

Preliminary Piloting of a Multidimensional Questionnaire on Anxiety in Science, Technology, Engineering, Mathematics Learning: Initial Evidence from a Retrospective Convenience Sample

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ABSTRACT

Science anxiety may influence students' engagement and persistence in Science, Technology, Engineering, Mathematics, yet its measurement in upper-secondary science remains fragmented. This pilot study developed and preliminarily examined a multidimensional questionnaire assessing subject-specific science anxiety, intolerance of uncertainty (IU), thinking-related anxiety, classroom context, and competence beliefs. A retrospective convenience sample of 44 1st-year teacher-education students completed the questionnaire based on their upper-secondary science learning experiences. Analyses focused on feasibility, internal consistency, item functioning, and preliminary associations among constructs. Most subscales showed acceptable to strong internal consistency, although some items and the perceived skills scale required refinement. Physics and chemistry were most often identified as the most anxiety-provoking science subjects. Descriptive correlations suggested that subject-specific anxiety, creative thinking anxiety, and IU were positively related, while teacher support, autonomy, and self-efficacy appeared partly distinct. Overall, the questionnaire provides a preliminary basis for further refinement and validation with current upper-secondary students.

KEY WORDS: Instrument development, intolerance of uncertainty, multidimensional questionnaire, science anxiety, science, technology, engineering, mathematics education, upper-secondary education

INTRODUCTION

Developing literacy and individual competence in Science, Technology, Engineering, Mathematics (STEM) is essential for understanding an increasingly complex and dynamic world, as well as for finding innovative solutions to global problems in a technology-driven society (Gough, 2015; Siekmann, 2016; UNESCO International Bureau of Education, 2019). Therefore, it is not surprising that STEM education, in the context of developing future competencies and accessing careers, has garnered significant attention in the Estonian national (Ministry of Education and Research, Republic of Estonia, 2021; U.S. Department of Education, 2022) and international education policies in recent decades (World Economic Forum, 2016; UNESCO, 2019; OECD, 2024). In addition, an increasing body of research has recognized the influence of STEM education on economic growth (Bacovic et al., 2022), as well as on national security and innovation (Corlu et al., 2014; Cai, 2021). It remains crucial for students to develop STEM competencies, not merely for political or employment-related reasons, but because research indicates that STEM education fosters critical thinking, enhances cognitive abilities, and equips individuals with problem-solving skills necessary for navigating complex

challenges (Duran and Sendag, 2012; Firdaus and Rahayu, 2019).

In this study, the focus is on the science component of STEM, as some STEM fields, such as technology or engineering, are not clearly represented subjects in general education (Bybee, 2013). In addition, focusing on science is supported by ongoing issues related to the practical implementation of the STEM framework in schools (Margot and Kettler, 2019). Nevertheless, STEM is used as a broader context because it provides a wider framework for understanding both career choices and the key outcomes of STEM learning that are not limited to disciplinary content. Research in secondary education emphasizes anxiety as a potential modulator of future career choices, particularly in shaping interest and persistence in STEM fields, as shown repeatedly in research on mathematics anxiety (Ahmed, 2018; Seo et al., 2019) and science anxiety (Megreya and Al-Emadi, 2023). At the same time, in STEM education, disciplinary knowledge is applied to authentic problems and is explicitly linked with broader competences such as problem solving, critical and creative thinking, collaboration, and communication, which are commonly positioned as core elements of STEM literacy (Falloon et al., 2020).

Despite broad agreement on the importance of STEM education, anxiety has gained increasing attention as a barrier to students' well-being and engagement in STEM learning. Such anxiety has been reported in the context of mathematics (Ramirez et al., 2018; Barroso et al., 2021), science (Hong, 2010), chemistry (Jegade, 2010), biology (Çimen and Yilmaz, 2015), and physics (González et al., 2017). Anxiety is a psychological state characterized by negative apprehension, unease, and worry about an upcoming event or task, often with a component of ambiguity or uncertainty, such as the possibility of failing a test in school (Zeidner and Matthews, 2010). Just as test anxiety is understood as a context-specific form of anxiety arising in evaluative situations where performance is judged, STEM anxiety can also be conceptualized as a phenomenon that emerges within a specific educational context. Anxiety can be described through cognitive (worry), affective (tension, nervousness), and behavioral (procrastination, avoidance) dimensions (Morris et al., 1982; Sarason, 2013). It is consistently related to decreased performance (Owens et al., 2014; Barroso et al., 2021; Tang and He, 2023), mainly through the mechanisms explained by processing-efficiency theory and attentional control theory.

