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An Exploratory Study Into How Students Perceive Chemistry at a Cutting-Edge Science and Technology Higher Education School

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Chemistry is vital for a society focused on innovation, well-being, and sustainability as it impacts industry, education, and research. In Portugal, students lack interest in chemistry, not only in secondary school but also in higher education. To explore the underlying causes of this phenomenon, this research was undertaken in June 2023. The first phase involved analysing national official databases to identify enrolment patterns in 12th-grade chemistry and related higher education courses over the past decade. The next phase included developing a validated questionnaire with open and closed questions to understand factors influencing students' choices in higher education chemistry courses. A pilot survey was conducted with bachelor's students at the NOVA School of Science and Technology, NOVA Lisbon University. This research identifies key factors influencing students' choices to enroll in chemistry courses, offering insights for policymakers. While 12th-grade enrolment in chemistry has remained steady over the past eight years, enrolment in higher education chemistry courses has declined in the last three years. Key factors affecting student choices include the quality of the secondary chemistry class, the secondary teacher of physics and chemistry, and emotional satisfaction, whereas intellectual accessibility has been identified as a significant barrier.

Keywords: chemistry, students' attitudes, science and technology school

Introduction

The rapid scientific and technological advancements of recent decades necessitate individuals to possess scientific literacy to participate in the development of 21st-century society actively. Scientific literacy is crucial for understanding these advancements and making informed decisions on science-related matters, empowering individuals to think critically and contribute responsibly and effectively to the knowledge society. It involves a diverse set of skills and knowledge that enable individuals to critically and effectively engage with scientific concepts, processes, and issues. Scientific literacy plays an important role in allowing individuals to make informed decisions, participate in civic discussions, and engage in the democratic process, especially concerning policies that impact public health, the environment, and technological progress. One key component of scientific literacy is attitudes toward science (a positive attitude toward science, curiosity, and openness to new ideas foster a lifelong interest in learning about scientific advancements and their impacts on society).

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Theoretical Background

This study aimed to answer the following questions: Why do students choose Science and Technology courses in Higher Education? And what attitudes do students have regarding chemistry areas? To achieve the research goals, it is necessary to glance at students' attitudes toward chemistry, the framework/pillars of this paper are the Osborne et al.'s (2003) attitudes definition as "feelings, beliefs and values held about an object that may be the enterprise of science, school science, the impact of science on society or scientists themselves" (p. 1053), the theory of planned behaviour, and intrinsic chemistry area characteristics (nature of chemistry science), that will be deepened next.

Attitudes

Attitudes are considered tendencies or predispositions to respond to certain stimuli. The traditional tripartite model comprises three major types of responses: cognitive, affective, and behavioural. Cognition refers to how individuals perceive objects, including knowledge, beliefs, and judgments. Behaviour can be defined as an action, concerning an object, as well as intentions to act. From the cognitivist point of view, an attitude has an evaluative nature based on cognitive, affective, or behavioural aspects. Evaluation involves assessing beliefs, thoughts, feelings, emotions, intentions, and observable behaviours. Attitudes can be positive or negative feelings, such as liking or disliking an item. Reid (2007) describes feelings as affective factors, while Alsop and Watts (2000, 2003) state that affective factors in science education encompass interest, motivation, attitudes, beliefs, self-confidence, and self-efficacy. In their 2003 study, Osborne and collaborators (2003) defined attitudes as "feelings, beliefs, and values held about an object, which may include the enterprise of science, school science, the impact of science on society, or scientists themselves" (p. 1053). In this sense, attitudes cannot be considered as a simple construct, but rather one with many subconstructs, as noted by Potvin and Hasni in 2014.

Numerous studies have examined attitudes towards science (Potvin & Hasni, 2014), yet there is a relative scarcity of research focused specifically on attitudes towards chemistry (Kahveci, 2015a; 2015b). Nonetheless, some evidence suggests that positive attitudes towards chemistry are linked to academic achievement (Kan & Akbas, 2006; Brandriet, Xu, Bretz, & Lewis, 2011; Xu et al., 2013; Kahveci, 2015a; 2015b; Ozel, Caglak, & Erdogan, 2013), but attitudes can change over time, becoming either more positive or negative (Cheung, 2009; Chan & Bauer, 2014). However, attitudes towards science can also be "a learned, positive, or negative feeling about science that serves as a convenient summary of a wide variety of beliefs about science" (Xu & Lewis, 2011, p. 562). Nevertheless, research tells us, that achievement and attitudes can be improved by promoting enjoyable science lessons, welcoming learning environments (Ozel et al., 2013) and reinforcing and accomplishing positive attitudes in the classroom (George, 2000; Metsämuuronen & Tuohilampi, 2014; Potvin & Hasni, 2014; Simpson & Oliver, 1990).

