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Knowledge of Scientific Concepts in Science Books at the Primary Stage and Self-Efficacy in Teaching Science among Student Teachers

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Abstract

The study aims to determine the level of knowledge of scientific concepts included in science books at the primary stage of teachers at Najran University. The study was conducted according to the mixed method (quantitative/qualitative). A cognitive achievement test of the most common concepts in science books for the higher grades of the primary stage, based on the analysis of the content of these books. The test, which had 58 questions, was applied to all student teachers (n=15) enrolled in the science diploma program for the primary stage during 2022. Also, interviews were conducted with a number of these teachers. The Science Teaching Efficacy Belief Instrument Form B (STEBI-B) was utilized. The study concluded that the level of knowledge of scientific concepts among student teachers is low; the average values were less than the standard average. In addition, no statistically significant association was detected between self-efficacy in teaching science and the possession of scientific concepts; however, given the small sample size (n = 15), this result should be interpreted as exploratory rather than definitive. The researchers recommend developing the content of the specialized courses taught by student teachers in the Higher Diploma of Science to fill the gap between the contents of these courses and science curricula in the primary stage.

Keywords: scientific concepts, self-efficacy in teaching science, student teachers, science teacher preparation

1. Introduction

The teaching of science today is witnessing a fundamental development to keep pace with the variables of the times. This development derives originally from the nature of science itself, which requires understanding the content of science and methods of scientific knowledge. Science curricula contain a set of concepts, facts, generalizations, theories, and skills. It, thus, represents a hierarchical image that begins its base with the knowledge and facts collected and classified considering the common characteristics of the formation of what is known as concepts. Then, these concepts meet in relationships to form generalizations, and the total generalizations form theories and laws.

Concepts are one of the main ranks of classification in cognitive construction. They organize the individual's ideas and understanding of the phenomena around him. Therefore, concepts help the individual learn an unlimited amount of the basics of knowledge and define things, phenomena, and accidents. The scientific concept is "what the individual consists of meaning and understanding related to the word (term) or a phrase or process related to science topics" (Zaitoun, 2005, p. 78). Scientific concepts, according to Alwan et al. (2014), indicate general characteristics about the thing to which it belongs. The formation of the concept depends on the previous experiences of the individual, that is, it is a conclusive process, and the concepts represent buildings that grow and seek integration.

Zaitoun (2005) points out that the scientific concept has several characteristics, the most important of which is that it consists of two parts, one of which is the name, symbol, or term, and the other is the verbal meaning of the concept. It includes generalization and can be perceived by senses, and every scientific concept has a set of distinctive characteristics shared by all members of the concept category and distinguishes it from other scientific concepts. It also has other variable or secondary characteristics and is formed through three processes: discrimination, organization and classification, and generalization. The formation and growth of scientific concepts is a continuous process that increases in difficulty from grade to grade and from one educational stage to another as a result of the growth of scientific knowledge itself and the biological and mental maturity of the individual (the student) and the increase in his educational experiences.

Scientific concepts are the most important components of the cognitive aspect in the lives of students and teachers. Through it, a huge number of scientific facts are summarized and linked together. It is also necessary for constructing generalizations, principles, laws, and scientific theories. They are also essential for sound scientific thinking, scientific communication, understanding the environment, and problem-solving. Therefore, the teacher's level of knowledge of scientific concepts represents an important factor in determining what is done in science classes and how it is taught. Until the middle of the last century, the level of a teacher's possession of scientific knowledge was considered a crucial criterion for judging his effectiveness in teaching science (Abed, 2009).

Accordingly, a deep understanding of scientific concepts, which represent the basic structure of scientific content in science curricula, is one of the competencies that a science teacher must possess. The ability to interpret concepts and apply them affects the planning, implementation, and evaluation of science lessons, and thus education is more profound and not just superficial education (Alshehry, 2014). Therefore, many scientific studies have been conducted to reveal the extent of students' understanding of scientific concepts, how to teach and develop them, and correct the wrong ones. Examples of these studies include Omar (2016), Bardawil (2018), and Al-Nashiri and Zidan (2020).

The National Science Teachers Association (NSTA) has developed standards for science teacher preparation that keep pace with the requirements of the times and its continuous developments. These six criteria were content knowledge, pedagogy, learning environments, safety, impact on student learning, and professional knowledge and skills. The first standard (content knowledge) emphasizes that effective teachers must understand and explain scientific knowledge. They should understand scientific and engineering practices and the relationship between them and make connections between key methodological ideas and scientific and engineering practices. They must have the ability to use and apply scientific concepts, principles, laws, and theories, and explain the nature of science and the development of scientific knowledge, in addition to knowledge of common concepts (comprehensive or cross-cutting) between the fields of science in its various branches and technology (Morrell et al., 2019).

