 6: Frequencies, Percentages, Means, and Standard Deviations for Dimension One: Cognitive Development.

No.	Item	High Frequency	High %	Medium Frequency	Medium %	Low Frequency	Low %	Mean	Std. Dev.	Dominant Opinion	Rank
1	Includes topics explaining the importance of knowledge production to achieve sustainable development for a promising human future.	25	17.6	15	10.6	102	71.8	1.46	0.78	Low	3
2	Includes activities that stimulate creative idea generation to solve sustainable development problems related to living organisms.	26	18.3	12	8.5	104	73.2	1.45	0.79	Low	4
3	Incorporates cognitive concepts related to sustainable development such as justice, earth protection, food security, biodiversity preservation, etc.	23	16.2	21	14.8	98	69.0	1.47	0.76	Low	1
4	Highlights the importance of achieving sustainable development by preserving living resources.	24	16.9	17	12.0	101	71.1	1.46	0.77	Low	2
5	Links biology topics to achieving sustainable development in real life.	12	8.5	25	17.6	10					
	Overall Mean							1.44	0.75	Low	

Table 6 shows that on the dimension of sustainable development, which is the sum of the cognitive aspect, the mean of the judgement made by the secondary school biology teachers is 1.44, thus classifying it as low in the interpretive scale. The mean scores of the individual items in this category were low (1.45-1.47), which implies that there was a low level of integration of cognitive concepts associated with sustainable development in the current biology curriculum. The very low responses to all questions are indicative of a tremendous gap in developing the knowledge, values, and awareness necessary to sustain sustainable growth as far as cognitive contents are concerned.

Results of the second research question: "From the perspective of educators, what are the contributions of science curricula to the economic dimension of sustainable development concepts among secondary school students?" To address this subject, frequencies, percentages, means, and standard deviations were computed considering the answers of the respondents to the questions in the second dimension of the questionnaire. The results have been given in Table 7.

Table 7: Frequencies, Percentages, Means, and Standard Deviations for Dimension Two: Economic Development.

No.	Item	High Frequency	High %	Medium Frequency	Medium %	Low Frequency	Low %	Mean	Std. Dev.	Dominant Opinion	Rank
1	Clarifies the mechanism of investing human capital in sustainable development.	21	14.8	19	13.4	102	71.8	1.43	0.74	Low	3
2	Focuses on industries that enhance the productive capacities of natural resources.	18	12.7	22	15.5	102	71.8	1.41	0.71	Low	4
3	Highlights the importance of possessing professional skills in biology specialties to achieve sustainable development in the labor market.	20	14.1	14	9.9	108	76.1	1.38	0.72	Low	5
4	Addresses topics on the latest rapid economic changes related to biology fields.	15	10.6	46	32.4	81	57.0	1.54	0.68	Low	2
5	Raises awareness of the optimal use of natural resources to reduce the risks of depletion.	7	4.9	62	43.7	73	51.4	1.54	0.59	Low	1
	Overall Mean							1.46	0.67	Low	

According to Table 7, the overall mean score of the contribution of the science curricula towards the development of the economic dimension of the concepts of sustainable development as perceived by the teachers in the secondary schools is 1.46, which is low. The means of individual items vary between 1.38 and 1.54; all of them are low according to the a priori evaluation criterion.

Table 8: Frequencies, Percentages, Means, and Standard Deviations for Dimension Three: Technical Development.