Theory of Planned Behaviour

The Theory of Planned Behaviour (TPB) (Ajzen, 1985) is a psychological theory that aims to predict and understand behaviours based on individual intentions. Developed by Icek Ajzen in the 1980s, the theory builds on the earlier Theory of Reasoned Action (TRA), which focused on the relationship between attitudes and behaviour. The key components and constructs of the Theory of Planned Behaviour are "Behavioural Intention" (which refers to a person's readiness to perform a given behaviour. A stronger intention to engage in behaviour increases the likelihood that the behaviour will be performed.), "attitude toward the behaviour" (this component involves the individual's positive or negative evaluation of performing the behaviour. It reflects the person's beliefs about the outcomes of the behaviour and the value placed on those outcomes. If a person believes that performing a behaviour will lead to positive outcomes, they are likelier to have a favourable attitude toward that behaviour), “subjective Norms” (these are the perceived social pressures to perform or not perform the behaviour. This component reflects the influence of people’s social environment, including family, friends, and broader societal expectations. If an individual believes that it is important others expect them to perform the behaviour, they may be more likely to intend to do so), and “Perceived Behavioural Control” (is the individual’s perception of the ease or difficulty of performing the behaviour. It includes factors such as the perceived availability of resources, opportunities, and personal capabilities. If a person feels he/she has control over the behaviour and the resources to perform it, it is more likely to intend to act).

The Chemistry Area

Chemistry educators and researchers must regularly assess changes in students’ attitudes, self-efficacy, and learning experiences to maintain academic excellence in chemistry education. One of the key characteristics of chemistry is the constant interaction between the macroscopic and microscopic levels of understanding. This presents a significant challenge for beginners in chemistry and physics (Bradley & Brand, 1985). In his early study, Johnstone (1974) reported that students continued to struggle with certain topics well into university education. The most challenging areas included understanding the concept of the mole, chemical formulae, and equations, as well as in organic chemistry.

Numerous reports support the view that the interplay between macroscopic and microscopic worlds is a source of difficulty for many chemistry learners. Examples include the mole concept, atomic structure, kinetic theory, thermodynamics, electrochemistry, chemical change and reactivity, balancing redox equations and stereochemistry, chemical bonding, solution chemistry, covalent bonding, ionic bonding, metallic bonding, intermolecular forces, chemical bonds and energetic use of anthropomorphic language and analogies, mental models and enhancing students’ conceptual understanding. The field of chemistry is inherently conceptual. While memorization can lead to successful performance in exams, true comprehension requires the integration of these concepts in a meaningful manner. Therefore, despite students demonstrating some level of learning and understanding in exams, researchers have identified misconceptions, reliance on rote learning, and gaps in understanding fundamental chemistry concepts, even at the degree level (Johnstone, 1984; Bodner, 1991). This indicates that what is taught may not always align with what is learned (Sirhan, 2007).

Chemical knowledge is learned at three levels: “sub-microscopic,” “macroscopic”, and “symbolic”, and the link between these levels should be explicitly taught. The interactions and distinctions between these concepts are integral to learning chemistry and are essential for grasping chemical principles. Consequently, struggles at one level may impact understanding at another. Johnstone (1984; 1991) pointed out that the complexity of chemistry concepts and their representation (macroscopic, microscopic, or chemistry difficult to learn), overload students’ working memory space. When students encounter learning environments with an overwhelming amount of information, they struggle to differentiate between important and unimportant details. This information has been likened to “noise”, making it challenging for students to discern the essential information from the extraneous. Chemistry language and communication (which includes unfamiliar vocabulary, shifting word meanings, and complex language), and chemistry concept formation, are inherent to chemistry learning and require a great deal of intellectual thought and discernment due to the abundance of abstract concepts. Understanding requires grasping key concepts and making meaningful connections to create a coherent whole.