In keeping with global developments in the field of preparing science teachers, the Education Evaluation Commission in the Kingdom of Saudi Arabia has developed standards for science teachers that include familiarity with what science is, teaching science, and scientific knowledge of biology, chemistry, physics, and earth and space science. It has also developed (12) professional standards. Common to all teachers in their different specializations, these standards include the areas of professional knowledge, learning promotion, learning support, and professional responsibility (National Center for Measurement, 2017; Education and Training Evaluation Commission, 2018). Hence, this study seeks to reveal the extent of knowledge of teachers who enrolled in the science teacher program for the primary stage about the scientific concepts in the science curriculum. It also revealed the nature of the relationship that links self-efficacy and mastery of scientific concepts to reach results that can be built upon in improving science education and its basic aspects. The study attempted to answer the following questions:

1. What scientific concepts are included in science books at the primary level in the Kingdom of Saudi Arabia?

2. What is the degree of knowledge of scientific concepts in science books at the primary level among student teachers at Najran University?

3. Is there a statistically significant correlation between self-efficacy in teaching science and knowledge of scientific concepts among student teachers at Najran University?

4. What are the impressions of the study sample about their knowledge of scientific concepts and the role of the higher diploma in qualifying them to teach science at the primary level?

2. Related Studies

Success and excellence in teaching science require that the teacher possess knowledge, skills, and attitudes related to the nature of science and its methods and the ability to comprehend and understand the world surrounding him. Therefore, the science teacher's mastery of scientific knowledge, the content he teaches, and his ability to create the educational environment are essential factors for the success of science education. All learners, regardless of their culture, gender, and social and economic status, can learn and understand science if they are provided with the appropriate learning environment. Accordingly, the success of science education at all educational levels is related to science teachers' competence (Menon & Sadler, 2016; Saka et al., 2015). Many studies, such as Wenner and Stevens (1996) and Wenner (1993), have confirmed that two main factors affect science education: the level of teachers' understanding of scientific concepts and their beliefs related to their effectiveness in teaching science. Smolleck et al. (2006) and Bencze and Upton (2006) also concluded that science teachers at the primary level; nevertheless, are prepared to teach all subjects, often do not feel comfortable teaching science and do not prefer to teach it. The reason may be attributed to their lack of sufficient scientific knowledge in science (Aschbacher & Roth, 2002; Koc, 2006; Sarikaya, 2004).

Given the importance of a teacher's familiarity with scientific concepts, many researchers have addressed the assessment of pre-service science teachers' mastery of scientific knowledge in general and scientific concepts in particular. Some also addressed the relationship between possessing scientific concepts and self-efficacy in teaching science. Menon and Sadler (2016) and Bleicher and Lindgren (2005) confirmed a positive relationship between self-efficacy and knowledge of scientific concepts. Studies have found an association between confidence in the ability to teach science (PSTE) and understanding scientific concepts and an impact on academic experience at the secondary level. Abed's (2009) study showed positive beliefs about self-efficacy in teaching science among classroom teachers at medium and high degrees, while the level of knowledge of scientific concepts was low. There was also a positive correlation between the knowledge of scientific concepts and confidence in the ability to teach science, and there was no correlation between the knowledge of scientific concepts and the impact on science education outcomes. Amr (2012) found that the level of self-efficacy among science teachers in the lower primary stage was average, while their level of understanding of the nature of science was high. Also, there was a significant positive relationship between the averages of science teachers' self-efficacy and their understanding of the nature of science. Tekkayya et al. (2004) investigated the understanding of scientific concepts and their relationship to the confidence of pre-service science teachers in their ability to teach them. The results showed misconceptions and a low level of knowledge of scientific concepts. However, the majority of the respondents showed self-confidence and expressed their optimism in the ability to teach science. Jale and Boone (2002), Sarikaya (2004), and Koc (2006) found that the level of pre-service primary school teachers' understanding of scientific concepts was low, and they had many misconceptions. Al-Madawi (2010) revealed a noticeable weakness in the knowledge of chemical concepts among pre-service chemistry teachers. Moreover, Abdullah (2013) indicated that the level of performance of student teachers at the College of Education in scores on an achievement test dealing with scientific content was less than average (60%) of the total test score. Abdel-Al (2020) showed that pre-service science teachers did not reach the specified level of mastery (80%) concerning the cognitive content of science books prescribed to primary education students. Safhi and Azzam (2018) revealed the low level of pre-service visually impaired teachers' mastery of the scientific concepts included in the science curricula for the primary stage. Al-Shehri's (2021) study showed the weak level of student teachers in mastering the scientific concepts in the content of the science curriculum at the primary stage.