No.	Item	High Frequency	High %	Medium Frequency	Medium %	Low Frequency	Low %	Mean	Std. Dev.	Dominant Opinion	Rank
1	Includes activities for developing green digital skills.	12	8.5	54	38.0	76	53.5	1.55	0.65	Low	2
2	Employs technology to acquire the knowledge necessary to achieve sustainable development in biology fields.	6	4.2	60	42.3	76	53.5	1.51	0.58	Low	3
3	Explains the role of nanotechnology in addressing medical, food, health, and other problems.	5	3.5	61	43.0	76	53.5	1.50	0.57	Low	4
4	Includes topics illustrating the impact of technology on scientific development and progress in biology.	12	8.5	62	43.7	68	47.9	1.61	0.64	Low	1
5	Highlights the role of biology in rapid technological advancements aimed at achieving sustainable development for living organisms, present and future.	0	0.0	67	47.2	75	52.8	1.47	0.50	Low	5
	Overall Mean							1.53	0.59	Low	

Overall Mean I 1.53 I Standard Deviation I 0.59 I Dominant Opinion: Low I

Results of the third research question: "what is the function of science curricula in

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promoting sustainable development concepts that enhance the technical competencies of secondary school students?" To respond to this issue, the frequencies, percentages, means, and standard deviations are determined with regard to the responses that the participants gave to the third question of the questionnaire. Table 8 summarizes the findings.

As shown in Table 8, the mean score on the faculty of scientific curricula in terms of boosting the technical component of the concepts of sustainable development, as seen by teachers, is 1.53 (poor efficacy). The personal scores are between 1.47 and 1.61; they are all low in accordance with the defined evaluation criteria.

Findings of the fourth research question: "What is the contribution of the science curriculum to shaping the social dimension of sustainable development concepts among secondary school learners as per teachers' perspective? To answer this question, frequencies, percentages, averages, and standard deviations are calculated out of the answers of the respondents to the fourth dimension of the questionnaire. Table 9 summarizes the findings.

Table 9: Frequencies, Percentages, Means, and Standard Deviations of Research Sample Responses on Axis Four: Social Development.

No.	Statement	High	%	Medium	%	Low	%	Mean	Std. Dev.	Prevailing Opinion	Rank
		F		F		F					
1	Focuses on concepts related to positive social behaviors for preserving the environment.	0	0.0	66	46.5	76	53.5	1.47	0.50	Low	1
2	Includes activities that develop diverse communication skills for discussing issues of sustainable development related to biology topics.	0	0.0	57	40.1	85	59.9	1.40	0.49	Low	3
3	Includes volunteer activities related to biology fields.	0	0.0	33	23.2	109	76.8	1.23	0.42	Low	5
4	Includes activities that emphasize certain sustainable development concepts related to community service (e.g., unemployment, poverty).	1	0.7	36	25.4	105	73.9	1.27	0.46	Low	4
5	Reinforces the principle of freedom of expression regarding ideas and viewpoints.	1	0.7	60	42.3	81	57.0	1.44	0.51	Low	2
	Overall Mean							1.36	0.48	Low	

Table 9 shows that the average score on the role of science curricula in promoting the social aspect of sustainable development based on the rating of educators stands at 1.36, which represents low effectiveness. The mean values of the items of this dimension vary between 1.23 and 1.47, and they are in the low category as per the given interpretive criteria.

What are the contributions of science curricula to promoting the environmental aspect of sustainable development among secondary school students from the perspective of teachers?

Table 10: Frequencies, Percentages, Means, and Standard Deviations for Dimension Five: Environmental Development.

No.	Statement	High	%	Medium	%	Low	%	Mean	Std. Dev.	Prevailing Opinion	Rank
		F		F		F					
1	Promotes the concept of environmental security.	24	16.9	17	12.0	101	71.1	1.46	0.77	Low	3
2	Focuses on environmentally friendly green resources.	12	8.5	25	17.6	105	73.9	1.35	0.63	Low	5
3	Raises awareness about the importance of rational consumption to protect the environment.	20	14.1	14	9.9	108	76.1	1.38	0.72	Low	4
4	Includes activities that stimulate future thinking to achieve environmental sustainability.	15	10.6	46	32.4	81	57.0	1.54	0.68	Low	1
5	Illustrates the Kingdom's efforts to protect the environment.	7	4.9	62	43.7	73	51.4	1.54	0.59	Low	2
	Overall Mean							1.45	0.68	Low	

Findings of the fifth research question: "What are the contributions of science curricula to promoting the environmental aspect of sustainable development among secondary school students from the perspective of teachers?" To answer this topic,

the frequencies, percentages, means, and standard deviations are calculated using the responses of the sample research participants on the 5th dimension of the questionnaire. The findings are shown in Table 10.

