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Development of a scientific knowledge-skills-attitude (KSA) diagnostic test for class seven students of Rangjung Central School

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Abstract

While Bhutan's National Science Curriculum emphasizes the development of scientific inquiry and STEM-related competencies, a significant gap remains in assessing student readiness during the transition from primary to secondary education. Much of the existing diagnostic literature focuses primarily on conceptual misconceptions within the cognitive domain, often overlooking the procedural skills and scientific attitudes essential for effective scientific practice. This study addresses this gap by developing a scientific knowledge-skills-attitude (KSA) diagnostic test for class six students to assess their readiness for learning science in class seven. Using a descriptive quantitative approach, a diagnostic test was developed to identify specific deficiencies that may contribute to learning regression during the critical transition from class six to class seven. The findings indicate that although students demonstrate a basic level of conceptual understanding, they show limited proficiency in scientific inquiry skills and display varying attitudes toward scientific engagement. The results of this diagnostic test highlight the need to shift teaching strategies from rote content delivery toward a more holistic, inquiry-based approach to science education. Ultimately, the study argues that comprehensive diagnostic assessment is essential for bridging educational gaps and ensuring that curriculum goals translate into meaningful student competence.

Key words: scientific knowledge-skills-attitude, diagnostic test, class seven students, descriptive quantitative research

Introduction

According to the rationale of the National Science Curriculum Framework (NSCF) of Bhutan, students who complete science education from Pre-Primary (PP) to class 12 are expected to "use and apply scientific knowledge and skills to explain physical and natural phenomena, design and conduct scientific inquiry, and analyze, interpret, and relate scientific data to appropriate contexts" (Department of Curriculum and Professional Development (DCPD), 2022, p. 2). Furthermore, the main goal of the curriculum is to "develop and apply the skills of scientific inquiry in understanding how scientists work and how scientific knowledge is constructed and accepted by the scientific community" (DCPD, 2022, p. 3). These statements emphasize the importance of not only understanding science but also practicing it as scientists do, which requires the necessary skills and attitudes to solve real-world problems within the community. In addition, the curriculum highlights the significance of STEM education in fostering critical thinking, innovation, and problem-solving skills.

How do we determine whether students possess the necessary scientific knowledge-skills-attitudes (KSA) to understand how scientists work? One possible way to assess this is through diagnostic tests. Diagnostic tests play a crucial role in identifying students' prerequisite knowledge and competencies. However, much of the existing literature focuses narrowly on conceptual misconceptions within the cognitive domain. For example, instruments such as the Thermodynamic Diagnostic Test (TDT) (Kamcharean & Wattanakasiwich, 2016), and specialized quantum mechanics questionnaires (Uccio et al., 2019) primarily assess conceptual understanding while often overlooking the affective and procedural domains.

Even the Force Concept Inventory (FCI) (Hestenes et al., 1992), an instrument designed to measure common-sense beliefs of high school and university students receiving introductory physics instruction, focuses primarily on students' misconceptions in Newtonian Mechanics. Stoen et al. (2020) note that the FCI can identify students' understanding of physics concepts and may also provide insights into their 'expert-like attitudes and problem-solving skills'. However, their study was based on findings from a large calculus-based introductory physics course.

In other fields of science education, Bayuni et al. (2018) studied class three students' misconceptions about chemical representation using a five-tier diagnostic test. Their diagnostic test was also explicitly designed to test students' scientific knowledge only.

These diagnostic tests lack items designed to assess students' holistic readiness across all domains of scientific KSA. Furthermore, diagnostic tests for middle school students are limited. Addressing this concern, the present study seeks to establish a scholarly framework for developing a diagnostic test that assesses general scientific concepts and the knowledge and skills required to begin their next academic year. Hence, we can use it to evaluate the scientific KSA of students graduating from class six, thereby helping determine their readiness for learning science in class seven. In doing so, it provides a rigorous rationale for the use of diagnostic tests as a means of guiding teaching strategies toward a more holistic approach to scientific inquiry (Mulyadi & Syahid, 2023; Taber, 2023).

Objectives

1. To develop a scientific diagnostic test that included all three domains of scientific knowledge and understanding (K), scientific skills and processes (S), and scientific values and attitudes (A).
2. To determine readiness of class six graduate students during transition to class seven in these domains.