Stevens and Wenner (1996) and Bleicher and Lindgren (2005) are among the studies that addressed the impact of academic background on the possession of scientific concepts among science teachers. Studies have found that going through academic experiences in science (high school and university studies) does not necessarily mean that students understand scientific concepts correctly, have positive attitudes toward teaching science, or have confidence in their ability to teach science well. It has also not been proven that there is a correlation between the number and nature of misconceptions among primary school teachers and the number of scientific courses they have previously studied in the secondary stage or university education. (Koc, 2006; Jale & Boone, 2002).

By reviewing these studies, researchers are interested in measuring the level of science teachers' knowledge before or during the service of scientific concepts. It also appears that there is no study, to the best of the researcher's knowledge, which aimed to evaluate the level of knowledge of scientific concepts included in the content of the science curriculum at the primary stage among a sample like the sample of the current study. All studies were applied to teachers or student teachers who obtained academic preparation in one of the fields of natural sciences, while this study was applied to teachers with different specializations who were qualified to teach science, and this confirms the specificity of this study and the importance of conducting it.

3. Methods

Qualitative analysis was used in this research, following a case study design. As described by Creswell and Poth (2019, p. 113). It is "a qualitative research method in which the researcher explores a contemporary, real-world system of one or more cases over a specific period by collecting detailed and in-depth data from multiple sources...and provides a description of the case and its underlying concept, with the unit of analysis being one or more cases". The qualitative data were coded using a standardized list of the study participants, including their data and responses. Each participant was identified by their initial and last name (e.g., Y, F). To ensure the greatest possible agreement among the researchers, the instruments were developed, the data collected, and the results recorded collaboratively and with mutual understanding, using a scale agreed upon by both researchers.

3.1 Population and Sample of the Study

The study population consisted of two categories: textbooks and teachers. In terms of books, the study population consisted of science books for the six primary school grades, numbering (12) books. Each book consists of two parts for grades one to six of primary school, and each semester has one book. In this study, the sample was limited to the books of the fourth, fifth, and sixth grades in the primary stage. Each book has two parts, including six books as these books contain the most important scientific concepts necessary for primary school students. The study population consisted of all teachers enrolled in the Higher Diploma in Science program at Najran University during the academic year 2022/ 2023.

Due to the limited number and accessibility to all of them, the inclusive method was used in selecting the study sample, i.e., the study was applied to all student teachers in the program. Table 1 shows the characteristics of the study sample.

Table 1. Distribution of study sample members according to categorical variables

Variable	Group	No.	%
Secondary stream	Scientific	4	26.7
	Literary	11	73.3
School stage	Primary	5	33.3
	Intermediate & secondary	10	66.7
Specialization	Islamic studies	6	40
	Arabic studies	8	53.3
	Social studies	1	6.7
Years of experience	-5 years	6	40.0
	+ 5 years	9	60.0
Total		15	100

Table 1 shows that most sample members work in post-primary schools (middle and high school). Sixty percent have more than five years of teaching experience. Teachers with a scientific background (graduates of the scientific track in high school) constitute 26.7% of the sample. The Arabic language major constitutes the highest percentage of the sample (53.3%), while the social studies major constitutes the smallest percentage (6.7%). Specialists in Islamic studies represent 40% of the sample.

3.2 Tools of the Study

3.2.1 Content Analysis Card

A card was designed to analyze the content of science books in the upper grades of primary school. The scientific concepts have been listed and classified according to the scientific fields to which they belong to create a list of the scientific concepts most frequently mentioned in these books to be the subject of achievement test questions according to the following specifications:

-The goal of the analysis process: The analysis process aimed to identify the most important scientific concepts included in the content of science curricula at the primary stage to rely on them when preparing the scientific concepts test.

-Unit of analysis: the topic was used as a unit to analyze the content of science curricula.

-Analysis sample: The analysis process included six science books in the fourth, fifth, and sixth grades of primary school, two books for each grade.

-Analysis category: represented by the word or sentence that expresses one of the scientific concepts.

-Reliability of the analysis: to ensure the reliability of the analysis card, the analysis was repeated after an interval of (14) days from the first analysis. The reliability coefficient using Holisti's equation was (0.98) (Ta'ima, 2004). The results were also compared with another analysis conducted by a science teacher on the same books at the same time. The reliability of the analysis process was verified by calculating the reliability coefficient between the analysis of one of the researchers and the science teacher using Holisti's equation. The reliability coefficient reached (0.94). These results confirm the reliability of both the analysis card and the analysis process and give confidence in its results.