Processing-efficiency theory proposes that worry consumes working-memory resources needed for accurate reasoning and problem solving (Eysenck and Calvo, 1992; Ashcraft et al., 1998; Caviola et al., 2012). Attentional control theory adds that anxiety shifts attention to threat cues, thereby undermining goal-directed task focus (Eysenck et al., 2007). Although much of the evidence comes from mathematics, these mechanisms are domain-general and also apply to science learning and science assessments, which often require abstract reasoning and problem solving (Hembree, 1990; Barroso et al., 2021). Longitudinal and experimental work together indicates a reciprocal relation: lower prior achievement can fuel later anxiety, and anxiety can impair concurrent performance (Ma and Xu, 2004; Carey et al., 2016; Pekrun, 2006). While research in mathematics is abundant, in science, deeper interactions between performance and motivational variables such as anxiety still require further investigation (Rozgonjuk et al., 2024), especially because science encompasses several subjects with identified subject-specific variables, such as laboratory work in chemistry (Kurbanoglu and Akim, 2010), while variables such as research methods or inquiry practices share similarities across several subjects and have also been associated with anxiety (Mensah et al., 2023). In addition, anxieties related to cross-cutting skills such as problem solving (Pleasant, 2020) and types of cognition such as creative thinking (Daker et al., 2023) are relevant in science and STEM learning contexts, emphasizing the unique and overlapping dimensions of anxiety within the science (and STEM) field.

Taken together, evidence from processing efficiency theory and attentional control theory points to a reciprocal cycle:

Lower prior competence can heighten science anxiety, and heightened anxiety can undercut concurrent performance. At the same time, some students with elevated anxiety can still perform well (Eysenck et al., 2007; Rozgonjuk et al., 2024), indicating heterogeneity in how anxiety manifests and functions across individuals. This dynamic suggests that science anxiety can be addressed from both sides: By strengthening students' competencies and by reducing anxiety-related drivers. It also highlights the value of supporting cross-cutting skills and classroom resources, such as tolerance of uncertainty, autonomy and competence support, and creative or flexible thinking, alongside subject-specific support where needed.

Despite increasing interest in anxiety in mathematics and science learning, measurement remains fragmented in general education contexts. Early work on science anxiety described it as a debilitating interplay of fear and cognition in science learning and noted that it can manifest in science-class assessments while remaining distinct from general test or performance anxiety (Mallow, 1978; Mallow, 2006; Alvaro, 1978). However, much of the existing measurement either continues to treat science anxiety broadly (Brownlow et al., 2000; Özbugutu, 2021) or focuses on single domains (Sahin, Caliskan & Dilek, 2015), which can overlook how anxiety may be experienced differently across science subjects. This distinction is especially relevant in upper-secondary education, where "science" is typically no longer a single integrated subject but is organized into separate disciplines (e.g., physics, chemistry, biology, and geography, as natural geography courses in the Estonian curriculum fit under science). As a result, subject-specific measurement becomes necessary, yet there is less insight into how subject-specific anxieties co-occur and form meaningful patterns within students. In addition, relatively few anxiety measures incorporate process-oriented components that are central to science and STEM learning, such as intolerance of uncertainty (IU) (Terry et al., 2023) and anxiety related to creative, open-ended problem solving. The current study addresses these gaps by developing and piloting a multidimensional questionnaire that combines subject-specific science anxiety with cross-cutting, process-relevant components (uncertainty- and creative-thinking-related anxiety) and classroom-context variables, providing preliminary evidence of feasibility, internal structure, and reliability.

This study has three aims:

1. To develop and preliminarily pilot a multidimensional questionnaire on science anxiety that incorporates both subject-specific and broader process-related dimensions;
2. To examine the preliminary evidence regarding the questionnaire's feasibility, internal consistency, and item functioning, in a pilot sample;
3. To explore preliminary associations among the included constructs in the pilot sample, with attention to whether the observed pattern of relationships was broadly consistent with the proposed conceptual framework.

Literature Review on Measuring Science in STEM

Each school level presents distinct psychological and educational challenges, which are reflected in the focus of anxiety research. Research indicates that negative emotions such as anxiety can begin to emerge in academic settings early in schooling, for example, as early as first or second grade in mathematics (Sorvo et al., 2017; Rina, 2024) and by around third and fourth grade in science subjects (Chiarelott and Czerniak, 1987; Henschel, 2021). Science-related anxiety has also been reported among high school students (Rozgonjuk et al., 2024), as well as in college-level contexts (Pfau et al., 2024) and among university students (Udo et al., 2004). Importantly, the way anxiety is conceptualized and measured often varies across educational levels. In general education, measurement typically reflects the structure of students' coursework: in lower grades (including in Estonia), science is often taught as a more general subject, whereas in upper-secondary education it is usually divided into separate disciplines such as physics, chemistry, biology, and geography. At the tertiary level, students' experiences are embedded in more specialized STEM tracks, and research often focuses on anxiety in demanding STEM courses and training contexts, including gender differences (Blickenstaff, 2005) and the challenge of balancing academic and personal life (Hegenauer, 2018; Pester et al., 2023). More broadly, the framing of anxiety also differs across educational levels: In higher education, anxiety is often discussed in relation to workload and adjustment demands (Hegenauer, 2018; Nelson et al., 2019), whereas in earlier stages of education it is more often linked to subject engagement and future educational or career pathways (Ahmed, 2018; Megreya and Al-Emadi, 2023; Seo et al., 2019).

