Secondary school students' perceptions and experiences of learning science and mathematics: The case of Bhutan

Abstract

Secondary students' perceptions of learning science and mathematics have been researched internationally, but less in the global South. This study investigated Grades 9 and 10 students' experiences of learning biology, chemistry, physics and mathematics in Bhutanese secondary schools. A mixed-methods sequential design was used. First, 524 students from 7 schools completed a survey capturing their perceptions of learning in the four subject areas. Then, 82 of those respondents participated in one of 8 focus groups, exploring patterns in the survey data. Chemistry was seen as the most challenging subject, associated with memorisation, poor performance, stress and fear. Biology was perceived as more interesting and less anxiety-provoking, although a need to memorise large amounts of content was common. Mathematics was polarising, with some students finding it easier and more enjoyable, others the opposite. These findings add to the international literature on students' perceptions and experiences of science and mathematics. They inform curriculum and pedagogic change to enhance students' experiences, reduce negative perceptions and anxiety, make the choice to study these subjects in senior secondary years more appealing, and lift performance.

Keywords

Student perceptions; attitudes; interest; science; mathematics; assessment; Bhutan

Introduction: science and mathematics education in Bhutan

Students' experiences and perceptions of science and mathematics subjects influence subsequent study choices and are linked with academic performance. As a country with an emerging educational system, Bhutan aspires to institute relevant and high quality science and mathematics school education programs, evident in the recent decision to establish a primer school for science, technology, engineering and mathematics (Rai, 2019).

Formal school education in Bhutan was introduced around 1950 and schooling there now comprises one year of pre-primary, six years of primary, and six years of secondary education. Education is presently universal and free until Grade 12. Ninety percent of each cohort gains admission to the final two years (higher secondary school) (Rinzin, 2019). Teaching of mathematics begins in pre-primary, and science is taught from Grade 4 to Grade 8 as an integrated subject 8. It remains compulsory and is taught as separate subjects (biology, chemistry, physics) in Grades 9 and 10. English is the medium of instruction in all schools in Bhutan, and the national language, Dzongkha, is taught as a separate, compulsory subject. Given the relative youth of the schooling system and challenges associated with Bhutan's economic development and remote mountainous geography, 85% enrolment in secondary education as of 2014 has been noted as a significant accomplishment (Ministry of Education, 2014). However, there remain significant challenges.

The *Bhutan Education Blueprint 2014-2024* (Ministry of Education, 2014) articulates the Bhutan Government's priorities. It highlights concerns around student learning outcomes in science and mathematics, mentioning numeracy skills, students' inability to understand core concepts and apply knowledge to real-life situations, and lower performance in questions not based on recall and rote learning. It notes declining test scores in these subjects. In 2017, science and mathematics test scores were the lowest of all subjects (Delma, 2018). In Utha & Rinzin's (2019) study, teachers said large class sizes and volume of syllabus led to extra classes outside of regular school hours being needed in Grade 10; students in this study also recognised these as being needed because their teachers were behind in syllabus coverage. Declining student interest beyond Grade 10 and concerns about student performance underlies an urgent need to better understand students' perceptions and experiences of studying these subjects (Ministry of Education, 2014).

Mathematics as 'a subject not many are keen to embrace and learn' (Ministry of Education, 2014, p. 34). Science and mathematics were found to compare unfavourably to English and Dzongkha in terms of enjoyment and difficulty. The Royal Education Council's (REC) recent review of science and mathematics curricula led to new textbooks, teachers' manuals, facilities such as science laboratories, and expanded professional development for teachers. Current pedagogical practices in Bhutan emphasize summative assessment (Rinzin, 2019). A typical Grade 10 student would sit two class tests, mid-term tests, a trial exam and end of year board examination, on top of several continuous assessments in each subject. Formative assessment remains under development in Bhutanese schools (Utha, 2015) and the Ministry of Education and REC have prioritized better balancing of formative and summative assessment (Rinzin, 2019).

Given the paucity of research in the Bhutanese context, our study asked: *What are Bhutanese secondary school students' perceptions and experiences of the three sciences and mathematics in relation to assessment, performance and competence, and interest and enjoyment?* The three focal areas of perceptions of assessment, performance and competence, and interest and enjoyment reflect key themes identified in Bhutanese policy and empirical work, as well as international literature on subject perceptions, attitudes and anxiety.

Review of literature

In this review our citation practice seeks to balance reference to well-known literature that has significantly influenced the field, with reference to studies from the global South, including Asia-Pacific and Africa.