Ausubel (1968) emphasized connecting new knowledge to existing concepts for meaningful learning, where misconceptions can arise when connections are not made accurately and motivation plays a crucial role in determining the success of learning, and educators often encounter challenges when students lack the drive to comprehend. Moreover, students' perception, of the level of difficulty in a subject, significantly influences their capacity and readiness to learn it. In the same paper, Sirhan (2007) also refers, based on literature ways to reduce obstacles to learning, to compensate for the limited capacity of working memory by restructuring the information chunking it (items are processed in working memory as "chunks" of information, which can range from single characters to complex images). Chunking involves organizing information so that multiple items can be seen as a single unit, typically with a name or label. This process is crucial for communication and learning (White, 1988) and is a learned strategy that reflects one's knowledge of a topic. To recall/link to previous knowledge (or to improve recall), learners must proactively create, organize, and centralize internal connections that bind information together. The systematic organization of knowledge involves arranging individual components in a logical, coherent, concise, and principled manner. This organization is essential for effective learning, recall, manipulation, and application of knowledge. Additionally, to pay attention to incoming information, learners must focus on specific tasks, even in the presence of distractions. They also need to be able to pick out the important information within the task. Teachers can determine if learners are paying attention by seeing what they are learning (Ausubel, 1968). Learners need to understand when and where to concentrate, and what they should focus on. Discoveries regarding neuroscience, and cognitive science, also give clues, namely instructional strategies, to enhance learning in chemistry effectively (Hartman et al., 2022).

Methodology

This research work followed a qualitative approach (Bogdan & Biklen, 2007), being a case study (André & Ludke, 1986; Yin, 2012), which is based on the following research questions:

- Is the higher education system responding to society's needs for people trained in chemistry for industry, education, and research?
- Why do students choose chemistry?
- What perceptions do students have regarding the chemistry area?

This research work had three different parts: background overview at a national level, higher education students enrolled in science courses in the present, and why students chose their higher education course. To understand the study background, firstly, the number of students enrolled at the national level enrolled in Chemistry, Physics, and Biology at the pre-university level (12th grade), was obtained through, Direção-Geral de Estatísticas da Educação e Ciência (Directorate-General for Education and Science Statistics, https://www.dgeec.medu.pt/np4/home) in 2023. The second part identifies the number of students enrolled in Chemistry or related areas in higher education at the national level. Data were collected from public data RAIDES. The third part of the research analysed the NOVA School of Science and Technology students' perceptions. Over the past decade, the number of students studying chemistry at this school has remained consistent. To evaluate students' attitudes regarding chemistry, a survey entitled "Attitude toward the subject of Chemistry Inventory" was applied to students in two courses, Science Materials Bachelor and Applied Chemistry Bachelor. Attitudes toward the Study of Chemistry Inventory (ASCI) (Chang & Menke, 2022) was used to measure students' attitudes. Originally developed by Bauer (2008), the instrument was later modified and validated (Xu & Lewis, 2011; Xu et al., 2012; Rocabado, Kilpatrick, Mooring, & Lewis, 2019; Chang & Menke, 2022). A scale modification was used. Instead of an eight-item seven-point semantic differential scored instrument with two subscales: (1) intellectual accessibility; and (2) emotional satisfaction, we used a 16-item 10-point (between two opposite adjectives) semantic differential scored instrument (each score should range from 0 to 10, and 5 is in the middle point (neutral)), with two subscales: (1) intellectual accessibility; (2) emotional satisfaction. A lower score means students feel positive regarding chemistry; Chemistry is interesting and useful, intellectually accessible, safe, and emotionally satisfying. To avoid bias, in some items firstly appears the positive adjective and in others the negative one.

With the reliability of instruments as an outcome of the first research question, the study reported evidence in support of the robustness of ASCI in the form of acceptable Cronbach's alpha values (0.81, Applied Chemistry Course; 0.92, Materials Engineering Course), indicating not only the reliability of the data obtained from these instruments but also internal consistency of their subscales. The results of Cronbach's alpha reliability obtained in this study have generally coincided with those reported by others (Chang & Menke, 2022). Therefore, the psychometrics of ASCI may find a great degree of affective-related applicability to measure the students' attitudes regarding Chemistry.

Results and Discussion

In the Portuguese curriculum, the natural sciences are present throughout the educational process of all students until the 9th grade, and chemistry as an independent subject is present between 7th and 9th grade. Despite the significant need for science education, chemistry and chemistry-related subjects are not compulsory during the whole secondary education in Portugal. Students must decide whether to take them or not around the age of 15-16 when they enrolled in secondary school. The curriculum in Secondary Education requires the development of a key competency called "The Essential Learnings" (approved in 2018 for primary and secondary education scientific-humanistic) in Mathematical and Sciences.

The subjects of physics and chemistry are often considered some of the most challenging, demanding, and rigorous by students (Bøe, Henriksen, Lyons, & Schreiner, 2011; Cleaves, 2005; Osborne et al., 2003; Ribau, 2020; 2022). Importantly, research indicates that this perception significantly influences students' decisions to enroll in physics and chemistry courses (Palmer, Burke, & Aubusson, 2017; Shirazi, 2017; Smyth & Hannan, 2006). Specifically, Smyth and Hannan (2006) found a greater likelihood of students opting out of science subjects due to the perceived difficulty of the material. Furthermore, they noted that students who view these subjects as interesting and valuable are more likely to pursue them. Intriguingly, Solbes (2011) discovered in his study with Spanish students that physics and chemistry were seen as the most difficult courses, overly theoretical, uninteresting, and only marginally useful and engaging.