A further reason for differences in measurement lies in limited conceptual clarity regarding what is meant by "STEM anxiety." Although the term has gained visibility in recent years (Albion et al., 2016; Charette, 2016; Gonzalez et al., 2019), most research has continued to examine subject-specific anxieties, particularly in mathematics and science. With some exceptions, such as work linking mathematics anxiety to STEM career choices (Ahmed, 2018), fewer studies have examined the extent to which students experience anxiety across multiple STEM contexts. At the same time, while some authors emphasize the growing adoption of integrated STEM education in schools (Moore and Smith, 2014), others note ongoing concerns about implementation and stakeholder readiness (Margot and Kettler, 2019). Measuring anxiety across all STEM domains presents additional challenges, particularly because engineering and technology are not typically offered as clearly defined, standalone subjects in school curricula (Bybee, 2013). As a result, anxiety in school settings is more often measured within subject-based domains, especially mathematics and science, even when broader STEM outcomes, such as career intentions and cross-cutting competences, remain relevant. The complexity increases further when broader frameworks such as STEAM or STEM+ are considered (Aguilera and

Ortiz-Revilla, 2021; Liao, 2016). Overall, the inconsistent ways in which STEM is conceptualized and enacted across educational systems highlight a critical challenge: Without a shared understanding of what constitutes STEM, it becomes more difficult to define, assess, and interpret anxieties associated with STEM learning.

In one of the few reviews explicitly addressing anxiety in STEM contexts, Grimes and Gardner (2023) provide a critical synthesis of how disciplinary anxieties across STEM have been conceptualized and measured. They note that integrated STEM is an ill-defined concept and that disciplinary anxiety literature has often been developed in isolation from one another, even though integrated STEM may generate new forms of anxiety as an emergent barrier in reform contexts. Based on antecedents identified across disciplinary anxiety literature, they propose a framework that groups potential causes into four domains - global, environmental, personal, and intellectual.

To clarify these domains, Grimes and Gardner describe intellectual antecedents as cognitive factors such as background knowledge, cognitive demands of tasks, required procedures or strategies, and trait anxiety. Personal antecedents are organized around identity-related factors, including demographic identity markers (e.g., gender identity, socioeconomic status) and academic identity components such as attitudes, self-efficacy, other content anxieties, and prior performance. Environmental antecedents include factors in direct contact with the learner, particularly the learning environment, peers, and teachers. Global antecedents refer to broader structural and systemic conditions, such as curriculum design and other macro-level features of schooling and assessment (Grimes and Gardner, 2023). This framework offers a useful starting point for conceptualizing STEM anxiety as multifaceted and context-sensitive, and it aligns with the need to consider both discipline-specific and cross-cutting experiences of anxiety. Related reviews have likewise suggested that anxiety manifests differently across STEM disciplines and that integrated STEM and engineering contexts remain comparatively underexamined (Christensen and Osgood, 2024).

Evidence from broader anxiety research in education suggests that different anxiety forms can co-occur but also cluster into distinct patterns within individuals. Using latent profile analysis, Carey et al. (2017) identified groups characterized by generally low to high anxiety levels, as well as profiles marked by relatively elevated academic anxiety (test and mathematics anxiety) versus elevated general anxiety. Notably, these profiles became more differentiated in older students, suggesting increasing specificity of anxiety with development. This person-centered perspective supports examining science anxiety not only as a single continuum, but also as potentially heterogeneous patterns, such as anxiety concentrated in particular academic domains or more broadly distributed across learning contexts.

STEM anxiety can be meaningfully examined both in subject-specific contexts, such as science classes, and in relation to particular processes or skills.

First, domain-specific anxieties (e.g., anxiety related to chemistry or physics) capture content and assessment features that are unique to each subject. Reviews and recent studies suggest that science anxieties frequently overlap with mathematics and problem-solving demands, yet still retain discipline-specific triggers (Grimes and Gardner, 2023; Li and Palaroan, 2024; Rozgonjuk et al., 2024). For example, Widanski and McCarthy (2009) assessed chemistry-related anxiety and distinguished among apprehension about learning chemistry, fear of evaluation in chemistry, and apprehension about handling chemicals. While fear of handling chemicals is specific to the chemistry context, fear of evaluation can manifest in any subject, illustrating the overlapping nature of anxieties.