Student engagement and performance in secondary school science and mathematics

Students' engagement, interest and performance in school science and mathematics is an international concern (Fonseca & Conboy 2006; Renninger, Nieswandt, & Hidi, 2015). Research findings correlate students' low academic performance in science and mathematics with negative experiences and anxiety (Ashcraft & Krause, 2007; Mallow, 2006; O'Keeffe, White, Panizzon, Elliott, & Semmens, 2018; Passolunghi, Caviola, Agostini, Perin, & Mammarella, 2016). Anxiety and negative attitudes to subjects are related to each other (Kaya & Yildirim, 2014), and further connect with the development of negative beliefs regarding students' own abilities (Ashcraft & Kirk, 2001), which can compound anxiety. Mathematics anxiety is prevalent concern worldwide, with a third of students internationally feeling stressed, tense or helpless dealing with mathematics, and 60% worried about poor grades (Aldrup, Klusman, & Lüdtke, 2020; Organisation for Economic Co-operation and Development, 2017).

Students' perceptions of learning science and mathematics

Secondary students' perceptions of learning science and mathematics have long been considered an important focus of research (Osborne, Simon, & Collins, 2003). Positive perceptions are associated with greater likelihood to continue studying these subjects when they are optional (Shirazi, 2017). Curriculum content, teaching/learning methods, and teachers, all make a difference. Heavy and overly demanding curriculum content is associated with negative attitudes, elevated anxiety and disengagement from learning (Patall, Hooper, Vasquez, Pituch, & Steingut, 2018). Perceived disconnection of abstract concepts from everyday concrete examples can lead students to view subjects as more difficult and uninteresting (Woldeamanueal, Atagana, & Engida, 2013). Students report that variation in teaching methods helps to make learning more interesting and builds their confidence (Osborne et al., 2003; Woldeamanuel et al., 2013; Miao, Reynolds, Harris, & Jones, 2015).

Anxiety is an important aspect of students' experiences of learning. Mathematics anxiety refers to students' feeling of tension, helplessness, mental disorganization and dread when required to manipulate numbers and shapes, and undertake problem solving (Ashcraft & Faust, 1994). Mathematics anxiety cannot be reduced to test anxiety or general anxiety (Dowker, Sarkar, & Looi, 2016), and affects the ability and confidence to learn mathematics (Chinn, 2008). Components of mathematics anxiety are often considered in terms of test anxiety and numerical anxiety, but these have been differentiated to specify components relating to learning mathematics, evaluation, everyday numeracy, performance, and social responsibility (doing maths in front of or for others) (Pletzer, Wood, Scherndl, Kerschbaum, & Nuerk, 2016). Those who think they are bad at mathematics are more likely to be anxious (Dowker et al., 2016). A 'triple cause' of inter-related factors influence mathematics anxiety: classroom issues, parental pressure and perceptions of mathematics as a rigid set of rules (environmental factors); self-doubt, mismatch between pedagogic practices and learning styles (intellectual variables); and reluctance to ask questions and low self-esteem (personality factors) (Chinn, 2008; see also Dowker et al., 2016).

Fear of mathematics can lead to students losing interest in the subject, avoiding elective mathematics, and performing poorly in it (Anigbo & Idigo, 2015; Ashcraft, 2002; Ashcraft & Kirk, 2001; Ashcraft & Krause, 2007; Passolunghi et al., 2016). Feeling one doesn't understand the rules and principles of a subject makes it harder to comprehend facts rather than just memorise them (Schreiner, Henning, & Nicole, 2010), and is associated with increased anxiety and poor performance (Eddy, 2000). Mathematics can be perceived as a subject that is 'not for' particular learners (Ekol, 2008). Students have linked negative attitudes to syllabus coverage constraints forcing a rapid pace, as well as perceptions that teachers lacked mathematical understanding (Sa'ad, Adamu, & Sadiq, 2014).

Science anxiety refers to the fear of science leading students to avoid and view the subject negatively and can begin at a young age (Mallow, 1986, 2006). Science anxiety is experienced during the study and learning of science, and cannot be explained by experiences of testing or general anxiety. It has multiple causes and components, mirroring those discussed above in relation to mathematics. Zangmo (2016) found attitudes of Grades 10 and 12 Bhutanese students towards science were generally positive. However, qualitative data suggested chemistry and physics were perceived to be most difficult and least interesting, leading Zangmo to conclude a need to further investigate science subjects separately in Bhutan. Nigerian secondary school students perceived chemistry as the most abstract and difficult subject, because it was vast, demanding, requiring lots of calculation with chemical equations (Jegeda, 2007). Studies have found students perceive physics as difficult and uninteresting compared to the other sciences, with reasons given relating to numerical problems requiring mathematical ability (Hamelo, 2016; Oon & Subramaniam, 2013).