3.2.2 Scientific Concepts Test

To measure the level of knowledge of scientific concepts included in the content of the science curriculum for the primary stage among student teachers (students in the science diploma program), the researchers prepared a cognitive achievement test. It included the most frequently mentioned concepts in science books for the upper grades of the primary stage in light of the result of analyzing the content of these books. Accordingly, the content of the achievement test for scientific concepts included in science textbooks at the primary level in the Kingdom of Saudi Arabia was determined. The test in its initial version consisted of 62 questions. It included Bloom's six levels of knowledge according to a table of test specifications that links the test's cognitive levels with the main scientific concepts included in the science curricula for the primary stage, classified into the four basic natural science fields (chemistry, biology, physics, earth, and space). The test items were formulated in the form of multiple-choice questions. Each question consisted of an introduction to the question, followed by four answers, only one of which was correct. The test materials were also prepared and consisted of a question booklet, a separate answer sheet, and a correction key. Each correct answer was assigned one point, while an incorrect or abandoned answer, or if more than one answer was chosen, was scored as zero. To ensure the face validity of the test, the test was presented in its initial form to eight specialists. They expressed their opinions on the suitability of the test to measure what it was prepared to measure in terms of the clarity of the test questions its suitability in terms of the connection of the questions with the subject of the test and its freedom from linguistic and scientific errors. Each question was based on the concept it addresses, the cognitive level in light of Bloom's taxonomy, the accuracy of the scientific and linguistic formulation of the questions, the clarity of the test instructions, and the suitability of the test for its purpose. Considering the experts' opinions, some modifications were made to the wording of some of the test items. Therefore, the test became valid for application to members of the exploratory sample. Then, a pilot study of the test was conducted on a survey sample consisting of 20 teachers outside the study sample. It appeared that all questions were appropriate, except for four of them because they were not clear enough, so they were excluded, and the final form of the test consisted of 58 questions. To verify the construct validity (internal consistency), the Pearson correlation coefficient was used to measure the relationship between the score of each question and the total score of the test. The results showed that the correlation coefficient values were statistically significant at the significance level (0.01) or (0.05). The correlation coefficients ranged between (0.471* - 0.789**). This result confirms that the test has an appropriate degree of validity. The researchers also verified the validity of the test by applying the test to the exploratory sample and calculating the values of the test reliability coefficient on the total score of the test using the Richardson coder 20. It was shown that the reliability coefficient reached (0.89), a high and appropriate value. By calculating the difficulty coefficient values for the test items, they ranged between (0.50-0.80). According to Odeh (2005), any item whose difficulty coefficient ranges between (0.20 - 0.80) is considered acceptable and thus kept in the test. Therefore, all questions were appropriate in terms of difficulty. By calculating the values of the discrimination coefficients for the test items, it was found that they ranged between (0.30-0.80). According to Odeh (2005), any item whose discrimination coefficient ranges between (0.20) and above is considered acceptable and thus kept. Therefore, all questions were appropriate in terms of the ability to discriminate. The average time taken by the survey sample members to answer all test items was approximately (60) minutes, in addition to (5) minutes to read the instructions. The time required to apply the test is (65) minutes. The level of proficiency for the student teachers' performance on the test was set at (80%), which is equivalent to (46.4) points out of the total test score of (58) points, based on consultation with some specialists in measurement and evaluation and reference to similar studies (Abdel-Al, 2020; Al-Shehri, 2021; Safhi & Azzam, 2018). Considering the above, the test in its final version is ready to be applied to the main study sample.

3.2.3 Personal Interview Card

To explain the results reached by applying the achievement test for scientific concepts and to obtain information that is not available through the test, interviews were conducted with the students according to a card prepared for that purpose. It is worth noting that the approval of the Scientific Research Ethics Committee at Najran University was obtained for the study tools before starting to apply them to the study sample.

3.2.4 Self-efficacy Scale for Teaching Science

To determine beliefs related to the ability to teach science, the Science Teaching Efficacy Belief Instrument Form B (STEBI-B), built on Bandura's view of self-efficacy was used. This scale was originally re-evaluated by Bleicher (2004). This scale has been used to evaluate the self-efficacy of pre-service teachers in many studies, such as Bleicher and Lindgren (2005), Palmer (2006), and Yilmaz and Cavas (2008). Among the Arab studies that used this measure were El-Deghaidy (2006), Hassouna (2009), and Abed (2009). The scale consisted of (23) statements distributed along two domains. The first domain deals with teachers' beliefs about the ability to carry out the required teaching behavior (PSTE) Personal Efficacy Teaching Science and includes (13) statements that measure pre-service teachers' confidence in their ability to teach science. The second domain deals with the expectation of a positive impact on learning outcomes, Science Teaching Outcome Expectancy (STOE) and includes (10) statements that measure these teachers' belief in the usefulness of their teaching of science and its positive impact on their students.

When the STEBI-B scale was developed by Larry et al. (1990), its validity and reliability were established. The alpha value for the first domain was 0.90, and for the second domain, 0.76. The scale was also applied in several studies, such as Sarikaya (2004), in which the alpha value for the first domain was 0.86 and for the second, 0.79, and Bleicher and Lindgren (2005), in which the alpha value for the first domain was 0.84 and for the second, 0.76 (Abed, 2009). The scale was standardized in Arabic-speaking contexts (El-Deghaidy, 2006; Hassouna, 2009; Abed, 2009). The modifications to the statements were minor, and the translations did not differ significantly. Reliability values were satisfactory in all these studies. For example, in Abed's (2009) study, the reliability coefficient for the overall scale was (0.86), the first domain was 0.82), and the second domain was (0.73).