Numerous challenges hinder the effective teaching of chemistry, and these obstacles are (Matuk, Linn, & Eylon, 2015): (1) The chemistry subject involves understanding the chemical nature of combining abstract theoretical concepts. To grasp this, learners need to connect their understanding of the macroscopic level with the microscopic level, while also understanding the symbolic representation of chemical concepts (Johnstone, 1991; De Jong et al., 2013); (2) The majority of chemistry teachers still rely on traditional instructional methods, such as frontal lectures (Blonder &Waldman, 2019), some lack qualifications and skills to effectively monitor their students' learning in diverse classrooms (Orgill, Killedar, York, & Lamm, 2021). This can impact the teachers' perceived success or failure in advancing their students (Blonder, Benny, & Jones, 2014) and their motivation to teach (Kousa & Aksela, 2019); (3) The chemistry students. Some students hold alternative conceptions or misconceptions regarding chemistry concepts. These conceptions may hinder their understanding and learning (Ausubel, 1968).

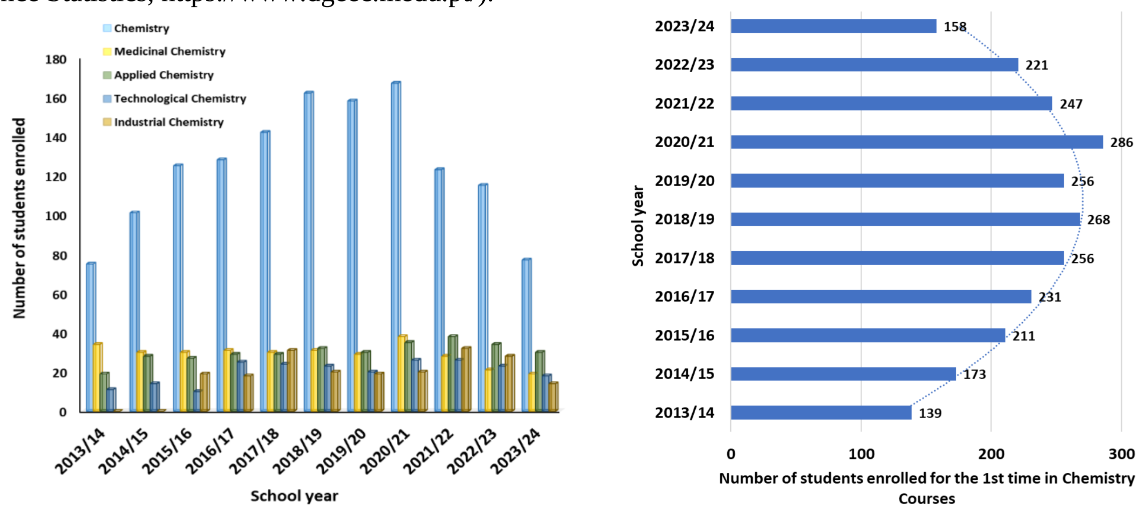
Students Enrolled in Physics, Chemistry, and Biology (12th Grade)

In the 2004 curricular reform, the compulsory attendance of two specific subjects (of the options: Chemistry, Biology, Physics, and Geology) for one subject, from the 2006/2007 academic year onwards, had the effect of relegating the subject of Chemistry in the 12th grade to one of the least chosen by the students. Considering the total number of students enrolled in the 12th grade (at the national level attending the Scientific-Humanistic Courses), between the academic year 2013/2014 and the academic year 2021/2022, the number of students varied between 9% and 10% of the total number of students attending secondary education (Directorate-General for Education and Science Statistics, https://www.dgeec.medu.pt/, Direção-Geral de Estatísticas da Educação e Ciência). At this point, there is a significant loss of students, since it is the moment when Chemistry becomes an optional subject, for students enrolled in the science field (scientific-humanistic), in the Portuguese educational system.

It is important to distinguish between two concepts: dropout and opt-out (Ardura et al., 2019; 2021). As pointed out by Ulriksen and collaborators (2010), “The term ‘drop-out’ is commonly used to describe those students leaving their study before they pass the final examination” (p. 209). However, the idea of opting out of a subject refers to not choosing it among a variety of optional courses (Ardura et al., 2018; 2019). In this sense, Portuguese students opt out of chemistry. Factors influencing the choice of physics and chemistry in secondary schools are diverse, such as social and cultural factors (grades in chemistry are lower than in other subjects in Portugal), school factors (not all schools offer Chemistry as a subject in 12th grade in Portugal), the difficulty of physics and chemistry subjects recognised by researchers, future studies (career prospects), gender effects and motivation, interest and attitudes towards science (Ardura et al., 2018; 2021).