Methods

The study used a mixed methods sequential explanatory design, in which quantitative then qualitative data were collected and analysed in consecutive phases (Ivankova, Cresswell, & Stick, 2006). The study aimed to identify patterns in Bhutanese secondary school students' perceptions and experiences of learning science (through quantitative survey data), and dig deeper into why these patterns might be that way (through qualitative focus group data).

Sample

Both phases involved seven secondary schools across five Dzongkhags. Dzongkhags are administrative districts in Bhutan, of which there are twenty. The five involved in the study were Thimphu, the capital; Paro, home to the second largest town; Samtse in the southwest; Pemagatshel in the southeast; and Trashigang, in the far east. Bhutan classifies schools from 'urban' to 'very remote' and 'difficult' (this can vary within a Dzongkhag; Ministry of Education, 2014). Table 1 summarises details of the seven schools in the sample. The numbers given below are used subsequently to indicate the source of quotations from data.

INSERT TABLE 1: Summary of Sampled Schools

From a list of schools in each Dzongkhag, schools with Grades 9 and 10 were identified. A purposive sample was then constructed, ensuring a mix of urban, semi-urban and remote schools across the seven schools, both day and boarding schools (the latter being common in Bhutan); convenience factors including ease of access for data collection were also considered. The sample tended towards 'urban' schools because schools in this category can vary greatly in terms of their facilities and accessibility, and some in what remain comparatively small settlements that might be deemed rural in other countries. This was reflected in the sample, as shown in Table 1.

At the time of study in 2018, there were 72 and 52 public middle and higher secondary schools respectively, plus 22 private schools. Each grade comprised several classes (called "sections" in Bhutan), streamed according to academic performance. Based on information provided by each school, a stratified random sample of approximately 90 students per school in Grades 9 and 10 was given a survey, ensuring proportional representation of students from higher, middle and lower academic streams. The study did not explore differences in student perceptions between the two grades, and the data from the two were combined in analysis.

A total of 622 students were given the survey, of whom 524 (84%) completed all items. This represents approximately 2% of the total population of Grades 9 and 10 students in Bhutan. Of the respondents, 47% were female and 53% were male, mirroring gender balance at the population level.

Qualitative data were collected through eight focus groups. One was conducted at each school, involving a male and female student from Grade 9 and the same from Grade 10. The eighth focus group was conducted with a whole class of Grade 10 students in School 7 (Samtse Dzongkhag). In total, 82 students participated in the qualitative phase (seven groups of four, plus a class of 26). The approach was semi-structured, exploring questions that arose as a result of the quantitative data generated through the survey. The protocol mirrored and expanded on the issues covered in the survey. It began asking students to discuss which subjects they (dis)liked and found more / less interesting, those found easier or harder and why, then focused on their feelings in relation to assessment, and then explored their views about performance. Next, questions about how each subject was taught were considered, before moving on to ask students about strategies they used to overcome fear or anxiety.

Focus groups were conducted in English, audio recorded, and transcribed verbatim. Consistent with procedures to conduct research in schools in Bhutan, approval was given by each Chief Dzongkhag Education Officer and respective school Principal. All participants gave informed consent to participate. Survey data was anonymous, and confidentiality maintained in reporting focus group data.

Survey details

The survey comprised four sets of 32 items – each set asking the same questions about one of the four subjects (see Table 2). In tables and figures below, 'X' denotes where the specific subject was mentioned (e.g., 'I feel a lot of stress taking an X test'). The order of item sets was random for each school. Students also gave their age and gender. The survey was informed by prior studies on student perceptions, experiences, and anxiety, and developed through collaboration between the Royal University of Bhutan and the University of Technology Sydney. Each set comprised eight items relating to students' attitudes and enjoyment, nine relating to assessment, and fifteen relating to perceptions of performance and competence. Students were asked to rate their level of agreement on a 5-point Likert scale: strongly agree, agree, unsure, disagree, and strongly disagree. Items adopted a mix of positive and negative framing. The survey was adapted to local uses of English to ensure contextual relevance.

INSERT TABLE 2: Items in the Survey

The analysis used descriptive statistics (frequency, mean, standard deviation) to identify patterns in subject perceptions and students' experiences of learning. Items were scored giving 5 points for 'strongly agree', and 1 point for 'strongly disagree'. Mean scores for each item enabled comparisons across the subjects. Standard deviations were calculated to indicate how varied the responses were in each subject. The percentage of respondents agreeing or strongly agreeing with each item was also calculated to enable item-specific analyses. To avoid the possibility of overlooking positive perceptions and experiences, means, standard deviations and frequencies were calculated separately for negatively and positively framed items. Qualitative focus group data were analysed purposively to aid interpretation of patterns in the quantitative data. They were not analysed systematically as a separate dataset.