To standardize the scale within the local context, the researchers adapted the Arabic translation of the scale used in the aforementioned studies to suit the study context. The proposed version was then presented to nine experienced faculty members specializing in science education, teacher training, and educational measurement. They confirmed the scale's suitability for the Saudi community, the study sample, and subject matter, suggesting minor modifications that were incorporated. After that, the scale was administered to a pilot sample of 20 science teachers who were not part of the study sample. Internal consistency was calculated using Pearson's correlation coefficient between the items and the total score for their respective domain, as well as between the items, the domain, and the total instrument score after inverting the negative items. These coefficients were found to be statistically significant at the 0.01 level. Pearson's correlation coefficients ranged from 0.990** to 0.995**, all of which were significant at the 0.01 level. (0.01).

Reliability coefficients were calculated for the domains of the Science Teaching Self-Efficacy Scale and the total scale score after inverting the negative items using Cronbach's alpha. The total scale score was (0.93). The reliability coefficients were (0.89) for the first domain and (0.91) for the second axis. These are high reliability coefficients suitable for the purposes of this study.

All statements were answered using a five-point scale: Strongly Agree, Agree, Unsure, Disagree, and Strongly Disagree. Positive statements were assigned values of 5, 4, 3, 2, and 1, respectively, while negative statements were assigned the opposite values. The scale was scored as follows: 1-1.8 = Very Weak, 1.81-2.6 = Weak, 2.61-3.4 = Moderate, 3.41-4.2 = High, & 4.21-5 = Very High.

It is worth noting that the recruitment period started on February 18, 2023, and ended on May 15, 2023. Before the study was applied to the study subjects, an approval of the Scientific Research Ethics Committee at Najran University (444-45-44416-DS) was obtained for the study tools on February 12, 2023. A written consent was also obtained from the study sample members to participate in the study.

4. Results

4.1 Scientific Concepts Included in Science Books at the Primary Level

To identify the scientific concepts in science books for the upper grades of primary school, the researchers prepared a content analysis card according to the scientific steps necessary to achieve the validity and reliability of the card. Table 2 shows the number and percentage of scientific concepts in science textbooks for the last three grades of primary school according to the basic fields of natural sciences.

Table 2. Distribution of scientific concepts according to the fields of natural sciences

	Biological concepts		Chemical concepts		Physical concepts		Earth and space concepts			
Grade	No.	%	No.	%	No.	%	No.	%	Total	%
Fourth grade	45	%38	13	%11.1	37	%31.4	23	%19.5	118	%28.23
Fifth grade	56	%32	21	%12	42	%24	56	%32	175	%41.87
Sixth grade	49	%40	23	%18.5	27	%21.5	26	%20	125	%29.9
Total	150	%36	57	%14	106	%25	105	%25	418	%100

Table 2 shows that biology had the largest share in terms of its inclusion in science textbooks in the last three grades of secondary school, at a rate of (36%). Physics and Earth science came in second place (25%), while chemistry came in fourth place (14%).

4.2 The Degree of Knowledge of Scientific Concepts Included in Science Books at the Primary Stage

Table 3 shows that the total score for the level of student teachers' knowledge of scientific concepts according to Bloom's cognitive levels came with a mean of (22.73) and a standard deviation of (5.738). Compared to the total score (58), it is found that it did not reach the adequacy limit estimated at (46.4), which is equal to (80%). The percentage reached (39.19%), and this result confirms statistically significant differences between these means and the hypothesized means in the four areas of the test and the test of scientific concepts. These differences were in favor of the hypothetical means with higher values.

Table 3. The degree of knowledge of scientific concepts among the study sample according to cognitive levels

No.	Cognitive level	total score	Hypothesized mean	Means	Standard deviations	t	Sig.
1	Remembering	10	8	4.60	1.352	9.738-	.000
2	Understanding	11	8.8	4.27	1.100	15.965-	.000
3	Applying	7	5.6	3.07	.884	11.103-	.000
4	Analyzing	10	8	3.93	1.280	12.306-	.000
5	Creating	10	8	3.47	.990	17.727-	.000
6	Evaluating	10	8	3.20	1.146	16.216-	.000
7	Total score	58	46.4	22.73	5.738	15.975-	.000

4.3 The Correlation between Self-efficacy in Teaching Science and Knowledge of Scientific Concepts among Student Teachers

The Self-Efficacy in Teaching Science Scale (STEBI-B) was applied, and the results showed that the teachers in the study sample estimated their level of self-efficacy in teaching science to a "high" degree, with a mean of (3.99) (Annex 1). Then, the Pearson correlation coefficient was calculated between the level of self-efficacy in teaching science and the degree of knowledge of scientific concepts. Table 4 shows no correlation between self-efficacy in teaching science and possession of scientific concepts ($r = -.023$, $p = .936$). However, this result should be regarded cautiously due to the small sample size (n = 15). The finding indicates that no discernible correlation was found in this sample, but it does not offer enough proof to support the lack of a relationship.