Literature Review

Modern science education emphasizes meaningful learning where students can acquire scientific knowledge, apply it to real-life contexts and develop a positive attitude towards learning science. Traditional assessment tools, including diagnostic tests, have often relied on recall to assess students' understanding. A diagnostic test has been one of the assessment tools used to determine students' prior knowledge, misconceptions and to check overall readiness for learning. Therefore, assessing students' understanding must go beyond the traditional recall-based investigations.

Diagnostic tests are defined as a systematic and rigorous process conducted at the beginning of the academic year or subject unit to understand the initial state of students (Hidrovo et al., 2020; Delgado et al., 2019). Diagnostic tests are not only used as the tools for assigning grades, it also helps to identify the starting point of the students so that it facilitates decision making that improves the teaching and learning process (Delgado et al., 2019). Orhani and Alija (2026) noted that initial level of preparation was crucial for building a personalized teaching strategy that can cater to the needs of the students.

Additionally, diagnostic tests include an exploration of students' values, attitudes and motivations. Effective diagnostic processes aim to sensitize students and direct them toward the creation of meaningful learning by reinforcing values, norms, and attitudes that support their academic journey (Hidrovo et al., 2020). This includes determining what motivates students to learn and what emotional conditions they bring to the classroom (Delgado et al., 2019). In specific fields like medicine, educators stress the importance of identifying the values such as humility and curiosity, which are essential for safe and effective medical practice. In the classroom teaching, diagnostic test is an essential tool for uncovering the misconceptions (Soeharto et al., 2019) and used as formative assessment tools (Hidrovo et al., 2020).

Despite the reported importance of diagnostic tests, several researchers have investigated flaws in their execution. For instance, while teachers notice the students' misconception, they frequently struggle to interpret the underlying reason (Hoppe et al., 2020). In addition, many teachers view in-depth diagnostic process as time consuming (Morrison & Lederman, 2003). Likewise, according to Hidrovo et al. (2020), if teachers are not properly trained in the design, implementation and analysis of diagnostic tests, they lose interest in them, even though these tests are beneficial to the educational system.

Bhutan's NSCF specifically emphasizes on students' holistic development and competency in all three domains of scientific KSA. Many diagnostic tests are used to determine students' scientific knowledge or misconceptions (Peterson & Treagust, 1989; Ding et al., 2006;

Kamcharean & Wattanakasiwich, 2016; Uccio et al., 2019; Chogyel, 2024); scientific skills (Kruit et al., 2018); as well as scientific attitudes (Tenzin et al., 2019).

However, there is limited literature on diagnostic tests that encompass all three domains of scientific KSA in one diagnostic test. This study attempts to fill in this gap by elucidating the process of development of a scientific KSA diagnostic test and report findings on the readiness of class six Bhutanese students for the transition to class seven.

Methodology

Participants

The study employed a census method to select the participants. That means all students who had graduated from class six and enrolled in class seven were included in the study.

Research design

A descriptive quantitative research design was used to collect data. This kind of design is mostly used when data is collected through tests and analyzed using frequencies.

Diagnostic test

The items in the diagnostic test were framed by eight science subject teachers based on the NSCF (Department of Curriculum and Professional Development, 2022) and class six science textbook (Department of School Education, 2020). These teachers were experts in their field of biology, physics and chemistry subjects with teaching experience ranging from six to 20 years.

Table 1 *Details of strand-chapter-topic for class six science subject*

Strand	Chapter	Topic
I. Life processes	1. Classification and Variation	1.1 Classification of Animals 1.2 Classification of Plants
	2. Living Things and their Environment	2.1 Feeding and Relationships 3.1 Nutrition
	3. Human and Animal	3.2 Double Circulation 3.3 Puberty
	4. Green Plants	4.1 Nutrition 4.2 Photosynthesis 4.3 Reproduction
II. Materials and their Properties	1. Classifying Materials	1.1 Elements and Compounds 1.2 Acids and Bases
	2. Materials and Change	2.1 Chemical Change 2.2 Hard water and soft water
	3. Separating Mixtures	3.1 Mixtures in Liquids

III. Physical Processes	1. Forces and Motion	1.1 Gravity and Factors 1.2 Floating and Sinking
	2. Energy	2.1 Forms of Energy
	3. Electricity and Magnetism	3.1 Circuits 3.2 Magnet
	4. Light and Sound	4.1 Properties of Light 4.2 Properties of Sound
	5. The Earth and Beyond	5.1 Solar Eclipse and Lunar Eclipse

Although literature reported on many diagnostic tests – as presented in the literature review section – the purpose of this test necessitated it be aligned with the NSCF.