Findings

This section presents findings from the quantitative phase. It identifies patterns across and within the four subjects, answering the research question: *What are Bhutanese secondary school students' perceptions and experiences of the three sciences and mathematics in relation to assessment, performance and competence, and interest and enjoyment?* The discussion section then considers these in light of data from the qualitative phase and the existing literature.

Perceptions and experiences of assessment

Assessment has a significant bearing on students' subject experiences and perceptions, and was the focus of nine items (Table 2). Table 3 presents mean sum scores and standard deviations of these nine items by subject.

INSERT TABLE 3: Mean and Standard Deviation on Assessment Items for Each Subject

Table 3 shows that negative perceptions and stressful experiences of assessment were highest in chemistry. The mean scores in the other three subjects were similar. The higher standard deviation in mathematics indicates greater variation in responses. The combined percentage agreeing or strongly agreeing with the nine items is presented in Figure 1.

INSERT FIGURE 1: Percentage of Respondents Agreeing or Strongly Agreeing with Assessment-related Items

Figure 1 shows that the pattern revealed in Table 3 is echoed in student responses to each item. The four subjects were similar in terms of which items scored higher or lower. For six of the nine items, between 20% and 40% of respondents agreed or strongly agreed, indicating the prevalence of negative assessment experiences.

Agreement or strong agreement was most frequent in chemistry for all assessment-related items. Nearly 40% of respondents reported that chemistry tests were frightening. Pressure, nerves, mind going blank, and test-related stress were all most likely to be agreed with for chemistry. Mathematics was second highest, physics third, and biology lowest on all items except item 23, about memorisation before tests. This was the item most agreed with in all subjects. Practices of memorisation were reported by nearly 60% of students for all subjects except mathematics.

Perceptions of performance and competence

Fifteen items asked students to report whether they did well or not in tests and assignments, feel confident or not in solving problems, and whether aspects of particular subjects come easily to them or are difficult to understand (Table 2). Perceived difficulty, and performance history and expectations are important facets of students' perceptions of school subjects (O'Keefe et al, 2018). Given the importance of relationships in learning, items also asked students about their working with others and their conduct in class. Avoidance of contributing in class could be due to low self-concept (esteem, efficacy), inattention, disinterest, or expectation of failure and possible ridicule, but is one of the 'triple causes' of (mathematics) anxiety (Chinn, 2008). As such, items 27 and 28 (Table 2) were not treated as direct indicators of low confidence in a particular subject, but were relevant as part of a set of items.

Of the 15 items, nine were negatively framed and six positively framed. The mean total scores of the negative and positive items and standard deviations are shown in Table 4.

INSERT TABLE 4: Mean and Standard Deviation on Performance and Competence Items for Each Subject

Table 4 shows chemistry was the subject most associated with negative perceptions relating to performance and competence. The inverse was the case for biology, with higher confidence, higher reported performance, lower perceived difficulty, and greater likelihood to enjoy working with others and participate in class. Values for physics and mathematics lay between the two, and higher standard deviations in mathematics indicate greater variation in responses.

The percentage totals for students agreeing and strongly agreeing with each item provide further insights, presented in Figures 2 and 3 for negatively and positively framed items respectively.

INSERT FIGURE 2: Percentage of Respondents Agreeing or Strongly Agreeing with Negative Performance and Competence-related Items

INSERT FIGURE 3: Percentage of Respondents Agreeing or Strongly Agreeing with Positive Performance and Competence-related Items

The patterns shown in Figures 2 and 3 are similar across subjects. Students were less likely to agree with items relating to reported performance than they were those relating to difficulty understanding and problem-solving. They were more likely to report feeling confident and enjoying answering questions in class than they were to report doing well in exams. Chemistry was associated with lowest reported performance and highest difficulty. Biology had lower agreement across the nine negatively framed items (Figure 2). However, mathematics scored highest on all but one of the positively framed items (Figure 3), the exception being item 25 on concepts coming easily.

Students' attitudes and enjoyment

Of the eight items on attitudes, enjoyment and liking, three were negatively framed, and five were positively framed (Table 2). Mean totals and standard deviations for the three negative items, and five positive items are shown in Table 5.

INSERT TABLE 5: Mean and Standard Deviation on Attitudes and Enjoyment Items for Each Subject

Table 5 shows that chemistry scored highest on the negative items and lowest on the positive ones. The inverse was found for biology. Figures 4 and 5 present the percentage agreeing or strongly agreeing with the negatively and positively framed items respectively.

