Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)
ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 07-2024
DOI: 10.5281/zenodo.12793263

HIGH SCHOOL BIOLOGY INSTRUCTIONAL PLANS BASED ON THE 5E INSTRUCTIONAL MODEL: A NEEDS ANALYSIS OF CHINESE HIGH SCHOOL TEACHERS

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Abstract

The 5E instructional model, a student-centred and inquiry-based approach, aligns closely with the competency requirements of the Senior High School Biology Curriculum Standards issued by China in 2017. This needs analysis aims to assess the demand for instructional plans based on the 5E instructional model among high school biology teachers in Henan Province. A 16-item questionnaire was developed and validated through Exploratory Factor Analysis (EFA) to identify three constructs: “Knowledge and Application of Core Literacy in Biology”, “Knowledge and Application of the 5E Instructional Model”, and “Teachers’ Needs towards Instructional Plan”. The validated questionnaire was distributed to 75 high school biology teachers via the online platform, Wenjuanxing. Data analysis revealed that the self-reported average scores for the three constructs were 4.420, 1.883, and 4.252, respectively. These results indicate that while teachers are proficient in core literacy in biology, there is a significant gap in their understanding and application of the 5E instructional model. Moreover, teachers express a strong demand for instructional designs based on the 5E instructional model, highlighting a dire need. This research underscores the importance of customizing 5E instructional plans for Chinese teachers. Such tailored plans not only broaden the pathways for high school biology instruction but also enrich teaching cases, assisting teachers in more effectively implementing concept-based teaching in the classroom.

Keywords: 5E Instructional Model, Instructional Plan, Needs Analysis; Quality Education, Biology.

BACKGROUND OF THE STUDY

The evolution of science and technology has significantly impacted educational practices, emphasizing practical approaches over theoretical knowledge. Modern science education now prioritizes cultivating students' scientific literacy, critical thinking, and problem-solving skills essential for the 21st century. Various organizations like the National Science Teaching Association (NSTA) and the American Association for the Advancement of Science (AAAS) are committed to enhancing science teaching standards. The Next Generation Science Standards (NGSS), developed by a consortium led by the National Research Council (NRC), exemplify this shift towards deeper understanding and application of scientific concepts. The 5E instructional model, a student-centered, inquiry-based approach, aligns well with these evolving educational standards. This model, comprising five phases—Engage, Explore, Explain, Elaborate, and Evaluate—promotes active learning and deeper understanding of scientific concepts. In China, the "General

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Senior High School Biology Curriculum Standards (2017 Edition)" (SHSBCS) reflect a similar shift, focusing on core literacies such as life concepts, scientific thinking, and social responsibility. This study aims to assess the need for instructional plans based on the 5E model among high school biology teachers in Henan Province, China. It explores teachers' understanding and application of the 5E model and their demand for such instructional plans, aiming to enhance biology teaching effectiveness.

LITERATURE REVIEW

Life concept

In January 2018, China's "General High School Curriculum Implementation Plan" integrated "core literacy" into its educational standards, marking a strategic shift towards holistic education that emphasizes skills like analytical thinking alongside knowledge acquisition (The Chinese Ministry of Education, 2017). This was complemented by the "General High School Biology Curriculum Standard (2017)," which focuses on enhancing core literacies across life concepts, scientific thinking, scientific inquiry, and social responsibility. This framework shifts away from rote learning, aiming instead to foster a deep, practical understanding of biology. The curriculum centers on "life concepts" to help students understand biological principles and their real-world applications, supporting the shift to a concept-based instructional approach that promotes knowledge transfer across various contexts. The approach is aligned with Erickson and Lanning's (2013) emphasis on deep conceptual understanding to facilitate lifelong learning and application of science. The significance of integrating core concepts into the curriculum was further emphasized by the publication of "Principles and Big Ideas of Science Education" by Wynne et al. (2015), following a 2009 international seminar. This work, alongside insights from Sinan (2007) and Adnan et al. (2021), advocates for embedding core concepts throughout the curriculum to ensure continuity and retention, enabling students to continuously explore and understand complex topics. Charles (2005) underscores the importance of big ideas in curricular construction and coherence, while Ross and Haas (2010) highlight their necessity for deep exploration and understanding across various topics, proposing that curricula should consist of a cohesive set of concepts that permeate the course and help students maintain continuous understanding.