Students Enrolled in Chemistry in Higher Education (1 Cycle, 1st Grade)

To perceive the number of students enrolled in the chemistry area, the national level was analysed using open data sources (survey RAIDES, retrieved on 2 January 2024 from Directorate-General for Education and Science Statistics, https://www.dgeec.medu.pt/).



(a) (b)

Figure 1. Number of students enrolled for the first time in courses in Chemistry in Higher Education at the national level. (a) in degrees in the area of Chemistry; (b) in all degrees in the area of Chemistry (Source: Directorate-General for Education and Science Statistics, retrieved on 2 January 2024 from https://www.dgeec.medu.pt/).

The number of students enrolled, at a national level, in the chemistry field since the 2020/21 school year has decreased. Why? The study of chemistry presents a challenging yet intriguing subject for many students. Chemistry is a critical branch of science that enhances our understanding of the world around us. Due to its focus on the structure of matter, many students find chemistry quite challenging. Chemistry encompasses essential abstract concepts important for driving progress in advanced chemistry and other scientific disciplines. These abstract concepts are crucial because a thorough grasp of these foundational concepts is essential for understanding more advanced chemistry and science theories. The complex and abstract concepts in chemistry, compounded by challenging content such as its mathematical aspects, necessitate that students possess a high-level skill set to succeed in chemistry classes. Chemistry is often considered a challenging subject, which sometimes discourages learners from pursuing further studies in this field (Sirhan, 2007; Ribau, 2020; Marchak, Shvarts-Serebro, & Blonder, 2021a; 2021b).

Higher Education Students Perception Regarding Chemistry (1 Cycle, 1st Grade)

The sample comprised students from two undergraduate courses (approximately 50% of the students enrolled in the three years), with 46.5% being female and 53.5% male. In the sample, 45% of the students were enrolled in the Materials Engineering program (41% enrolled in the first year; 31% in the second year; 28% in the third year of enrolment), while 55% were pursuing Applied Chemistry (45% enrolled in the first year; 13% in the second year; 43% in the third year of enrolment). For both courses, external examinations (national exams) of Mathematics and Physics-Chemistry, are mandatory for access to higher education.

The final admission grades of students have been consistently stable in recent years (data retrieved from RAIDES), in the Bachelor of Applied Chemistry since 2018 the evaluation of the last students entering the course was 14.7 ± 0.4 (maxim level is 20), and in Materials Engineering bachelor was 14.9 ± 0.5 (maxim level is 20).

To gauge the level of satisfaction regarding the goals and achievements they set when starting the course, respondents were asked to evaluate their overall satisfaction with the higher education program they attended. The data reveal that in the Materials Engineering course, 7.7% are dissatisfied, 53.9% are satisfied, and 38.4% are very satisfied. Only 2% of students who attended the Applied Chemistry course are dissatisfied, 51.0% are satisfied, and 47% are very satisfied.

To understand the background of the majority of the respondent students, they had to answer the question "What classes did you study during your senior year in high school?" and to assign two of these, see Table 1.

Table 1

Subjects of Respondents' Students That Had Been Enrolled in the 12th Year of Secondary School

Subjects	Applied Chemistry	Materials Engineer
Physics	6%	44%
Chemistry	68%	51%
Biology	68%	21%
English	19%	18%
Psychology	15%	13%
Informatics Applications	23%	38%
Economy C	0%	5%
Computing	0%	5%
Geology	0%	3%
Geography	0%	3%

More students in Applied Chemistry chose Chemistry as a terminal subject in secondary education (68% of students in an Applied Chemistry degree chose Chemistry; 51% of students in the Materials Science degree chose Chemistry). This decision may be a consequence in many secondary schools there is no chemistry as a subject in 12th grade, but also it could be influenced by how students perceive the field of Chemistry. To gain insight into how students perceive the demands of learning chemistry, they were presented with three statements to choose from: "Learning chemistry is less demanding than learning other subjects in the sciences, such as physics, biology, geology, and mathematics"; "Learning chemistry is equally demanding compared to disciplines in the sciences, such as physics, biology, geology, and mathematics"; "Learning chemistry is more demanding than learning other subjects in the sciences, such as physics, biology, geology, and mathematics".