INSERT FIGURE 4: Percentage of Respondents Agreeing or Strongly Agreeing with Negative Attitude and Enjoyment-related Items

INSERT FIGURE 5: Percentage of Respondents Agreeing or Strongly Agreeing with Positive Attitude and Enjoyment-related Items

Figures 4 and 5 show that overall attitudes tended to be more positive than negative in terms of liking, excitement and joy in studying. Just over half said biology and mathematics were among their favourite subjects; fewer than half said the same of physics or chemistry.

Figure 4 shows that 20% of respondents had a special dislike for chemistry, and 21% rated it as one of their worst subjects; 18% also agreed or strongly agreed that chemistry is boring. This is echoed in Figure 5, which shows students were least likely to agree with four of the five positive items when referring to chemistry. The trend was for more positive attitudes to be reported in biology, followed closely by mathematics, then physics, then chemistry. Biology emerged as most liked and least disliked of the four subjects. Fifty-two percent agreed or strongly agreed it was their favourite subject, and 70% said they enjoyed it.

The picture with mathematics was more complex. Frequencies generally placed mathematics just behind biology in terms of positive attitudes and the inverse for negative attitudes. Figures 4 and 5 indicate polarisation in attitudes to mathematics: 51.6% percent indicated it was among their favourite subjects, however 20% indicated it was one of their worst subjects 20%. Physics was consistently third in both positively and negatively framed items, except in relation to boredom, where physics agreement was second highest.

Discussion

Findings relating to students' perceptions and experiences of assessment, performance and competence, and attitudes and enjoyment will be discussed in turn. Reference to existing literature and the qualitative data aids interpretation to suggest explanations for the patterns identified above.

Perceptions and experiences of assessment

A fifth or more of the respondents reported finding tests frightening, or being nervous and feeling under a lot of pressure or stress taking a test in one or more of the four subjects (Figure 1). Students reported being less fearful of assignments than tests. Some explained that this was because mistakes in assignments could be addressed later:

> No, I am not afraid of submitting because even if we make mistakes, after getting our books back we can correct them. [Male, School 1]

Difficulties remembering in tests and relying on memorisation before tests were prominent across all four subjects (although lower in mathematics). Childs, Tenzin, Johnson, and Ramachandran (2012) found teacher questioning in Bhutanese science classrooms in Grades 9 to 12 was predominantly based on simple recall, and that teachers and students perceived the curriculum to be very content heavy, especially chemistry. Students mentioned a 'vast amount of memorisation' (p. 288) in all three sciences, something confirmed in all lesson observations in that study.

Chemistry was most likely to be a source of assessment-related anxiety. In all focus groups, students said that they found the abstract content in chemistry difficult, and that memorising was hard due to the volume of content:

> For me, chemistry is hardest because it is abstract. For example, atom, we cannot see. We should memorise. We cannot find application in life. [Female, School 3]
>
> In chemistry there are so many equations and formulae with different elements, it's hard to memorise all of them and their reactions with other elements. [Male, School 5]
>
> The size of the textbook makes me lazy to study. There is a need to read again and again to understand. [Female, School 7]

Kaya and Yildirim (2014) found students felt less worried about tests provided they felt well prepared. This is reflected in the Bhutanese findings, but appears to be more complex in chemistry: students were less anxious when they felt prepared, but in chemistry, preparation involved memorisation, which was itself a cause of stress and worry. Furthermore, students found it difficult to relate ideas in chemistry to their concrete experience. These data suggest negative perceptions and stress in chemistry reflects a combination of challenging content, large syllabus, and associated difficulty memorising volume of content and specific equations, an interpretation supported by studies in Bhutan (Childs et al., 2012) and elsewhere (Jegeda, 2007). This reflects precisely the concerns expressed in the *Blueprint*

(Ministry of Education, 2014), and studies from elsewhere that found abstract content and disconnect from real life leads to anxiety (Woldeamanuel et al., 2013).

Assessment in biology was perceived as less frightening and stressful. Students found biology easiest to understand, and more concrete. However, they reported memorising a lot when preparing for biology tests because they felt that questions in tests relied on recall of facts:

> Biology is a vast subject. During the examination, the questions may be asked from any angles so we must memorise and be perfect with every diagram and the definitions. [Male, School 7]

This echoes Soe's (2018) findings among students in Myanmar, and Zangmo's (2016) study in Bhutan.

Mathematics was second most associated with nerves, stress and pressure related to assessment. Stress, fear and worry in relation to mathematics assessments relate to the component of mathematics anxiety relating to evaluation (Pletzer et al., 2016). Qualitative data indicated that this anxiety related to the abstract nature of content, similar to students in Ashcraft's (2002) study, who felt confused in tests due to similarities between formulae. However, there were marked variations contrasts in the way students in the present study perceived mathematics. The quotations below help to explain higher variation in responses for mathematics than for other subjects (Table 3). For some students, formulae were a matter of practice that could unlock solutions; others felt little need to memorise formulae as they could be derived from questions; and others were anxious around mathematics assessment precisely because they felt they needed to rely on memorising.