5E instructional model

In 1989, the American Biological Sciences Curriculum Study (BSCS) introduced the 5E instructional model, which is centered around constructivism and concept change (Bybee et al., 2006). This teaching model comprises five phases: engagement, exploration, explanation, elaboration, and evaluation. Its purpose is to construct students' scientific concepts, aiming to foster active, collaborative, and inquiry-based learning (Joswick & Hulings, 2024). The 5E instructional model aligns very well with the SHSBCS. The 5E instructional model has demonstrated significant effectiveness across various educational levels and subjects, markedly enhancing conceptual understanding in comparison to traditional teaching methods. Studies highlight its success in improving comprehension of physics among secondary and undergraduate students (Bahtaji, 2021;

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Ceran & Salih, 2019) and in advancing biological knowledge for middle and high school students, as well as undergraduate nursing students (Cardak et al., 2008; Feizabadi et al., 2017). The model also significantly benefits pre-service teachers, enhancing their pedagogical skills and conceptual grasp (Büyükdede & Tanel, 2019). These findings confirm the 5E model's efficacy as a potent educational tool that surpasses traditional methods, offering extensive benefits for enhancing conceptual understanding, particularly in the context of science education.

METHODOLOGY

Research Design and Sample

This study employed a cross-sectional survey design, which allows researchers to rapidly acquire current data (Connelly, 2016). Utilizing the widely-used and professional Questionnaire Star platform, this survey aimed to comprehensively understand the perspectives and needs of high school biology teachers in Henan Province, China, regarding instructional plans based on the 5E teaching method. The questionnaire targeted all local high school biology teachers, totaling 75, thus providing a solid statistical basis for reliable analysis.

Instrument

The needs assessment tool utilized was a questionnaire comprising 16 items on a 5-point Likert scale. The first part of the questionnaire included demographic information, enriching the research data and enhancing the practical application of the study to ensure more precise and effective educational interventions (Klare et al., 2012). To overcome the limitations of quantitative research and obtain a more comprehensive dataset, an open-ended question was added at the end of the questionnaire to further collect teachers' specific needs regarding instructional designs based on the 5E teaching method, preparing for subsequent design and development phases.

Initially, 16 statements were formulated to determine the current application of the SHSBCS in biological concepts, teachers' knowledge and application of the 5E instructional model, and their needs for instructional plans based on this method. Subsequently, the questionnaire underwent content validity verification by experts and Exploratory Factor Analysis (EFA) to establish its structural validity, along with a Cronbach's alpha test to measure its reliability. After these preparatory steps, the questionnaire was distributed to 75 high school biology teachers for actual data collection. These steps ensured the validity and reliability of the questionnaire, providing strong data support for the research.

Validity and Reliability

The design framework of the scale is illustrated in Table 1 where the newly designed questionnaire includes demographic information (items 1-4) and 17 other items (items 5-21), comprising 16 five-point Likert scale items and one open-ended question. To ensure that the measured content aligns accurately with the intended content, these 17 questions were distributed via WeChat to six experts from different fields to evaluate each item's

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relevance or representativeness to the associated content dimensions. According to Lynn's (1986) standards for Item-Content Validity Index (I-CVI), when the number of experts is five or fewer, the I-CVI should be 1.00, meaning all experts must agree on the item's high relevance to the conceptual content to consider its content validity as adequate. When there are six or more experts, the standard is relaxed, requiring an I-CVI of no less than 0.78. For instance, if one out of six experts rates an item with a score of 1 or 2, resulting in an I-CVI of 0.83, the item is still deemed acceptable.

The final scores, as shown in Table 2, reveal that all 17 items in the scale have an I-CVI greater than 0.78, and a Kappa statistic (K*) greater than 0.74, indicating excellent content validity for the items. Fourteen items were rated 3 or 4 by all experts, resulting in an S-CVI/UA of 0.82, surpassing the threshold of 0.80, indicating good content validity of the scale (Davis, 1992).