In the NSCF, the science curriculum is organized into content and process strands. The process strand encompasses information on the importance of working scientifically whereas the content strand describes the organization of the content into three strands, viz. life processes, materials and their properties, and physical processes. From classes PP to eight, these strands are integrated into one science textbook. The details of chapters and topics under each strand are listed in Table 1: Details of strand-chapter-topic for class six science subject.

From each strand, three questions were designed – one each for three domains of scientific KSA (as shown in Figure 1: code of strands/chapters/domains). These questions were from every chapter but not necessarily from every topic. The questions were a mixture of multiple choice, filling in the blank and open-ended questions based on Bloom's taxonomy. Thus, the paper-and-pencil diagnostic test comprised of 36 questions which took an average of an hour to complete. The content of the diagnostic test was validated by a science teacher from a neighboring Primary School who verified whether all the basic important class six science contents were covered or not.

To further validate that the questions were based on scientific KSA, a Physics Program Officer from Department of Curriculum and Professional Development (DCPD), Ministry of Education and Skills Development (MoESD) was consulted. Based on feedback such as question format and appropriateness in level of language, changes were made to the items. The diagnostic test was implemented for three consecutive years (2022 – 2024) in the beginning of each academic year, prior to the onset of academic sessions, to avoid any interference on students' prior knowledge and test what they had learnt in the previous year. During the period of implementation of the diagnostic test, a total of 147 students (39 in 2022; 44 in 2023; 64 in 2024) were assessed. The same diagnostic test was implemented for all three cohorts of students by the same teachers. Entry of the data into excel sheets was assisted by science laboratory assistants. However, the correction of the students' responses and data analysis were initiated by the same group of teachers who designed the diagnostic test items.

Data analysis

Students' responses were analyzed using categorization and dichotomous scoring methods. Depending on the question type, different categories were framed. For scientific knowledge

questions, responses were categorized either as "correct, incorrect or NA" or as "all correct, all incorrect, three correct, two correct, only one correct, or NA". The responses to scientific skill and attitude questions were categorized as "yes, no, or NA". For every criterion that indicated student with correct scientific KSA, one or 0 was scored. Based on this, percentage on the total scores were calculated for each domain of scientific KSA.

To avoid prejudice and ensure minimum error, the evaluation of the responses was divided among three groups of subject teachers for each strand. All members were thoroughly briefed on the scoring rubrics. To ensure no biasness arose from students' handwriting, answer scripts from the paper-and-pencil test responses were numbered and their identity kept anonymous. Students' literal grammatical mistakes were overlooked if the question was answered with relevant and correct ideas in the domains of scientific KSA.