> Mathematics is hard because it's really hard to memorise all the formulas and ways in the sequence. [Female, School 1]

> You don't have to memorise much unlike chemistry and biology. That's why it all depends upon practice, which is easier than memorising. [Male, School 4]

> There will be only one general formula we can apply to all other problems to be solved. [Female, School 4]

> For me maths is easy. From the question itself, we can derive the formula. [Male, School 3]

Physics occupied a middle ground in which the smaller perceived syllabus and more concrete content created less anxiety and less need to memorise. For those who found the mathematical parts easier, this led them to be less worried about assessments in physics too. This aligns with prior studies that have linked perceptions of assessment in physics to the need for competence in mathematical calculations (Hamelo, 2016; Oon & Subramaniam, 2013). However, in a distinctive finding, some students explained that although they found mathematics harder, they did not feel so stressed about physics assessments because there was less content to remember, that it was easier to memorise than the diagrams in biology, and overall, less reliant on mathematics:

> I don't feel that physics exam is burdensome because the textbook is thin compared to the other two [sciences] which are bulkier. There are calculations, which is part of math and is one of my easiest subjects. The memorising is not much compared to chemistry, so physics exam is not that much hectic job. [Male, School 4]

Perceptions of performance and competence

We now consider students' perceptions of performance and competence. The findings suggested students perceive a difference between how difficult they find subjects, and the results they achieve in assessments. Students were more likely to report feeling confident, enjoying answering questions in class, and that concepts came easily to them, than they were to say they do well in exams (Figure 3).

Reliance on memorisation was discussed in the focus groups as a way to make up for difficulty in understanding when preparing for tests. This could explain why some students feel they are able to do better in assessments than their perceived competence with subject matter would suggest. It may also explain why some feel they do worse than they might – because they feel tests are assessing memory more than deep understanding.

Chemistry was the subject students perceived themselves to be weakest in. They explained that chemistry problems were hard and time-consuming to solve because not only did they involve formulae, but students had to know which element to use, and make frequent reference to the periodic table. Figures 2 and 3 showed that students generally found mathematics intrinsically harder, but felt they were less likely to do well in chemistry. The focus groups revealed this is because they make up for understanding through memorising, and because of a perceived discrepancy between taught and tested curriculum.

Some students felt that teachers and teaching contributed to their poor performance, as has been found elsewhere, particularly around rigid focus on syllabus coverage (Sa'ad et al., 2014; Ekol, 2008); mismatched pedagogic practices have been noted as a cause of mathematics anxiety (Chinn, 2008). Participants in this study felt that teaching promoted memorising rather than deep understanding:

> Our teacher just memorises the things and repeats what's there on the textbook. [Male, School 4]

> Most of the time rather than learning, it's memorising. [Male, School 5]

Other reasons included a lack of practical work and predominance of teacher talk, or that when practicals were offered, these remained in the hands of the teacher.

> Our biology teacher just explains from the front and there's not much use of teaching aids and practical works. [Male, School 1]

> The reason behind being not able to understand in class is because in science subject most of time there are students doing the practical work and teacher might do most of the practical and students putting less effort. [Male, School 1]

Teaching methods with emphasis on singular method can contribute to negative perceptions of performance and competence, and fuel anxiety (Ashcraft, 2002). Prior studies noted widespread teacher- and textbook-centred pedagogies in Bhutanese secondary schools (Childs et al., 2012; Keller & Utha, 2014; Utha, 2015), and the *Blueprint* (Ministry of Education, 2014) highlighted the need for more practical learning and the laboratories. Some students in this study attributed their performance to their own study practices, but linked these with feeling demotivated because of teaching methods that left them uninspired:

> Because we do not put effort from our side as the teacher teaches in the same way for all subjects. [Male, School 7]

Qualitative data revealed how some students appear to find mathematics relatively easy, and once the formulae make sense, they become empowering as tools (provided they can remember them), but others perceive content as difficult, and/or find it hard to remember which equations to use:

> If we remember the formula we could do it easily. But if we do not remember the formula, we could refer the textbook but that is time consuming. [Male, School 4]

> Maths is very hard because most topics are similar and we don't know what equation to write. [Female, School 5]

Students who perceive themselves as weaker in mathematics are more likely to be more anxious about studying it (Dowker et al., 2016), as are those who regard mathematics as a rigid set of rules (Chinn, 2008). The idea of numerical anxiety points to a group of learners who find mathematics intrinsically more challenging and anxiety provoking (Pletzer et al., 2016) – a subject that just 'isn't for them' (Ekol, 2008) – something that appears to apply to a subset of the respondents in the present study.