The average of the ICVIs, calculated as S-CVI/Ave, was 0.97, exceeding the recommended value of 0.90 (Waltz, Strickland, & Lenz, 2005). These findings collectively suggest that the scale demonstrates superior content validity.

Table 1: The Design Framework of the Survey Questionnaire

Survey Content	Survey Dimension	Corresponding Items	Number of Items
demographic information questions	Personal and Professional Background	1-4	4
Scale questions	the implementation of the new curriculum standard (pointing to concept teaching)	5-8	4
	knowledge and application of the 5E instructional method	9-12	4
	The necessity of instructional design based on the 5E pedagogy	13-15	3
	Specific Structural Elements Based on the 5E Instructional Model	16-20	5
Open-ended question	Supplement regarding Structural Elements	21	1

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Table 2: Experts ratings and calculation of CVIs

items	Expert Rating										
	A	B	C	D	E	F	Number of experts rated 3 or 4	I-CVI	Pc	K	Evaluation
1	3	4	4	3	4	4	6		0.016	1.00	Excellent
2	4	4	3	3	4	4	6	1.00	16	1.00	Excellent
3	4	4	4	4	3	3	7	1.00	0.016	1.00	Excellent
4	3	4	4	4	3	3	7	1.00	0.016	1.00	Excellent
5	3	3	4	3	4	4	8	1.00	0.016	1.00	Excellent
6	4	3	3	3	3	4	8	1.00	1.016	1.00	Excellent
7	4	2	4	3	3	4	9	0.83	0.094	0.83	Excellent
8	3	3	4	2	3	4	9	1.00	0.016	1.00	Excellent
9	3	4	4	3	3	3	10	1.00	0.016	1.00	Excellent
10	3	4	4	4	4	3	10	1.00	0.016	1.00	Excellent
11	3	4	4	4	3	3	11	1.00	0.016	1.00	Excellent
12	4	4	4	3	2	4	11	0.83	0.094	0.83	Excellent
13	4	3	4	3	3	4	12	1.00	0.016	1.00	Excellent
14	3	4	4	4	4	4	12	1.00	0.016	1.00	Excellent
15	3	3	4	4	3	4	13	1.00	0.016	1.00	Excellent
16	4	3	4	3	4	4	13	1.00	0.016	1.00	Excellent
17	4	3	4	3	3	3	14	1.00	0.016	1.00	Excellent

To assess the factor structure of the 16-item questionnaire, EFA was utilized. Before conducting the EFA, the Kaiser-Meyer-Olkin (KMO) measure was applied to test for sampling adequacy (Kaiser, 1974). The KMO value obtained was 0.925, and the Bartlett's Test of Sphericity showed significant results ($\chi 2 = 6138.847$, $df = 120$, $p < 0.001$), indicating substantial relationships worthy of exploration (Tobias & Carlson, 1969). Three factors were extracted based on the eigenvalues (>1) and the scree plot, explaining 83.373% of the variance cumulatively, highlighting a strong factor solution.

The communalities post-extraction was generally high, indicating that most items shared a substantial common variance with others. The rotated factor matrix demonstrated clearly defined factors, with several items exhibiting strong loadings on a single factor while maintaining minimal cross-loadings. As presented in Table 3, the first four items (items 1, 2, 3, and 4) appear distinctly characterized by their factor loadings, all exceeding 0.76 on Factor 1. These items collectively form a construct that reflects teachers' application of the new curriculum standards, hence, this factor is labeled "Knowledge and Application of Core Literacy in Biology." The second group of items (items 5, 6, 7, and 8) all have factor loadings above 0.898. They form a cohesive group representing teachers' knowledge of the 5E instructional model and its implementation in the classroom. Thus, this second factor is designated as "Knowledge and Application of the 5E Model." Lastly, the third factor is closely associated with eight items (items 11-16), with all loadings on this factor exceeding 0.754. These items measure teachers' needs for instructional plans based on the 5E instructional model. Consequently, this factor is identified as "Teachers' Needs towards Instructional Plan." Accordingly, this 16-item questionnaire is psychometrically supported and suitable for research purposes.