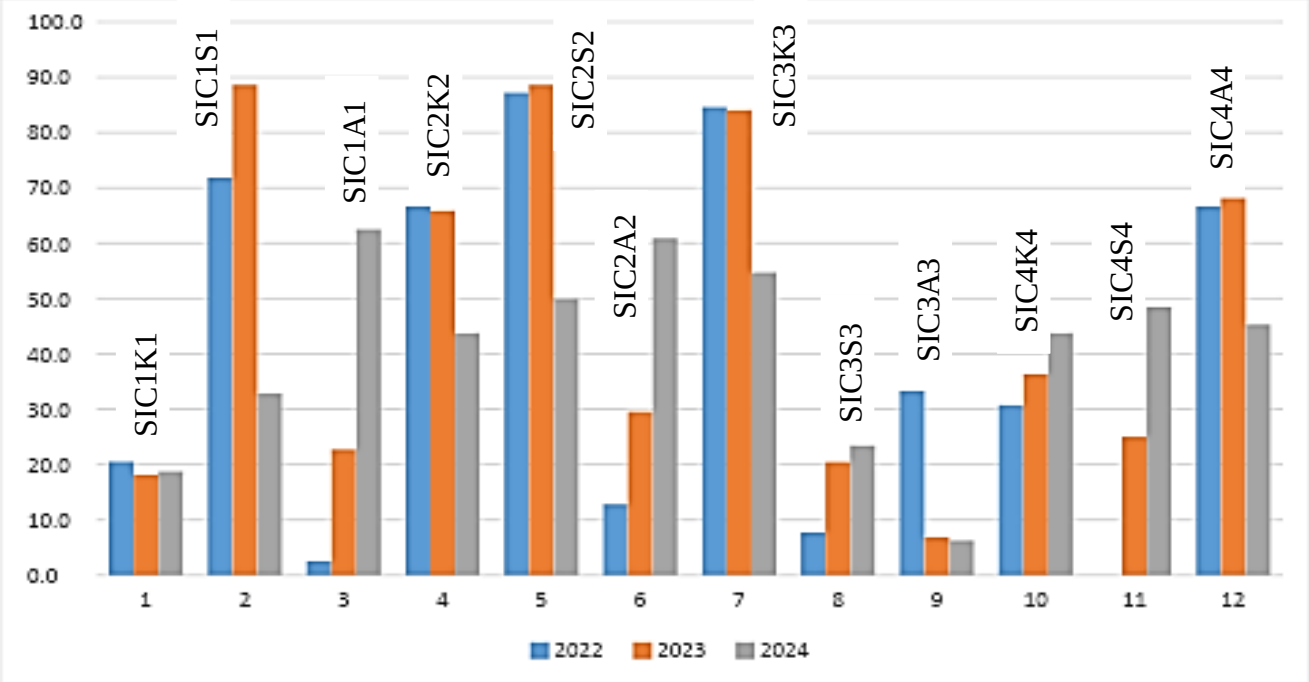
Result and Discussions

Using the scoring method discussed above, the following figures show findings from different strands and domains of scientific KSA.

According to Tshering and Choden (2023), test data can show students' knowledge and skills among others such as classify performance into a hierarchy of thinking skills and determine the relevance of knowledge and skills to societal and technological change.

Figure 2

Percentage of students with scientific KSA in various concepts under Life processes strand



The figure above shows the percentage of students demonstrating competency in strand one (SI) Life Process. Based on the comparative analysis from three years (2022 - 2024) shows a

decrease in the domain scientific skills (S) from 41.7% to 38.7%. This suggests that while students might have retained some conceptual knowledge but their ability to apply scientific skills had significantly declined. Furthermore, the figure tracks the student's difficulty level across the Life Process Strand, indicating that students may have graduated from class six with a basic conceptual understanding of science but may not possess holistic competency required for class seven. It is evident that though students learnt science concepts for many years in primary school, the analysis of the diagnostic test demonstrated low proficiency level.

Additionally, literature suggests that traditional assessment relies on the rote learning, however, the NSCF mandates the students to apply skills to explain the natural phenomena and design and conduct scientific enquiry. The gap shown in figure 2 gives some evidence that a gap maybe present between the curriculum goal and actual outcome of the students. Delgado et al. (2019) as well as Orhani and Alija (2026) argued that diagnostic test should be used as a "starting point" to develop personalized teaching strategies. Concordantly, the result from the above figure provides specific data needed for the teachers to move from traditional teaching approach to inquiry-based approach.

Figure 3

Percentage of students with scientific KSA in various concepts under Materials and their properties strand