While biology tended to be seen as less difficult than the other two sciences because of its concrete nature, participating students' perceptions of (poor) performance in this subject were tied to the volume of content and memory required to answer questions.

> Biology is all about the environment as well as body parts and I think it's easy because we can see in our everyday life. So it makes a biology question easy to answer. [Male, School 5]

> Biology, seems like over burdening. We have to memorise so many things. I am a lazy person who does not do work. So, memorising so much of big definitions, diagrams, functions all things seems hard for me. [Male, School 4]

Despite mathematics being perceived as comparatively difficult, students were more likely than in other subjects to say they enjoy showing others how to answer mathematics questions, and that they like answering questions in mathematics class. Qualitative data revealed that students felt confident helping others in mathematics once they knew they had the correct formula to work with. In chemistry they were less sure of themselves because each equation and reaction was different, and understanding how to solve one question did not necessarily help with solving others.

Students' attitudes and enjoyment

Positive perceptions were more common than negative ones for each of the four subjects (see Figures 4 and 5). However, between a tenth and a fifth of participants had strongly negative attitudes to one or more of these subjects. Biology was most associated with positive attitudes, followed by, mathematics, physics then chemistry. The qualitative data aid interpretation of these findings. Students found the abstract content of chemistry less interesting, but enjoyed the concrete focus in biology on the natural environment and human bodies:

> Biology is easy because it tells about cells and reproductive system and it is easy to understand. [Female, School 3]

Attitudes and liking for subjects were not disconnected from experiences of assessment, and particularly in biology, some described being put off the subject because it relied so heavily on memorising:

> I don't like biology because it's much more memorising and my memorising power is less. [Male, School 1]

Mathematics was the second most liked and second most disliked subject (Figures 4 and 5). The qualitative data highlighted a contrast between those whose liking of mathematics related to its more abstract processes, and those for whom perceived connections with everyday life were important. Often, positive attitudes were coupled with finding mathematics easier.

> Math is interesting subject unlike History, it keeps our brain engaged, we play with formula, should know what formula to use. [Female, School 7]

> I like math better because it is based on reality. For example each time we go to the shop, we calculate how much money we have spent and then that's based on experiences. So I found that easier. [Male, School 5]

Perceptions of mathematics as abstract were associated both with liking and with disliking the subject. This supports arguments that understanding anxiety needs to take into account factors outside the subject itself (Chinn, 2008; Pletzer et al., 2016).

A similar connection was evident in physics, where interest and positive attitudes reflected perceptions of relevance to everyday life and a sense of ease and lower memory burden:

> I like physics, it is very easy because it all has to do with our everyday life and it's very easy once you can relate the life situation to physics. [Female, School 5]

Broader discussion

The data showed clear differences between the three sciences. In summary:

1. Chemistry was the subject in which assessment was most associated with anxiety and reliance on memorisation to make up for poor understanding, perceptions of performance and competence were most negative, and interest and enjoyment were lowest, the latter attributed to abstract content.
2. Biology was perceived as interesting and relevant, but volume of content created a heavy burden of memorisation, which students felt compromised their performance
3. Physics was consistently associated with more moderate perceptions, where a slimmer curriculum and comparative ease in working with equations, and perceived applied content made the subject easier and more enjoyable
4. Mathematics was associated with a polarized pattern, with some students finding the subject easy and interesting, and others becoming confused by similarity between formula.

One major concern is the feeling among many students in different countries that they are overwhelmed by the volume of content they are supposed to learn, such that they are not able to understand deeper principles fully, and rely on rote learning instead (Patall et al., 2018; Schreiner et al., 2010). Assessments become a matter of memorisation, something that can be compounded if understanding in the classroom is itself limited. The latter can be fuelled by teacher-centred methods, which can lead students to find content less interesting, and they become less motivated to study (Woldeamanueal et al., 2013). Across all four subjects, students in this Bhutanese study reported classroom experiences dominated by teacher-centred approaches, and linked these with lower interest and performance, and higher anxiety. Teacher-centredness, transferring knowledge from a textbook, is common in Bhutan (Childs et al., 2012; Keller & Utha, 2014). This speaks to concerns expressed by the Ministry of Education (2014) that core concepts are not being learned properly while rote learning dominates.

Furthermore, this study suggests an opportunity to couple the shift to formative assessment (Rinzin, 2019) with approaches that depend less on memorisation, a refinement of curriculum volume, and promotion of pedagogies that actively engage students and help them connect content with practical applications. A less crowded curriculum could enable teachers to move away from teacher-centred approaches, giving time to dwell in content so students feel confident in deeper understanding and so depend less on memorisation, continuing the approach of being informed by curriculum developments internationally, while contextualising Bhutanese cultural values (Childs et al., 2012).