Among the students of Applied Chemistry, 65.9% believe that learning chemistry is equally demanding, 23.4% feel it is more demanding, and the remaining students find it less demanding. In contrast, among the students of Materials Engineering, 48.7% consider learning chemistry to be equally demanding, 7.7% think it is more demanding, and 43.6% believe it is less demanding.

A question was presented to students about the criteria for selecting a higher education course. They needed to choose the four statements that best applied to their situation. The results are presented in Table 2.

Table 2

Students' Response to the Question: What Criteria Did You Use to Choose Your Higher Education Course? (They Had to Select the Four That Best Apply to Their Situation)

Item	Applied Chemistry	Materials Engineering
Be my area of interest	85%	82%
The themes of the disciplines/subjects	83%	38%
The proportion of practical classes	49%	5%
Course curriculum design	13%	3%
The number of places on the course	0%	8%
The minimum entry grade for the course in the previous year	21%	33%
The opinion of other students about the course	13%	26%
Career prospects	55%	38%
Employability rate	15%	69%
Expected remuneration	13%	31%
Good travel prospects	4%	3%
Have the opportunity to meet new people and places	11%	5%
Teaching quality	45%	36%

The main criteria for selecting the higher education course were "be the interest area" for both courses (assigned by 89% of the Applied Chemistry respondents and by 82% of the Materials Engineer respondents). For Applied Chemistry students the next most important reason was the "themes of the subjects" (87%) followed by "career prospects" (55%). For the students enrolled in Materials Engineering, the second most important criterion was "employability" (assigned by 69% of the respondents).

The survey also accessed "the reasons why students choose science and technology as their higher education area", as shown in Table 3. Among the respondents, the primary factor influencing their decision is the Science classes they took in secondary school, with 96% of Applied Chemistry students and 85% of Materials Engineering students assigning this reason. Additionally, the impact of science teachers is significant, with 72% of Applied Chemistry students assigning it, and 54% of Materials Engineering students mentioning their teachers as a key influence in choosing their higher education courses. Furthermore, 51% of Materials Engineering students noted that the influence of family and friends played a role in their decision. Osborne and collaborators (2003) also emphasize that teaching quality is crucial to engaging students in the science field. As Osborne, Simon, and Collins (2003) state "The single most important change that could be made to improve the quality of science education would be the recruitment and retention of able, bright enthusiastic teachers of science" (p. 1069).

Table 3

Results Regarding Which Influences Helped the Students Make Their Decision to Attend a Course in Science and Technology

Items	Applied Chemistry	Materials Engineering
Science classes in secondary education (Physics, Chemistry, Biology, Geology)	96%	85%
Scientists who went to the classroom/school to give a lecture	9%	18%
Enthusiastic science teachers (Physics, Chemistry, Biology, Geology)	72%	54%
Attendance at Science Clubs	6%	3%
Visits to science centres and museums	34%	36%
Television documentaries.	28%	38%
Books and magazines	19%	13%
Family and friends	30%	51%
Participation in "Ciência Viva" programs during the summer holidays	9%	0%

Considering the TPB, attitudes toward chemistry refer to how positively or negatively a student evaluates the subject. Subjective norms reflect the perceived social pressure related to learning chemistry, indicating whether that pressure encourages or discourages engagement with the material. The level of perceived control over learning chemistry describes how easy or difficult students find the learning process, shaped by their experiences in lectures, workshops, and laboratories. Attitudes toward chemistry, subjective norms, and perceived behavioural control regarding chemistry influence behavioural intentions, which ultimately manifest in behaviours (attending chemistry courses). Based on the results it is possible to see that family and friends are important for Materials Engineering (51% assign that option) and Applied Chemistry (30% assign that option) students, meaning that subjective norms had a rule in the student's choice.

To assess attitudes toward chemistry, the next question aimed to evaluate it. Data regarding Intellectual Accessibility and Emotional Satisfaction were collected for students enrolled in Applied Chemistry (Table 4). Intellectual accessibility refers to the ease with which individuals can understand, engage with, and relate to a particular subject. Several factors contribute to enhancing intellectual accessibility, such as clarity of language (which can significantly improve comprehension), relevance of the message (when a subject is relatable or applicable to an individual's personal or professional life, it becomes more engaging), availability of diverse resources (such as books, articles, videos, and lectures), adequate teaching methods and prior knowledge (which can scaffold learning as it allows building on learners' existing knowledge and experiences) that can facilitate the grasp of new concepts more effectively.