Table 10 indicates that the general mean of the contribution of science courses to the environment under the aspect of sustainable development as perceived by educators is 1.45, which is a low level. The average score of the single items is between 1.35 and 1.54, with low being the range of scores in the assessment criteria.

Findings related to the main research question: What is the role of the scientific curriculum in promoting the principles of sustainable development among schoolchildren at the secondary level from the perspective of the educators? The answer to this question is through cumulative response to all sub-questions of the five pillars of sustainable development. Table 11 demonstrates the overall results.

Table 11: Role of Science Curricula in Promoting Sustainable Development Concepts from Teachers' Perspectives.

Dimension	Mean	Std. Dev.	Judgment Level	Rank
Cognitive Development	1.44	0.75	Low	4
Economic Development	1.46	0.67	Low	2
Technological Development	1.53	0.59	Low	1
Social Development	1.36	0.48	Low	5
Environmental Development	1.45	0.68	Low	3
Overall Dimensions	**1.45**	**0.63**	**Low**	

Table 11 suggests that the general mean score on the significance of science curriculum in instilling the concept of sustainable development among the secondary school students, in the view of the teachers, is 1.45, which is poor in terms of effectiveness. Out of the five checked dimensions, the technical development is the highest, followed by economic development, environmental development, cognitive development, and social development, respectively.

The results have shown that there is a severe gap in the integration of sustainable development principles in the biology curriculum in the studied parameters. Most teachers report that they apply these principles to a small degree. The prevalence of the technological dimension can indicate the national attempts to promote the digital transformation by making modern technologies accessible and exposing people to the latest achievements of science, such as nanotechnology, which can support the teaching and understanding of biology.

The second-ranked position in the economic dimension can be explained by the lack of enrichment activities related to the future biology-related jobs or by the encouragement of sustainable use of natural resources. Some of the classes cover issues related to tourism and biodiversity, including commercially important trees or the study of proper investment in natural resources, including water, soil, and forests. However, such events are not common, and they are confined to the context of individual courses.

The lower-ranked elements (cognitive and social) are minimally, heterogeneously, or even inferentially dealt with, leading to a lesser educational influence. The fragmented approach deprives the students of having a holistic understanding of the principles that relate to sustainable development.

The obtained empirical evidence highlights the dire need to include the principles of sustainable development in the biology courses systematically. Such integration was

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entail fair representation of all five dimensions that should be frequently incorporated in the learning materials so as to sufficiently equip the learners with the skills of dealing with the contemporary sustainability issues.

6. Discussion

The discussion section clarifies the quantitative results regarding the research objectives and the level to which the scientific curricula foster sustainable growth from the perspective of the teachers. These findings bear implications on the theory, practice, and consistency with current literature. We presented it in the following way: analysis of the findings, theoretical and practical implications, comparison with the literature available, methodological implications, explanation of similarities and discrepancies, and scholarly justification.

6.1. Interpretation of Results

The findings of this study have provided a statistical base in understanding the extent to which the science curriculum in the secondary schools includes the five outlined factors of sustainable development as viewed by the educators. The findings show that the measure generated mean values that were categorized as low in all five classes of curricular integration, which include cognitive, economic, technical, and social, as well as environmental. The technological dimension had the best mean score (M = 1.53, SD = 0.59); then the economic (M = 1.46, SD = 0.67), environmental (M = 1.45, SD = 0.68), cognitive (M = 1.44, SD = 0.75), and social (M = 1.36, SD = 0.48) dimensions followed. All these findings, together, imply that the existing science curriculums, especially those in the discipline of biology, do not sufficiently cover the precepts of sustainable development. It therefore statistically nullifies all original hypotheses of the idea that scientific courses actually trained all five dimensions. The similarity in the poor scores in the dimensions is an indication that there is a deficiency in the whole system as opposed to a lack of individual abilities. Similar trends can be seen in Amprazis and Papadopoulou (2025), who report a general lack of science education in South Africa instead of explaining the lack of various indicators of sustainability by the individual.