Conclusions

This study reports new data on secondary school students' perceptions and experiences of school science and mathematics in Bhutan. It goes beyond prior studies in Bhutan, enabling detection and preliminary explanation of patterns within and between these subjects. Zangmo's (2016) study found overall positive attitudes to science, pointing to the need to further investigate perceived difficulty and disinterest in chemistry and physics. Zangmo's quantitative data did not treat the sciences separately (and did not incorporate mathematics), and focused more on out-of-school aspects such as homework and parental involvement. The present study collected new quantitative data about the four subjects separately, including items specifically linked to anxiety and assessment, which were not addressed in Zangmo's study.

Aiming to fill a gap in knowledge in the Bhutanese context, we answered the following research question: *What are Bhutanese secondary school students' perceptions and experiences of the three sciences and mathematics in relation to assessment, performance and competence, and interest and enjoyment?*

This study found varied perceptions and experiences across the four subjects, with a sizeable proportion of students expressing anxiety, disinterest, perceived irrelevance of content, high difficulty, and reliance on memorisation. Clear differences between subjects were detected, with Chemistry most associated with negative perceptions, and a polarised pattern evident in mathematics. These findings complement and contribute further to international research on this topic. The fact that many findings echo results from other countries suggests key themes are shared across diverse contexts. Students' interest in these subjects is important because it influences their choice to continue studying them or not, and ultimately their learning in higher secondary grades when these subjects are compulsory (Palmer, 2020).

The findings have implications for curriculum and pedagogy in Bhutan. Chemistry is the subject that requires most urgent attention, requiring scope, difficulty, and perceived irrelevance to be addressed. Streamlining curricular scope could help to reduce anxiety around assessment in biology, especially given generally more favourable perceptions of content, and that difficulty was associated with needing to memorise so much content. Physics could be taken as a reference point, as despite the inclusion of abstract content and equations, many more students found it manageable, interesting and enjoyable. Unlike in other countries, where many students report finding physics hard because of the mathematics involved (Hamelo, 2016; Oon & Subramaniam, 2013), this was not evident in Bhutan. In mathematics, possibilities include reducing reliance on remembering formulae in assessments, and pedagogies focused on helping students differentiate between topics so they can determine which equation to use more confidently. Given the evidence that some students feel mathematics is 'not for them' (echoing Ekol, 2008), it seems that efforts to promote a 'growth mindset' (Dweck, 2006) would be particularly valuable in this subject, where students are more likely to associate poor performance with innate ability, and anxiety rises with learned helplessness and expectations of poor grades (Aldrup et al., 2020; Chinn, 2008).

This study has some limitations. Student self-report can be unreliable, especially in relation to performance, where students may not have uniform expectations of themselves, and may over- or under-estimate their achievements. In the absence of actual performance data, we treated identified broad patterns, but did not subject these to statistical tests of association. Geographical variation is a key feature of the Bhutanese education system, with teaching and learning in rural and remote schools identified as a priority in the Blueprint (Ministry of Education, 2014). While semi-urban and remote schools were sampled, the analysis has not made comparisons on a geographic basis – something that would be important in further research. Further analyses that investigate whether perceptions of one subject are associated with similar perceptions of others would also be valuable – exploring cases where all four subjects are perceived positively or the opposite, or potentially detecting other patterns of association (e.g., whether perceptions of mathematics and physics tend to correlate).

Nonetheless, this study addresses reveals prevalence and patterns that have important implications for Bhutanese education.

Through its focus on the less well-researched context of Bhutan, while also detecting patterns that resonate with prior studies in other countries, the study adds to an international body of knowledge on students' perspectives in science and mathematics. Findings echo patterns and causes for concern that have been highlighted in other countries in Asia and beyond, pointing to priority areas for curriculum and pedagogic reform. Volume of content, perceived irrelevance, and reliance on memorisation are warrant close attention and review. A challenge requiring further research concerns how inclusive and engaging pedagogic practices can be offered in conditions of heavy curriculum, limited classroom resources, and strong expectations of following national textbooks or teachers' guides, as in Bhutan but also elsewhere. Differences in students' perceptions and experiences between subjects mean reducing anxiety and promoting interest will require approaches that address specific qualities of content and pedagogy in each subject. Chemistry stands out internationally as requiring particular attention. Findings demonstrate the importance of equipping teachers to differentiate curriculum to reduce a perception among students that they have no means to do well, particularly given that perceived low ability can aggravate negative perceptions and fuel poor study habits. Reducing anxiety and negative perceptions in science and mathematics will require nuanced approaches that address curricular scope, content and pedagogic aspects.

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