Second, cross-cutting, process-oriented components reflect anxiety elicited by recurring features of learning tasks, such as uncertainty, evaluation pressure, or need for idea generation and flexible thinking, that can appear across subjects. This aligns with emerging work on cognition-specific anxieties, defined as a tendency to feel anxious when faced with situations that require a particular type of thinking (e.g., creative thinking), which may be linked not only to performance but also to avoidance of related activities and pathways (Daker et al., 2023). Uncertainty is especially relevant in this framework because it links science learning with anxiety through both epistemic and pragmatic control. From an uncertainty-theory perspective, anxiety is not only a reaction to a known threat, but also to a possible threat for which the occurrence, meaning, or manageability remains unclear; it therefore involves both the need to know what may happen and the need to feel able to influence or manage the situation (Miceli and Castelfranchi, 2005). Related models similarly describe uncertainty as anxiety-relevant when it is appraised as threatening, uncontrollable, or difficult to resolve (Carleton, 2016; Grupe and Nitschke, 2013; Tanovic et al., 2018). In academic settings, tests and grades provide a familiar example: Students may experience uncertainty both about what result they will receive and about what they can do to improve or control that result. This overlap is important for science education because science learning often requires students to work with incomplete information, alternative explanations, open-ended inquiry, and uncertain outcomes. Thus, IU is included here not as a separate clinical trait, but as a cross-cutting learning-related construct that may help explain why some students experience science tasks as affectively demanding across subjects. It may also point to different ways of reducing anxiety: By reducing unnecessary uncertainty through clearer instructions and expectations, or by helping students manage unavoidable uncertainty in tasks where there is no single clear solution.

Measuring both levels, therefore, offers stronger diagnostic value: Subject-specific scales identify situations where anxiety

is most prominent, while cross-cutting components (e.g., IU, autonomy support, creative vs. control-task anxiety) help explain why some students experience anxiety broadly across classes. This dual approach also aligns with intervention logic: targeted, subject-specific supports can address discipline demands, whereas strengthening general competencies can transfer across science (and broader STEM) contexts (Grimes and Gardner, 2023; Li and Palaroan, 2024).

Theoretical Background and Conceptual Framework for the Questionnaire

The present study is grounded in expectancy-value theory (EVT) (Eccles and Wigfield, 2002), social cognitive theory (SCT) (Bussey and Bandura, 1999), self-determination theory (SDT) (Deci and Ryan, 2000), and control-value theory (CVT) of achievement emotions (Pekrun, 2006; 2018; 2021). EVT and SCT emphasize the role of students' expectations for success or failure, competence beliefs, and perceived capability in shaping engagement, persistence, and future educational choices. SDT complements this perspective by highlighting the importance of autonomy, competence, and relatedness for intrinsic motivation and optimal functioning (Deci and Ryan, 2000). Together, these perspectives provide a rationale for including autonomy, competence-related beliefs, and classroom contextual variables in the present framework.

CVT conceptualizes anxiety as a negative activating achievement emotion shaped by students' appraisals of control and value (Pekrun, 2006; 2018; 2021; Forsblom et al., 2022). Recent work further suggests that task-related uncertainty can influence perceived control and, through it, achievement emotions such as anxiety and enjoyment (Li, 2026). Within this logic, science-related anxiety may arise when students perceive science tasks as important but difficult, uncertain, or only partly controllable. This supports examining science anxiety not only at the subject-specific level, but also alongside cross-cutting, process-oriented components such as IU and creative-thinking-related anxiety.

The conceptual framework of the present study (Table 1) distinguishes between subject-specific science anxiety, cross-cutting, process-oriented anxiety components, and contextual variables. Subject-specific anxiety refers to anxiety experienced in relation to particular science subjects, whereas cross-cutting components capture recurring features of learning situations that may elicit anxiety across subjects, such as uncertainty and demands for creative or controlled thinking. These are examined together with classroom-context variables (teacher support, autonomy), competence-related beliefs (self-efficacy, perceived knowledge, self-perceived skills), and STEM-related intentions, which may help explain variation in students' anxiety experiences and their motivational implications. Within Grimes and Gardner's (2023) framework, the constructs included in the present study capture primarily intellectual antecedents (e.g., perceived knowledge, self-perceived skills,