Emotional satisfaction refers to the feelings of fulfilment, enjoyment, and connection that individuals experience while engaging with a subject. Several factors can influence this satisfaction, including personal relevance (when a subject resonates on a personal level, it fosters a deeper emotional connection and fulfilment), passion and interest (a genuine enthusiasm for a topic can enhance engagement and lead to greater emotional satisfaction), community and connection (interacting with others who share similar interests can amplify emotional satisfaction through shared experiences and discussions), achievement and personal growth (overcoming challenges or mastering complex subjects often results in feelings of accomplishment and joy), and creativity and exploration (opportunities for creative expression or the exploration of new ideas can significantly enhance one's sense of satisfaction).

Table 4

Average, Standard Deviation, Median, Kurtosis and Skewness, for the Intellectual Accessibility and Emotional Satisfaction Scales (0 Indicating Intellectual Accessibility or Emotional Satisfaction and 10 Indicating Intellectual Disability or Emotional Dissatisfaction)

	Chemistry is …	Average	Standard deviation	Median	Kurtosis	Skewness
Intellectual Accessibility	Simple (0) ... complicated (10)	6.57	1.51	7.00	-0.22	-0.03
	Easy (0) … difficult/hard (10)	6.07	1.81	6.00	-0.54	-0.58
	Clear (0) … confused (10)	4.49	1.42	5.00	0.90	-0.60
	Understandable (0) ... incomprehensible (10)	2.48	1.58	2.00	-0.71	0.18
	Challenging (0) … unchallenging (10)	1.00	1.26	1.00	1.10	1.30
	Average	4.12	1.52	-	-	-
Emotional Satisfaction	Safe (0) … dangerous (10)	4.30	2.24	5.00	0,.10	0.07
	Organised (0) … chaotic/confused (10)	4.02	2.37	4.00	-0.54	-0.19
	Comfortable (0) ... uncomfortable (10)	3.04	1.50	3.00	-0.16	-0.39
	Satisfactory (0) … frustrating (10)	2.50	2.08	2.00	0.66	0.78
	Fun (0) ... scary (10)	2.17	1.96	2.00	0.63	0.93
	Pleasant (0) ... unpleasant (10)	1.70	1.50	2.00	1.96	0.98
	Exciting (0) …boring (10)	1.28	1.36	1.00	5.09	1.71
	Attractive (0) … repulsive/disgusting (10)	1.67	1.85	1.00	0.33	1.05
	Interesting (0) … dull (10)	1.07	1.62	0.50	7.39	2.46
	Good (0) … bad (10)	1.00	1.41	0.00	1.36	1.48
	Useful/Worthwhile (0) … useless (10)	0.70	1.67	0.00	20.94	4.15
	Average	2.13	1.78	-	-	-

The average score for intellectual accessibility was 4.12 ± 1.52 (M ± SD), while the average score for emotional satisfaction was 2.13 ± 1.76 (M ± SD). This suggests that students feel a higher level of emotional satisfaction, even though they are slightly less confident about their intellectual accessibility. This gap may be related to their perception of the complexity of the chemistry subject. Scrutiny of kurtosis and skewness provided evidence for good normality of the item scores, as no item had values less than -1.00 or greater than +1.00 in almost all items. But the items "exciting/boring", "interesting/dull", and "Worthwhile/useless", had Kurtosis values higher than 3 which indicates that there are outlier values, which may be the reflection of extremely positive perceptions or extremely negative perceptions of some students. Skewness higher than 1 indicates a data concentration in the positive part of the scale concerning the average score, which reflects a more positive attitude of almost all respondents' students.

Materials Engineering students evaluated their attitudes towards chemistry. The analysis of Intellectual Accessibility and Emotional Satisfaction is viewed in Table 5. The average score for Intellectual Accessibility is 4.60 ± 1.84 (M ± SD), while the average score for Emotional Satisfaction is 3.96 ± 2.13 (M ± SD). Examination of kurtosis and skewness provided evidence for good normality of the item scores, as no item had values less than -1.00 or greater than +1.00.

Table 5

Average, Standard Deviation, Median, Kurtosis and Skewness, for the Intellectual Accessibility and Emotional Satisfaction Scales