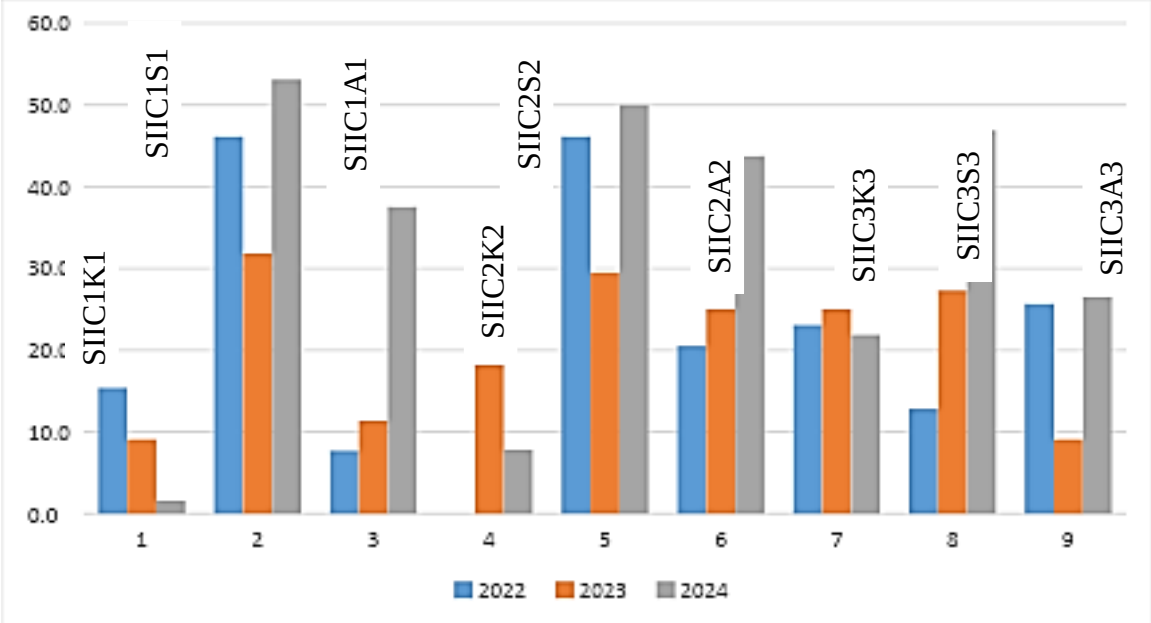


Figure 3 above illustrates the percentage of students' competency in scientific KSA within the Materials and their properties strand (SII) across the years 2022-2024. The data consistently showed that the lowest percentage score in all three years (12.8%, 17.4% and 10.4% respectively in 2022, 2023 and 2024) occurred in the domain of scientific knowledge (K) from all chapters. These chapters tested the fundamental concepts in element, acid and alkali; chemical change; and separating mixtures. Conversely, the domain of scientific skill (S) showed the highest percentage

score in the year 2024 from all chapters. This domain tested the students' ability to identify the solution as either acid or base; ways to convert hard water to soft water; and explain the process to separate mixtures.

These findings indicate that although students possess acceptable scientific skills in one chapter or scientific knowledge in another chapter, they lack holistic competency to integrate scientific KSA required for transition to class seven.

Figure 4

Percentage of students with scientific KSA in various concepts under Physical processes strand