Table 1: Theoretical grounding and conceptual role of the study constructs

Construct	Main theoretical grounding	Role in the present framework
General science-related anxiety; Subject-specific science anxiety	Academic emotions; domain-specific anxiety research; CVT	Core anxiety construct tied to particular science subjects; contextualized achievement-related emotion. Prevalence and focus of subject-specific anxiety.
Intolerance of uncertainty	Uncertainty theory of anxiety: need for control; CVT	Cross-cutting, process-oriented anxiety component related to tolerating uncertainty in learning. Inhibitive influence of uncertainty.
Creative-thinking anxiety	Uncertainty theory of anxiety; Cognition-specific anxiety; open-ended task demands.	Cross-cutting, process-oriented component related to idea generation and flexible thinking.
Control-task (non-creative) anxiety	Uncertainty theory of anxiety; Achievement emotion/performance-focused task anxiety.	Cross-cutting, process-oriented component related to solving familiar tasks with clear instructions, opposite to creative tasks.
Perceived social support from the teacher	Social-context models; classroom environment; environmental antecedents.	Classroom-context variable; possible protective variable from anxiety.
Perceived autonomy	CVT, SCT, SDT, Motivational-context perspectives; environmental antecedents.	Classroom-context variable related to perceived control and learning environment.
Self-efficacy	SCT, EVT expectancy beliefs.	Competence and academic identity-related beliefs.
Perceived subject-specific knowledge	SDT, SCT; Competence beliefs; intellectual antecedents	Self-perceived competence in specific science subjects
Self-perceived science skills	SDT, SCT, transferable scientific competences; intellectual antecedents	Self-perceived competence across science-related skills
STEM career intentions	EVT value and choice logic; academic identity	Future-oriented motivational outcome
Work-skills preference	Career motivation; transferable competence orientation	Future-oriented preference for broader skill-based work characteristics; relation to creative thinking

SCT: Social-cognitive theory, CVT: Control-value theory, EVT: Expectancy-value theory, STEM: Science, technology, engineering, mathematics

and uncertainty-related processes), environmental antecedents (teacher support and perceived autonomy), and personal or academic-identity-related antecedents (self-efficacy and STEM career intentions), rather than systemic antecedents.

The present study draws on a set of constructs that address science-related anxiety from partially different but complementary perspectives. Some capture anxiety as tied to particular school subjects, whereas others reflect broader cognitive-affective tendencies that may become relevant in contemporary science and STEM learning environments, such as responding to open-ended tasks or managing uncertainty. Table 2 provides a brief overview of the theoretical grounding and conceptual role of each construct.

METHODS

Sample and Procedure

Data was collected in early October 2025. Participants were primarily 1st-year bachelor's students enrolled in the University of Tartu teacher education program and preparing to become lower-secondary (Grades 7–9) science teachers. The survey was administered during the course Teaching and Learning in Science and Mathematics Education. Participation was voluntary and anonymous. In total, 45 students accessed the survey, of whom 44 submitted complete questionnaires that were included in the analyses. Partial responses were excluded. Of the 44 participants, 77.3% (n = 34) identified as female, 20.5% (n = 9) as male, and one participant selected “Other” in the gender field. No additional demographic information was collected.

Before responding, participants were provided with a short introductory text explaining the purpose of the study and the voluntary, anonymous nature of participation. They were informed that the questionnaire concerned experiences related to learning science subjects and were asked to respond retrospectively, reflecting on their upper secondary school science learning. The introduction also stated that there were no right or wrong answers, that completing the questionnaire could take up to approximately 45 min, and that the survey included questions about knowledge, skills, emotions, and anxiety experienced in science classes. Anxiety was briefly described as an emotional state that may involve worry, tension, or nervousness and may have both activating and unpleasant aspects. The questionnaire was administered online through LimeSurvey. In accordance with institutional guidelines, formal ethical approval was not required for this pilot study. General feedback on the aggregated results was later provided within the same course.

The questionnaire comprised 93 items covering the following domains: subject-specific science anxiety, creative and non-creative thinking anxiety, IU, perceived social support from the science teacher, self-efficacy and perceived autonomy in science class, self-perceived knowledge in science, and self-perceived skills in science (Table 2). The questionnaire was developed pragmatically on the basis of existing literature on science-related anxiety and conceptually related constructs. This aim arose from the observation that existing measures often assess anxiety either at a general science level, within a single subject domain, or in relation to isolated affective constructs. In response to this gap, the present instrument was constructed by combining adapted items from previously validated scales