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Table 3: Rotated Factor Matrix

Item	statement	component		
		1	2	3
1	I know the key competency of biology.	0.789		
2	I have my own understanding of the key competency of “life concept” in the curriculum Standard.	0.898		
3	I can list some of the concepts of life listed in the Curriculum.	0.875		
4	I will deliberately teach the formation of students’ life concept in the concrete implementation of teaching.	0.76		
5	I have some knowledge of 5E instructional model.		0.898	
6	I can specifically state the names of the 5 steps in the 5E instructional model.		0.916	
7	I can explain the steps.		0.915	
8	I have used the 5E instructional model in my teaching.		0.93	
9	5E instructional model is a student-centered, inquiry-based pedagogy that encourages active student participation, critical thinking and knowledge construction. In my opinion, the 5E instructional model is in line with the ability requirements of students in the new biology curriculum standard.			0.766
10	I would like to apply the 5E instructional model to the teaching of biology concepts in high school.			0.815
11	I need a instructional plan based on an emphasis on student-centered, inquiry-based pedagogy.			0.754
12	I believe that the teaching objectives should be included in the instructional plan based on the 5E instructional model.			0.924
13	I think the teaching environment should be included in the instructional plan based on the 5E instructional model.			0.923
14	I think the teaching process should be included in the instructional plan based on the 5E instructional model.			0.932
15	I believe that teaching resources should be included in the instructional plan based on the 5E instructional model.			0.925
16	I think the teaching evaluation should be included in the instructional plan based on the 5E instructional model.			0.932

Extraction Method: Principal Axis Factoring.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 5 iterations.

After conducting validity tests, we assessed the reliability of the questionnaire using Cronbach’s alpha coefficient. Cronbach’s alpha measures the internal consistency of items within a scale, reflecting how closely items measure the same underlying concept (Bryman, 2016). Typically, an alpha coefficient exceeding 0.70 indicates high reliability of questionnaire items. Research has shown that sample sizes smaller than 40 may yield unreliable results (Kennedy, 2021), while a sample size of 100 or more significantly enhances the reliability of the measurement tool (Erford, 2013). Therefore, this study selected 277 high school biology teachers from different cities within the same province as the sample, ensuring the reliability and validity of the questionnaire assessment. The needs analysis questionnaire has a Cronbach’s alpha of 0.942, indicating high internal

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consistency, and removing any of the 16 items does not increase this coefficient, suggesting all should be retained.

RESULTS AND DISCUSSION

The analysis shows that high school biology teachers have a strong grasp of core literacy concepts in biology, with an average score of 4.420. Item 2, scoring highest at 4.520, indicates that most teachers have a deep understanding of the core biological literacies outlined in the new curriculum. This aligns with Xu's (2022) findings from Jiangxi Province, where teachers also demonstrated familiarity with the 2019 biology textbook and the 2017 curriculum standards. Teachers can list various life concepts (Item 3, average = 4.36) and are committed to teaching these concepts (Item 4, average = 4.36).

In contrast, teachers' understanding of the 5E instructional model is notably lacking, with an average score of 1.883. They report a poor understanding of the model (Item 5, average = 1.733), its steps (Item 6, average = 1.987), and how to implement these steps (Item 7, average = 1.853). Consequently, the application of the 5E model in teaching is infrequent (Item 8, average = 1.960). These findings are consistent with Liang’s (2022) interviews, where teachers initially unfamiliar with the 5E model acknowledged its effectiveness for inquiry-based teaching after gaining some exposure.

Despite initial unfamiliarity, teachers showed strong support for the 5E instructional model once explained, aligning it with the new curriculum's goals (Item 9, average = 4.227). They expressed a strong need for instructional plans incorporating the 5E model (average = 4.252) and a willingness to use this method in their teaching (Item 10, average = 4.427). They also emphasized the need for student-centered, inquiry-based instructional plans to guide their biology teaching (Item 11, average = 4.360).