Table 4. Self-efficacy in teaching science and knowledge of scientific concepts

Correlation		Possession of scientific concepts
Self-efficacy	Pearson	-.023-
	Sig.	.936
	No.	15

4.4 Participants' Impressions about Knowledge of Scientific Concepts and the Role of the Higher Diploma in Qualifying them to Teach Science

The results of the interview that was prepared in light of the results of applying the scientific concepts test are presented and supported with students' responses:

1) After you graduate from the program, how do you describe its benefit in qualifying you to teach science as a new specialty for you?

The answers were mixed; One described her benefit from the program as "it was wonderful and knowledgeable about all the topics of the specialty." Others described it as "good", "awesome, excellent" and "useful". One of them stated "the benefit is great, and I believe that this study, with good preparation for the subject, will make it easier for me and for the teachers who specialize in this field," while a student stated that he "did not benefit from the program fully."

4) Through your academic study of specialized science courses, describe the extent to which your understanding of scientific phenomena and concepts has changed, and cite examples of concepts that you had wrong. One student mentioned, "Before specializing in the program, I undoubtedly had some misconceptions about some scientific concepts, as I was not specialized in this field, and of course the program helped us correct that, whether through lectures or in the laboratory, and examples of this include the concepts of speed, acceleration, force, and motion." And others." Another said, "I improved a lot and learned a lot of phenomena and concepts." A third stated, "Most of the concepts I took in the diploma were new and I had not studied them before," and another added, "Through my study of science, many concepts and phenomena were studied, such as the universe, objects, and earthquakes." Another described, "The change was in some concepts, especially in biology, earth science, and space... and I had wrong concepts, but after studying and benefiting from this program, many of my concepts changed."

5) When a teacher expresses high confidence in his ability to teach a course while his level of achieving the scientific concepts contained in this course is low, how do you explain that?

One of the students explained this by saying, "The teacher here may be under the illusion that achieving scientific concepts in the course is not that important for achieving educational goals." Another supported him by saying, "Maybe he thinks it's unnecessary." Another described this as "a mistake and he must develop himself further." Some responses came in the form of suggestions, such as enrolling in additional courses to raise their level. Another explained, "Maybe this teacher did not take advantage of the time and take enough of the material or the program in general, but if the teacher compensates for that by preparing and researching well for each lesson, he will be able to deliver the information to the learner well," while one of the students responded, "It is wrong to teach a subject in which he is not specialized."

6) How capable are you now, after graduating from the program, of teaching science at the primary level?

One of the students answered: "After looking at the primary stage topics in science, and what was studied in the program, I will be able to teach the subject, especially since the program topics were intensive and specific with regard to the primary stage and more." Others said that after the program they were able to teach science, while one student stated that he "could without needing a diploma." Another described his ability as "good," while another defined it as "medium to high."

7) Do you think that a teacher's confidence in his ability to teach a subject necessarily means expecting high learning outcomes among his students?

One of the students mentioned, "The teacher is one of the elements in the school that helps students achieve high learning outcomes. There is the curriculum and the school environment, so the teacher's confidence in his ability to teach a subject is part of other parts that help raise the learning outcomes of students." Others answered, "Yes," and one of them said, "A large percentage of no," while a student answered, "Maybe...but the teacher must take into account the condition of the learners and the appropriate teaching method in order to raise their level."

8) If you were given a choice now that you have graduated from the program between teaching science or teaching the subject of your main specialty, which would you choose? And why?

The teachers agreed unanimously in their preference for teaching their main specialty, and they justified this by saying that they had previous experience for several years. One of them welcomed teaching science alongside his specialty subject if the school needed it.

9) In your opinion, what is the impact of the course of study in the secondary stage (scientific/literary), the years of experience, and the educational stage in which the diploma-graduate teacher works on his ability to teach science in the primary stage?

One student answered, “Years of experience may have an effect, and as for the course of study in secondary school, it may not constitute an effect because most of the subjects related to the secondary stage in chemistry, physics, and biology were studied in the program.” Another believed that “the science diploma is supposed to be for scientific specializations only,” while others believed that years of experience and course of study at the secondary level do not have an impact or that their impact is limited.