Table 2: Instrument sources and construct theoretical justification

Instrument name	Citation of instrument development	Instrument structure	Scale*	Modification in the present study	Example item	Theoretical context
Subject-Specific Science Anxiety	Combination of items from Rozgonjuk et al., 2024 and country's grade level science assessment in 10 th grade. Original: Internal reliability of the scale, Cronbach's $\alpha=0.87$.	1 item about listing anxiety levels in science and math subjects. 1 item about choosing the most anxiety-provoking subject (science options only) 5 items about subject-specific anxiety in the most anxiety provoking subject	1=Completely disagree to 5=Completely agree	Original scale is 4-point Likert	Please indicate whether you experience anxiety in the following subjects. From the list above, select one subject in which you feel the most anxiety. I often worry that it is difficult for me in [chosen subject - chemistry/physics/geography/biology] lessons.	Subject-specific measurement remains the most common approach in science anxiety research and is well-suited to secondary school contexts where biology, chemistry, physics, and geography are taught as separate disciplines (Grimes and Gardner, 2023). This approach acknowledges that different science subjects may evoke anxiety through distinct content, practices, or learning situations, even when these are not measured in detail within the present instrument. It also supports the identification of science anxiety profiles by showing which subjects students perceive as more or less anxiety-provoking and how anxieties across subjects may cluster.
Creativity Anxiety Scale	Daker et al., 2020 Original: Internal reliability of the scales Cronbach's α CA=0.96 NAC=0.94	12 items: - 8 creativity-specific anxiety items (CA) - 4 noncreativity anxiety (control) items (NAC)	1=not at all anxious 5=very anxious	The original scale has other context options besides science class.	Below you will find various statements. Please indicate how anxious each situation would make you feel in the subject you selected. CA: Having to come up with a unique way of doing a task. NAC: Having to precisely follow an established method of doing something.	Creative thinking anxiety was included because science and STEM learning increasingly emphasize open-ended and complex problem-solving (Lee and Grapin, 2022). Here, creativity is understood (Plucker, Beghetto & Dow, 2004) as the generation of novel and valuable ideas or solutions (Runco and Jaeger, 2012; Daker et al., 2020). The construct therefore refers to anxiety toward creative thinking as a way of thinking rather than toward a specific subject domain. This is relevant in science education, where such thinking often requires students to engage with novelty, ambiguity, and uncertainty, all of which may heighten affective demands (Daker et al., 2020; Hirsh et al., 2012).
A short version of the Intolerance of Uncertainty Scale (IUS-12)	Freeston et al., 1994; Carleton et al., 2007	12 items: - 7 prospective IU items - 5 inhibitory IU items	5-point scale 1=Not at all like me to 5=Completely like me	Original items were retained, but each item was contextually adapted by adding the phrase "in the chosen science subject." No further wording changes were made.	When its time to act, uncertainty (in the chosen subject lesson) paralyzes me.	IU refers to a dispositional tendency to react negatively to uncertain situations and outcomes (Ladouceur et al., 2000). It has been linked to worry and anxiety (Çavdar & Boyacioglu, 2025) because uncertainty may be appraised as threatening, difficult to manage, or beyond one's control (Koerner and Dugas, 2006; Grupe and Nitschke, 2013). In educational contexts, IU is relevant because learning often involves ambiguity, incomplete knowledge, and uncertain performance outcomes. This may be especially salient in science-related contexts, where students are expected to engage with unfamiliar, complex, or open-ended problems.
Child and Adolescent Social Support Scale (CASSS), teacher subscale	Malecki et al., 2000; Malecki et al., 2003; Rueger et al., 2010	12 items, 3 items for each support type: - Emotional, - Informational, - Appraisal, - instrumental	1=Never to 5=Always	Originally, the instrument included both a frequency scale (1=never to 6=always) and an importance scale (1=not important to 3=very important).	My science teacher is fair to me.	Perceived teacher support was included because social support has been associated with students' academic functioning, self-concept, and emotional adjustment (Demaray and Elliott, 2001; Demaray and Malecki, 2002a; 2002b; Malecki and Demaray, 2003a; 2003b).

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Table 2: (Continued)

Instrument name	Citation of instrument development	Instrument structure	Scale*	Modification in the present study	Example item	Theoretical context
				Only the frequency scale was used here, in a modified 5-point format (1=never to 5=always). Additionally, the original version included other sources of social support, like parental support. Originally, two scales were used: frequency: 1=never to 6=always; importance: 1=not important to 3=very important).		In line with the framework underlying the Child and Adolescent Social Support Scale, social support is understood as students' perceptions of available or enacted supportive behaviours from members of their social network that enhance functioning and may buffer adverse outcomes (Tardy, 1985; Malecki et al., 2000). In the case of teachers, this may include emotional, informational, instrumental, and appraisal support (Malecki et al., 2000). This is also relevant in math and science learning, where perceived social support has been linked to more positive attitudes and stronger perceived ability (Rice et al., 2013).
Autonomy Scale	Based on Eccles et al., 1991; Modrek et al., 2021 Original: Internal reliability of the scale Cronbach's $\alpha=0.78$.	5 items	1=never to 5=always.	The original scale was framed in relation to "science" in general. In the present study, the wording was modified to refer to "the chosen science subject" in order to make responses subject-specific. Additionally, the original version included 5 items about autonomy wanted. In current study, only the autonomy given items were retained. original scale context was "science," in the current study "in chosen science subject"	I have a say in what counts as a good answer or a good piece of work in the chosen subject.	Autonomy is a core construct in self-determination theory (Deci and Ryan, 1985) and refers to students' experience of choice, volition, and non-controlling support in learning contexts (Black and Deci, 2000). In education, students' perceptions of instructor autonomy support have been associated with increases in autonomous motivation (Jungert & Koestner, 2015; Hagger et al., 2015) and perceived competence and with decreases in anxiety (Yu et al., 2016) over time; these changes have also been linked to course persistence and performance (Black and Deci, 2000). Accordingly, perceived autonomy provides a theoretically grounded indicator of classroom climate that is relevant for students' engagement and affect (Niemic & Ryan, 2009) in science learning (Guay, 2022).
Patterns of Adaptive Learning Scale (PALS), self-efficacy subscale	Midgley et al., 2000; Van Aalderen-Smeets et al., 2019	5 items - self-efficacy	1=Completely disagree to 5=Completely agree	Originally, the scale used a 4-point Likert format and was framed in relation to "STEM." In the present study, it was adapted to a 5-point scale and contextualized to "the chosen science subject."	I am certain I can master the skills taught in the chosen subject classes.	Self-efficacy refers to a person's belief in their capability to successfully perform tasks in a specific domain or situation (Bandura, 1997).