This study highlights the necessity for instructional plans tailored to the Chinese educational context, particularly those based on the 5E model. Such plans can bridge the gap between theoretical knowledge and practical application, providing teachers with the tools to implement inquiry-based learning effectively. Improving teacher training is crucial for adopting the 5E model successfully. Providing both theoretical support and practical guidance can help teachers overcome challenges and engage students more effectively in active learning.

High school biology teachers in Henan Province need instructional plans based on the 5E instructional model to meet the new curriculum standards. The 5E model, emphasizing inquiry-based learning, can help students understand biological concepts more deeply, improving their learning outcomes and capabilities. Addressing teachers' familiarity with the 5E model and providing adequate training and support are critical steps towards enhancing biology education in line with the General Senior High School Biology Curriculum Standards (2017 Edition).

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Table 4: Descriptive Result of the Questionnaire Data

Item	statement	Mean	SD
	Construct: Knowledge and Application of Core Literacy in Biology		
1.	I know the key competency of biology.	4.453	0.622
2.	I have my own understanding of the key competency of "life concept" in the curriculum Standard.	4.520	0.623
3.	I can list some of the concepts of life listed in the Curriculum.	4.360	0.607
4.	I will deliberately teach the formation of students' life concept in the concrete implementation of teaching.	4.347	0.780
	Construct: Knowledge and Application of the 5E Model		
5.	I have some knowledge of 5E instructional model.	1.733	0.963
6.	I can specifically state the names of the 5 steps in the 5E instructional model.	1.987	1.072
7.	I can explain the steps.	1.853	1.099
8.	I have used the 5E instructional model in my teaching.	1.960	1.084
	Construct: Teachers' Needs towards Instructional Plan		
9.	5E instructional model is a student-centered, inquiry-based pedagogy that encourages active student participation, critical thinking and knowledge construction. In my opinion, the 5E instructional model is in line with the ability requirements of students in the new biology curriculum standard.	4.227	0.847
10.	I would like to apply the 5E instructional model to the teaching of biology concepts in high school.	4.427	0.791
11.	I need a instructional plan based on an emphasis on student-centered, inquiry-based pedagogy.	4.360	0.747
12.	I believe that the teaching objectives should be included in the instructional plan based on the 5E instructional model.	4.213	0.703
13.	I think the teaching environment should be included in the instructional plan based on the 5E instructional model.	4.160	0.679
14.	I think the teaching process should be included in the instructional plan based on the 5E instructional model.	4.227	0.709
15.	I believe that teaching resources should be included in the instructional plan based on the 5E instructional model.	4.173	0.724
16.	I think the teaching evaluation should be included in the instructional plan based on the 5E instructional model.	4.227	0.709

Table 5: Average Mean by Each Construct

Construct	Average Mean
a) Knowledge and Application of Core Literacy in Biology	4.420
b) Knowledge and Application of the 5E Model	1.883
c) Teachers' Needs towards Instructional Plan	4.252

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CONCLUSION

These data illustrate that while teachers demonstrate proficient understanding and application of core literacy in biology (average = 4.420), there is a significant deficiency in their comprehension and application of the 5E Instructional Model (average = 1.883). Furthermore, implementing instruction based on the 5E model in the classroom proves particularly challenging. Additionally, teachers have expressed a strong personal demand for instructional designs based on the 5E model, as evidenced by the high average value of 4.252 in the construct “Teachers’ Needs towards Instructional Plan.” Consequently, the development of a detailed instructional plan that aligns with this model is urgently needed. In response, the next phase of this research involves developing an instructional design based on the 5E Instructional Model, aimed at assisting high school biology teachers in effectively implementing core biological concepts centered around life sciences in their classrooms. Future efforts will also evaluate the effectiveness of this instructional design in practice, aiming to enhance frontline teaching. Such research not only addresses the needs of teachers but also advances innovation and development in educational practices.

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ISSN: 1671-5497
E-Publication: Online Open Access
Vol: 43 Issue: 07-2024
DOI: 10.5281/zenodo.12793263

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