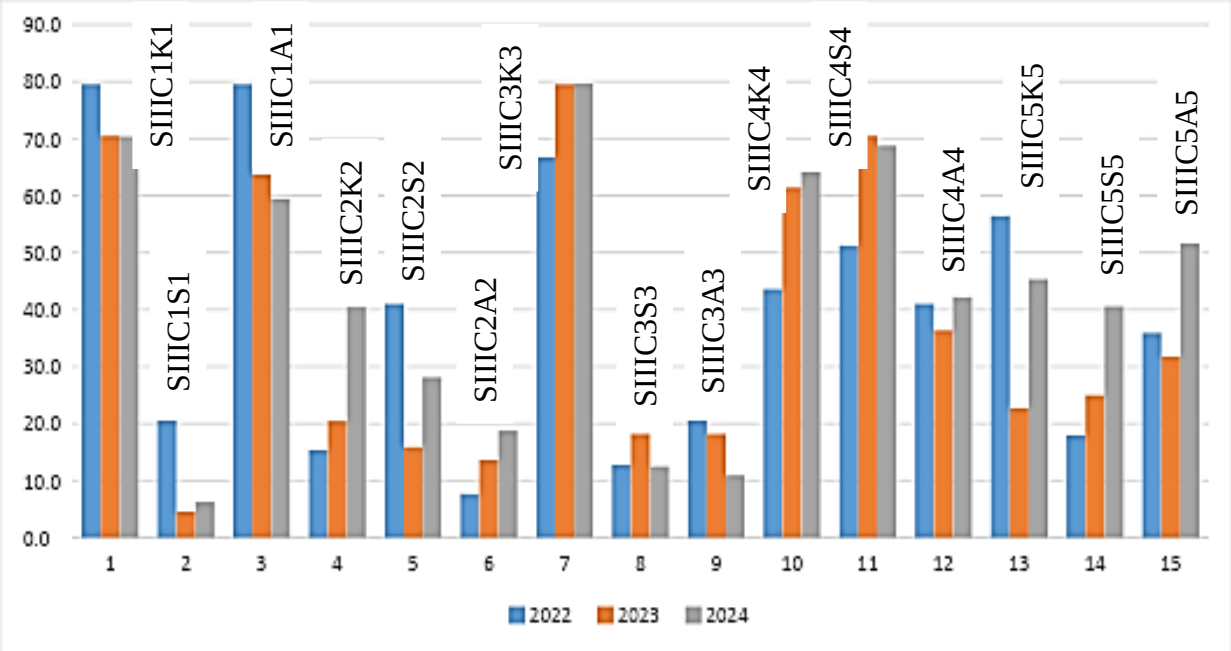


Figure 4 show data from strand – physical processes. From the three domains of scientific KSA, the lowest percentage score was in the domain scientific skills (SIIIC1S1, SIIIC3S3 and SIIIC5S5) from Forces and Motion, Electricity and Magnetism, and The Earth and Beyond chapters. And in these same chapters, the highest mean scores were found from the domain scientific knowledge (SIIIC1K1, SIIIC3K3 and SIIIC5K5). In the scientific attitude domain, Chapter Two on Energy and Chapter Three on Electricity and Magnetism (SIIIC2A2 and SIIIC3A3) had the lowest percentage among all five chapters from the strand. In chapter 4, amongst the 3 domains of scientific KSA, the lowest percentage was in scientific attitude (SIIIC4A4).

Overall, higher percentage scores were seen in the domain scientific knowledge from strands one and three whereas strand two had a higher percentage score in the domain scientific skills.

Summary of findings

The competency-based education (CBE) model recognizes that learning is 'progressive' and 'built on foundational strengths to develop' both scientific knowledge and skills (Sharma et al., 2021).
Findings from strand one and two resonated (Life processes and Physical processes, respectively) showing, on an average from all chapters, the lowest performance in the domain of scientific skills, followed by domain of scientific attitude. In strand II, the lowest score was seen in the domain of scientific knowledge.

Though students graduate from class six after a high-stake National level Competency Based Examination (CBE), the diagnostic test results indicate that students lack holistic scientific KSA in various chapters across all strands. This shows that class six graduate students may not be ready to learn science in class seven.

Findings from this scientific KSA based diagnostic test highlight the need to question the holistic competency level of students and their preparedness for the next higher classes. Testing students solely on the the prescribed curriculum rather than on their competencies may fail to indicate the actual levels of learning students have attained (Sharma et al., 2021, p.6).

Limitations

In the present scientific KSA diagnostic test, questions from every topic under each chapter and from all three strands weren't developed to avoid too lengthy diagnostic test. This may have unintentionally resulted in exclusion of some topics that students could have correctly answered.

The same diagnostic test was used for all three academic years. However, the results from the first year (2022) weren't used to update the items for implementation in the following year. Also, the study was carried out in only one school and therefore, the result from the present study cannot be generalized to other schools.

Recommendations

The NSCF stresses the importance of students' competencies in all areas of scientific KSA. And accordingly, test items developed by Bhutan Council for School Examinations and Assessment (BCSEA) in the National paper-and-pencil test include questions based on these competencies. The report after the completion of the national level examinations for class six (Competency Based Assessment Test - CBAT), however, indicates only the strand-wise overall performance. Therefore, insight into the readiness of students based on competencies as well as scientific domains may need to be studied in detail.

The findings from this scientific KSA diagnostic test reinforce the need for science teachers to emphasise not only the domain of scientific knowledge but also the domains of scientific skills and attitudes. Further research into this kind of diagnostic test is recommended.

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