5. Discussion

The results of identifying scientific concepts included in science books for the upper grades of primary school showed that topics related to biology are the most frequently included in science books in the last three grades of primary school (36%), followed by topics related to physics, earth science, and space science (25%). Chemistry came in fourth place (14%). It is noted that the scientific content in science books at the primary stage focuses largely on aspects related to human life and living creatures (biology) because it is one of the topics most closely related to the life of a primary school student, the most closely related to his interests, and the easiest to understand for this age group. Topics related to physics and earth and space came second, while chemistry concepts came last in terms of availability. This result may be due to the difficulty of understanding it for primary school students.

The results also showed by applying the cognitive test of scientific concepts included in the primary school curriculum that the overall score of the student teachers in the study sample was low. When comparing this score to the total score (58), it reached the equivalent of (39.19%). This result means that it did not reach the score that was adopted in the study as a minimum level of adequacy, which is (46.4), which is equal to (80%). This result confirms statistically significant differences between these means and the hypothesized means in the four areas of the test and the test of scientific concepts. These differences are in favor of the hypothetical means with higher values. By comparing the six levels of the cognitive field, it was found that the highest scores were in the levels of remembering and understanding. This result is consistent with those results in Koc (2006), Sarikaya (2004), Aschbacher and Roth (2002), Tekkayya et al. (2004), Al-Madawi (2010), Abed (2009), Abdullah (2013), Safhi and Azzam (2018), Abdel-Al (2020), and Al-Shehri (2021). The level of achievement of scientific concepts among student teachers was low in all these studies. This result can be explained by the weak level of the student teachers in the study sample in testing scientific concepts. The result is due to the following reasons:

1- There is a large gap between teachers’ academic and practical experiences and the scientific concepts included in the content of science curricula at the primary stage. Not all members of the sample did study or teach science.

2- The qualification period to practice the science teaching process. The duration of the program is two semesters, which is not sufficient to provide the student teacher with enough scientific knowledge, especially the scientific concepts included in science textbooks at the primary level.

3- Student teachers do not devote themselves to studying. They teach in the morning and then receive lectures in the rehabilitation program in the evening, which may negatively affect their achievement.

4- The field of work is not compatible with the field of evening study in terms of scientific content. Teachers teach their students Islamic education, Arabic language, or social studies courses in their schools, then they move to the university to teach courses in the fields of natural sciences, their curricula, and teaching methods.

5- There are many misconceptions among these teachers, which is not surprising. Studies have confirmed these misconceptions among science specialists, so what about those who do not specialize in this field?

6-Inappropriate teaching methods used in teaching specialized courses in the College of Science. The teaching process is dominated by the traditional method, which does not allow the student to apply, analyze, and evaluate scientific knowledge.

7- Weak scientific activities and evaluation methods used to evaluate students’ learning, which focus on memorization and memorization may contribute to forgetting many scientific concepts shortly after completing their studies.

Moreover, no statistically significant association was detected between self-efficacy in teaching science and the possession of scientific concepts; however, given the small sample size (n = 15), this result should be interpreted as exploratory rather than definitive. The result of this study differs from those of Menon and Sadler (2016) and Bleicher and Lindgren (2005), who found a positive relationship between self-efficacy and knowledge of scientific concepts. The result between the level of self-efficacy and the level of knowledge of scientific concepts is consistent with the findings of Tekkayya et al. (2004), Bleicher and Lindgren (2005), and Abed (2009). The sample members showed a high level of self-efficacy in teaching science, while their level of knowledge of scientific concepts was low. Also, this result is in line with the findings of several studies that, although primary school science teachers are prepared to teach all subjects, they often do not feel comfortable teaching science and do not prefer to teach it, due to their lack of sufficient scientific knowledge in science (Bencze & Upton, 2006; Koc, 2006; Sarikaya, 2004; Aschbacher & Roth, 2002). How about teachers who did not receive intensive preparation (as was the case with the study sample); they are likely to have less self-efficacy in teaching the sciences. These teachers' positive beliefs about their self-efficacy in teaching science, along with their low level of knowledge of scientific concepts can be interpreted as an indication of the presence of many misconceptions among them. They think they know scientific concepts, but they do not know them scientifically correctly.

Furthermore, student teachers expressed their impressions of the program they enrolled in to rehabilitate them to be able to teach science at the primary level. They talked about many aspects related to self-efficacy in teaching science, as well as knowledge of scientific concepts and their development. From the interviews conducted with some teachers, several results have been extracted. Most of the teachers in the study sample believe in their ability to teach science at the primary level, despite their weak knowledge of the scientific concepts contained in science books at the primary stage, as shown by the test results. Teachers have a clear deficiency in estimating their self-efficacy in teaching science, as they link it to the experiences they have in teaching in general. They do not give scientific knowledge the importance it deserves in understanding and teaching science. Although the qualification period for these teachers to teach science is short, some of them find it sufficient to begin practicing their new duties as science teachers if necessary. If given the choice, most of them will still prefer to teach the subjects of their original specialty because of the confidence they have gained because of experience and practice. Teachers lack self-motivation and a real inclination towards science and its teaching. None of them would have wanted to change their teaching career path had it not been for the incentives that accompanied the program aimed at rehabilitating them, the most important of which was increasing the opportunity for the program graduate to move to his area.