(Contd...)

Table 2: (Continued)

Instrument name	Citation of instrument development	Instrument structure	Scale*	Modification in the present study	Example item	Theoretical context
Perceived subject-specific knowledge in science (Original scale developed for the study)	Unpublished	22 items, perceived knowledge in science subjects: - 6 physics - 6 chemistry - 6 biology - 4 geography	1=very little to 5=very good	None, original scale.	Please evaluate your knowledge in the following topics: - Pressure in gases and liquids. - Chemical reactions with polymers. - Human nervous system and functioning. - Renewable energy resources.	It is one of the most frequently assessed affective constructs in STEM-learning measurement, reflecting its central role in students' engagement and persistence (Wieselmann et al., 2023). Theoretically, self-efficacy is proposed to function as a key pathway linking students' implicit ability beliefs to STEM intentions: Students with entity beliefs (abilities are fixed) may interpret setbacks as evidence of low innate ability, which can undermine self-efficacy, whereas incremental beliefs support effort-based attributions that help preserve self-efficacy over time (van Aalderen-Smeets and Walma van der Molen, 2016). Lower self-efficacy, in turn, is associated with weaker STEM aspirations and reduced likelihood of choosing STEM-oriented study paths or careers, making it an important target for understanding and supporting STEM participation (e.g., Betz and Hackett, 1983; Wigfield and Eccles, 2000). Perceived subject-specific knowledge captures how much students believe they know in a given science subject. This is relevant because students' judgments of what they do and do not know form part of metacognitive awareness, which supports monitoring of understanding, self-regulation, and more effective learning (Ziegler and Montplaisir, 2014). It is also educationally important because subject-specific content knowledge provides a foundation for success in science learning, and stronger preparation is associated with continued participation in science-related pathways (Newell et al., 2015). The topics included in the scale were derived from the country's upper secondary science curricula and were selected based on the assumption that they are familiar to students.
Perceived skills related to science learning (Original scale developed for the study)	Unpublished	16 items	1=Very little to 5=Very good	None, original scale.	Please evaluate your skills on a scale from 1-5. - I can use the scientific method to solve different science-related problems. - I can formulate research questions. - I can distinguish scientific evidence from non-scientific information	Self-perceived subject-specific skills captures how capable students believe they are of performing subject-related tasks. This is relevant because such self-perceptions reflect perceived competence, which is an important part of students' self-beliefs in science and has been associated with engagement, achievement, and future aspirations (Beghetto, 2007).

*All instrument scales were unified to the 5-point Likert scale in the study. Notes are added to modified scales. No note indicates that the 5-point Likert scale was used in the original instrument. STEM: Science, technology, engineering, mathematics

with newly developed subject-specific components intended to capture anxiety across different science subjects as well as related experiences relevant to science learning. In particular, the questionnaire sought to capture both anxiety tied to specific science subjects and broader experiences that may shape how students encounter uncertainty, competence, and demanding thinking processes in science learning. The pilot study served as an initial test of this multidimensional instrument. All scales were translated into the native language and reviewed by a professional language and translation expert as well as science education specialists to ensure linguistic accuracy, conceptual equivalence, and contextual appropriateness for the country's upper-secondary students.