	Chemistry is …	Average	Standard deviation	Median	Kurtosis	Skewness
Intellectual Accessibility	Simple (0) ... complicated (10)	6.00	1.54	6.0	-0.56	-0.31
	Easy (0) … difficult/hard (10)	4.95	1.80	5.0	-0.43	-0.44
	Clear (0) … confused (10)	4.87	2.21	5.0	-0.29	-0.02
	Understandable (0) ... incomprehensible (10)	3.59	1.85	3.0	-0.26	0.18
	Challenging (0) … unchallenging (10)	3.58	1.83	3.0	0.10	0.39
	Average	4.60	1.84	-	-	-
Emotional Satisfaction	Safe (0) … dangerous (10)	4.53	1.80	5.0	0.24	-0.11
	Comfortable (0) ... uncomfortable (10)	4.50	1.68	5.0	0.56	0.36
	Organised (0) … chaotic/confused (10)	4.45	2.54	4.0	-0.72	-0.06
	Exciting (0) …boring (10)	4.26	2.20	4.0	-1.05	0.11
	Pleasant (0) ... unpleasant (10)	4.24	2.01	4.0	-0.04	-0.05
	Satisfactory (0) … frustrating (10)	4.24	2.49	4.0	-0.88	0.17
	Fun (0) ... scary (10)	3.92	1.94	4.0	0.16	-0.13
	Attractive (0) … repulsive/disgusting (10)	3.84	2.05	4.0	-0.59	-0.12
	Interesting (0) … dull (10)	3.24	2.41	3.0	-0.95	0.38
	Good (0) … bad (10)	3.21	2.04	3.0	-0.63	0.45
	Useful/Worthwhile (0) … useless (10)	3.13	2.27	2.3	-0.11	0.87
	Average	3.96	2.13	-	-	-

This suggests that Materials Engineering students report a lower level of emotional satisfaction compared to their peers in Applied Chemistry, as well as less confidence in their intellectual accessibility.

Conclusions

The current research project started as an attempt to capture a glimpse of the answer to the question: How can we engage students in chemistry? According to information from the Portuguese Ministry of Education, the percentage of students enrolling in chemistry for the 12th grade has remained consistent over the past ten years, accounting for 9% to 10% of all students in that grade. Some students who pursued chemistry area courses in higher education didn't enroll in chemistry in 12th grade. Most students consider that learning chemistry is as demanding as learning other subjects in the sciences, such as physics, biology, geology, and mathematics, but 23.4% of students in Applied Chemistry believe that it is more demanding, opposite to Materials Engineering whereas 43.6% believe it is less demanding. To perceive the reasons for this, we looked to investigate the students' background regarding their options in the 12th grade (the last school year before they entered higher education), and attitudes towards Chemistry, also scrutinized the main reason to pursue a science field, which for these respondents was related to the type of classes/lectures students attend and the science teachers in secondary school.

Analyses of factors, which influence students' intentions towards studying chemistry, were performed against the background of the "Theory of Planned Behaviour", which interprets people's behaviour by considering three factors: attitude towards behaviour (advantages or disadvantages of being involved in the behaviour, studying chemistry); subjective norm (approval or disapproval of important people towards engaging in the behaviour, parents, teacher, general norms of the society); perceived behavioural control (skills, knowledge, cooperation of others, abilities, efforts required to perform the behaviour). Analysis of these factors revealed some reasons for students' withdrawal from chemistry and pointed to factors which may facilitate students' persistence in the subject. A general analysis of students' attitudes towards different aspects of Chemistry revealed that students' attitudes towards chemistry tended to be emotionally satisfying, students enjoy chemistry, and consider that it is useful, good, interesting, comfortable, and pleasant—these feelings are more positive in the students of Applied Chemistry, although positive in both cases. On the other hand, students have felt less confident in their intellectual abilities regarding chemistry, they consider that the subject is complicated, and some that it is also confusing, but above all, they also have a positive attitude regarding intellectual accessibility.

Students in Applied Chemistry express satisfaction with the course, aligning with their emotional connection to chemistry, despite considering it complicated.

It should be noted that the feelings that emerge when students think about chemistry as safe/dangerous (medium 5) reveal that some students fear it (which may be due to unpreparedness or a sense of insecurity in laboratory work), showing the necessity for teachers, not only in secondary school but also in the higher education, to promote safe environments in the classroom, especially in laboratory environments. Regarding anxiety related to chemistry, a positive perception emerges, as the classification of chemistry regarding fun/scary, exciting/boring, and attractive/disgusting is positive in the two groups' study. Considering the perception of chemistry using the lens of interest and utility, it is possible to recognise that almost all students look at chemistry as useful. However, this positive image of chemistry, which emerges in this study is not enough to promote the chemistry area, the intellectual accessibility is more negative, which hinders the attitude to choose chemistry in higher education. Intellectual accessibility implies understanding and reasoning which fosters engagement. When a subject is intellectually accessible, individuals are more risen to invest time and effort, resulting in increased emotional satisfaction, which in turn, stimulates the feedback loop as positive feelings about learning and can enhance intellectual curiosity. When learners enjoy what they are studying, they are more motivated to seek out additional knowledge and learn. Thus, it is essential to create a supportive environment—one that prioritizes both accessibility and emotional support, such as inclusive classrooms and nurturing online communities (especially in higher education) to cultivate deeper engagement in chemistry.

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