6. Conclusion

This study has addressed very important components related to science teaching. Scientific concepts are the most important forms of scientific knowledge and the starting point for achieving scientific theories. On the other hand, the teacher’s role in imparting it to students is linked to the knowledge he has about science topics, especially scientific concepts, as well as his beliefs about his self-efficacy in teaching science. This concept, “self-efficacy in teaching,” has its philosophical origins in the social learning theory developed by the Canadian scientist Albert Bandura. The qualification period (two semesters) allocated to enable the teacher to teach science after years of university study and teaching practice in subjects in specializations other than the natural sciences was short, and the level of performance of these teachers in testing the scientific concepts included in science textbooks at the primary stage was low. However, the results of applying a standardized measure of self-efficacy in teaching science showed a high degree of confidence among the teachers in the study sample in their ability to teach science at the primary level.

The results of the interviews with teachers were consistent with the principles of Bandura’s theory and emphasized the necessity of paying attention to the emotional aspects of the teacher. Teachers expressed a weak desire to switch to teaching science, based on their previous experience in teaching other subjects and the knowledge and skills they acquired during their studies in the Higher Diploma in Science program.

Based on the results of the study and the theoretical framework and previous studies, the researchers recommended developing the content of the specialized courses in their various branches taught by student teachers in the Higher Diploma of Science to bridge the gap between the content of these courses and the content of the science curricula at the primary stage. Also, there is a need to review the methods of teaching specialized courses and their evaluation methods and work to develop them so that they move away from memorization and rote learning and focus on the learner’s activity to achieve the acquisition and retention of scientific concepts. In addition, a comprehensive review of the Higher Diploma in Science program must be conducted so that its study plan includes more time and specialized courses. This ensures that students are empowered with the scientific concepts necessary to teach science at the primary level.

Moreover, the level of readiness to teach science and measuring confidence in the ability to teach science should be detected among those wishing to join science teacher preparation programs or programs to qualify non-specialists to teach science. They are essential in predicting self-efficacy for teaching science and the ability to acquire scientific concepts. Furthermore, those holding a science diploma are to be enrolled in more training programs to cover the cognitive and educational aspects that graduates of the program did not acquire as required to raise their efficacy in teaching science. Finally, science teacher preparation programs include educational courses or activities aimed at enhancing self-efficacy for teaching science among pre-service teachers.

The application and generalizability of the findings of the current research are limited by the following:

1- Small sample size: The research sample consisted of students enrolled in a specialized training program to enable them to teach science. They are a specific group within the regional education administration, and the instruments were administered to all 15 male students. The researchers did not exclude any individuals or specify a particular gender. This sample size may be suitable for a case study approach like the current research. However, it may result in weak statistical significance for Pearson's test. Therefore, the results in Table 4 are exploratory rather than confirmatory, which necessitates refraining from drawing strong conclusions regarding the null hypothesis based on this limited sample size.

2- Restriction to a single institution: The College of Education at Najran University is the only educational institution in the Najran region tasked with implementing the aforementioned training program.

3. Purposive sampling: Given the research objectives and topic, spatial, and temporal limitations, the study was limited to the aforementioned group and employed purposive (targeted) sampling rather than random selection.

4. Potential bias: In self-report surveys, individuals may exhibit self-bias when responding to a measure of their self-efficacy in teaching. However, the procedures implemented to construct the measure and verify its validity and reliability should minimize this potential bias to an acceptable level.

In continuation of what this study addressed, the researchers proposed to conduct studies on the effectiveness of a proposed program in general sciences to develop the scientific concepts included in science curricula for the primary stage among teachers who have graduated with a higher diploma in science. There is also a need to explore the level of in-service science teachers' mastery of the scientific concepts included in the content of science curricula for the primary stage. Finally, a study is suggested to examine changes in the acquisition of scientific concepts, self-efficacy in teaching science, and teaching performance among science teachers who graduated from the in-service Higher Diploma in Science program.

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Author contributions

YAF was responsible for conceptualization, methodology, formal analysis, investigation, data curation, writing — original draft, writing —review & editing, visualization, project administration. AAA was responsible for conceptualization, methodology, formal analysis, investigation, data curation, writing — original draft, writing — review & editing, visualization, project administration. All authors have read and agreed to the published version of the manuscript.

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Obtained.

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The Publication Ethics Committee of the Redfame Publishing.

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No additional data are available.

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Annex 1. Means and standard deviations of the level of self-efficacy in teaching science

No.	Domain	Mean	Standard deviation	Degree
1	PSTE	4.12	0.427	Very High
2	STOE	3.81	0.560	High
Total score		3.99	0.407	High