6.2. Theoretical and Practical Implications

The results are theoretically significant in that there is disparity in the conceptual framework of ESD and its application in the science curriculum. The lack of coverage of sustainability content in the curriculum has led to the failure of translation of the pedagogical intent into the instructional materials. This discrepancy compromises the effectiveness of the current curriculum development principles and requires a review in line with the global requirements of Education for Sustainable Development (ESD). Therefore, the results have great implications for policymakers, curriculum developers, and educational leaders. Lack of exposure to sustainability-related issues can contribute to the failure of students in acquiring the necessary competences needed to solve the modern global challenges. This would be improved by adding a greater environmental focus on multidisciplinary efforts toward sustainability, authentic problem-solving, and connecting learning goals and the national goals of sustainability. These findings have been supported by Liu et al. (2025), who note the mismatch between the teacher training curriculum and the sustainability needs of the African curriculum and recommend national changes in line with Vision 2030 to boost ESD capacities.

6.3. Comparison to Other Literature

The findings are in great agreement with the arguments against the lack of sustainability issues in science education as the situation is proposed in the current literature. Calero et al. (2024) reported similar levels of low engagement on sustainability subjects in cognitive terms that were reported on pre-service biology educators. This also represents the cognitive aspect of the given study, which is characterized by a low level of knowledge production and conceptualization. In addition, technical motifs are moderately reflected in some of the scenarios reported by Ramachandra (2025), which correlates with a high mean score reported in our research on the technological dimension. In turn, these comparisons strengthen the validity of the existing results and emphasize the importance of situational variables, such as teacher readiness, curricular policy, and instructional resources. As it was indicated by Bulut and Borromeo Ferri (2025), teacher awareness of the importance of ESD integration is not widespread across all regions of Southeast Asia to ensure systematic application, which supports the fact that the global tendencies reflect our results.

6.4. Methodological Insights

The methodological rigor and analytical validity were observed in the study due to the use of descriptive statistics, Pearson correlation, and Cronbach alpha as statistical methods. The small standard deviation entities signify that the data is not scattered freely in any of the dimensions and consequently, confirm the uniformity of the low mean scores in any of the dimensions. Further, good alpha coefficients are generated to ensure internal dependability of the measuring instrument, hence validating its reliability. It is not possible to deny the fact that there are certain limits. The external validity of the results were limited by the sampling frame since it was limited to a single educational district. Moreover, self-reporting scales have high susceptibility to perceptual bias or error and are not determinable through observational procedures. Qualitative triangulation is not provided, which limits the interpretative flexibility. Despite these shortcomings, the study approach is very sound for efficiently investigating the views of teachers and offers a model that could be applied in future studies that will focus on larger and more heterogeneous groups. The limitations are mentioned in the recent research of Meyer et al. (2025) that pointed to the importance of combining self-reports and observations in ESD assessment studies.

6.5. Reasoning about Similarities and Discrepancies

The findings of the study contained here are contradictory and consistent with the previous quantitative studies depending on the existence of the contextual factors. The results of Roberge et al. (2025) support the low scores in both the cognitive and social dimensions, which means that social responsibility, environmental justice, and active citizenship are not given enough attention in the curriculum. The relatively high score in the technological dimension could be attributed to certain national policies, including the Saudi Arabia Vision 2030 with its focus on digital transformation and technological expertise. This could have influenced the judgement of the educators regarding the adequacy of technology content in the curriculum. The difference between current results and the comparatively high sustainability incorporation seen in the West can be explained by the differences in educational infrastructure, educator training programs, and governmental requirements. Institutional, cultural, and demographic factors are

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therefore considered as likely roots of the perceived differences in curriculum efficacy. As Azevedo et al. (2025) stressed, the environmental and sustainability development (ESD) strategies must be adapted to the specific context, and the adaptation of the strategies contributes greatly to the positive implementation outcomes, which recent comparative evaluations have proven.

6.6. Scholarly Support

The interpretation and implications of the results are supported by the current literature. As part of the technological theme of the proposed study, Olawumi and Akintolu (2025) support the introduction of the sustainability concept into the digital learning environment and, in such a way, seek to develop critical consciousness among future educators. Garin et al. (2025) support the concept of implementing the Sustainable Development Goals directly into all areas of study, including the health sciences, which is why they support extensive integration of curriculum. Also, Gnann et al. (2025) examined curricular preparation of Malaysian biology teachers and confirmed the structural and pedagogical weaknesses characterized in this study. These academic studies all support the conclusion to this study that the existing curriculum is not preparing students enough to deal with the challenge of sustainability. To correct these flaws and raise the debate on sustainable development in education, a knowledge-based, interdisciplinary approach to curriculum reform is needed.

7. Conclusion

This study critically examines how well the Saudi secondary school biology curriculum promotes sustainable development principles as determined by the teachers. The findings indicate that the level of integration is wanting in all of the five domains that are taken into account, which include cognitive, economic, technical, social, and environmental. The highest-ranked category was technological, which implied that it would be in line with the national plan of digital transformation, and the lowest-ranked category was social, which showed significant gaps in the curricula.

The study plays a vital role in educational research on the application of sustainability by means of the triangulation of the views of teachers and hard data. It highlights the urgency of the issue of the need to redefine the curriculum in order to properly incorporate the concepts of sustainable development, competencies, and goals in the teaching of biology. This study contributes to the discussion by identifying particular areas that require curriculum improvements and offering evidence-based reasons as to why the content of curricula should be harmonized with the goals of Vision 2030 in Saudi Arabia.

The benefit of this study is that besides its field-based data on diagnosing, it has the advantage of basing its study on the national educational policy contexts. Not only are its thoughts academically convincing but also involve tangible attempts to make biology curricula more sustainable in teaching. This is able to shape the way the future generations will participate and perceive the sustainability issues both at the local and global levels.

7.1. Recommendations

The educational authorities should embark on reforms in the national curriculum by encouraging biology performance to incorporate the concept of sustainable development more conspicuously with explicit reference to cognitive, social, economic, environmental,

and technological aspects based on Vision 2030. One of the goals of this project is to gain teacher training oriented to sustainability-oriented instruction through providing pedagogical frameworks and practical tools to support project execution, as it is backed by real-world projects and interdisciplinary modules. Sustainable-associated information and simulations need to be integrated into digital learning platforms to allow the students to learn and practice their knowledge in the real world. The systematic assessment system is impossible without tracking the correspondence of the contents of the curricular material and the Sustainable Development Goals to the curriculum and updating the contents of the sustainability-oriented science curriculum through the adaptive and continuous improvement strategies.

7.2. Study Limitations

Despite the strength of the scope of this study, there are several limitations that inhibit it. First, it is geographically restricted to Al-Kharj education district, which may not be representative of curricular practices in other regions of Saudi Arabia. Secondly, the research is based only on self-reported information gathered from teachers, which, in its turn, brings the possibility of bias caused by personal subjective judgments and evaluations. The research is limited to quantitative evaluation of five pre-identified sustainability aspects, and possibly it omitted more subtle aspects of the curricular aspects that could have been determined through qualitative approaches.

7.3. Implications for Research and Practice.

The findings also highlight the dire need to change the area of biology education to include the systematic use of the concept of sustainability in cognitive, economic, social, environmental, and technical aspects. The study reveals the unaddressed areas and suggests the improvements, which have an influence on curriculum development, educator education, and school policy. Further research is supposed to use mixed methods, extend geographic scope, and examine the relationship between curriculum content, classroom activities, and student outcomes over time.

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