The questionnaire followed a two-stage structure. First, students indicated on a 5-point Likert scale the extent to which they experienced anxiety in each science subject and in mathematics. This initial step aimed to capture the broader distribution of anxiety across subjects, including whether students reported little or no anxiety overall, elevated anxiety in one specific subject, or elevated anxiety across multiple subjects. Second, students were asked to identify the one science subject in which they experienced the most anxiety from among biology, chemistry, physics, and geography. They then completed the remaining subject-specific sections with that selected subject in mind. For example, a student who selected chemistry subsequently answered the creative thinking anxiety, teacher support, and other subject-specific items in relation to chemistry. This design was intended to combine three complementary perspectives: a general overview of anxiety across science subjects, a forced-choice indicator of the subject perceived as most anxiety-provoking, and a more detailed contextualized assessment anchored in the selected subject. Importantly, the subject-specific anxiety subscale consisted of five items referring to the chosen subject, which allowed the analysis to distinguish between students who were actually highly anxious in that subject and those who selected it only as the relatively most anxiety-provoking option among generally low anxiety levels. The perceived knowledge scale addressed subject-specific content knowledge, whereas the perceived skills scale was not tied to one specific subject but captured broader science-related self-perceptions.

All scales in the questionnaire were adapted to a 5-point Likert scale, although the original instruments varied between 4- and 7-point response formats. The endpoints of the scale were labeled reflecting the specific subscale, for example, 1 = Completely disagree to 5 = Completely agree or 1 = Very little to 5 = Very good.

A short feedback form was included at the end of the questionnaire, inviting respondents to indicate any unclear wording or confusing items. Based on this feedback, minor wording revisions were made. In addition, because participants noted redundancy in some items, two items were removed from the self-efficacy scale.

Average questionnaire completion time was approximately 13.2 min, which was considerably shorter than expected.

Because the questionnaire was administered online, completion time was examined as one possible indicator of response quality. Prior web-survey research suggests that unusually rapid responding may reflect satisficing or careless responding, although fast completion time alone does not necessarily indicate invalid data (Zhang and Conrad, 2014; Leiner, 2019). Completion time was therefore interpreted cautiously in light of the questionnaire design, including the use of grid items and Likert-type responses. Inspection of the fastest cases did not reveal clear straight lining patterns; thus, these responses were retained.

Analysis

The first objective of the present study was to develop and preliminarily pilot a multidimensional questionnaire on science anxiety that integrates subject-specific and cross-cutting, process-related dimensions. To address this objective, an instrument was assembled by combining adapted versions of previously developed scales with two newly developed scales targeting perceived subject-specific knowledge and science-related skills. The questionnaire was piloted in a sample of bachelor students ($n = 44$), who were asked to reflect on their earlier upper-secondary school experiences, providing an initial test of the instrument's feasibility, clarity, and functioning. Overall, the pilot suggested that the proposed multidimensional structure was workable and suitable for further refinement and testing in the target school population.

The second objective of the present research was to collect evidence of the feasibility of the adapted versions of the instrument's anxiety and other affective construct items that are based on previous questionnaires designed by other authors (Malecki and Demary, 2002; Rueger et al., 2010; Daker et al., 2020; Rozgonjuk et al., 2024; Van Aalderen-Smeets et al., 2019; Modrek et al., 2021) and to test original instruments on perceived knowledge and skills in science for use in country's upper secondary schools grades 10 and 12. Data analysis was conducted in JASP, version 0.95.4 (JASP Team, 2026). Composite scores were calculated as mean scores across items, with reverse coding applied where necessary (e.g., the fixed ability self-efficacy item). Subject-specific anxiety was treated as a single-item index reflecting anxiety in the self-identified most anxiety-provoking subject and was used primarily for descriptive comparisons across nomination groups. For illustrative purposes, low (≤ 2.5) and high (≥ 4.0) anxiety thresholds were defined by position on the 1–5 response continuum and used descriptively to characterize anxiety levels within nomination groups.

For the third aim, tentative associations between constructs were examined using Pearson correlations (with Spearman correlations used as a robustness check where appropriate). Descriptive statistics were calculated for each questionnaire scale (7) - means, standard deviations, skewness, and kurtosis. Internal consistency was evaluated using Cronbach's α , alongside item rest correlations to identify poorly functioning items and potential ceiling effects. Given the Likert-type

response format and the small pilot sample, departures from normality were expected and were used for descriptive diagnostics only. Internal consistency was also analyzed with McDonald's ω , but since results were very close to Cronbach's α , the values are not reported.

RESULTS

In line with the study's first and second aims, the following analyses examined the descriptive characteristics, internal consistency, and item-level functioning of the questionnaire in order to assess its feasibility in a pilot sample and identify aspects requiring refinement. Descriptive statistics and internal consistency estimates for the study measures are presented in Table 3. The observed internal consistency coefficients suggest that several scales showed sufficient coherence to justify their retention for further development, although these results should be interpreted strictly as preliminary and not as evidence of validation. Item-rest correlations were generally satisfactory, although several items were flagged for possible refinement. Overall, the pilot results suggested that the instrument functioned largely as intended, while also

indicating the need for further refinement and testing in the intended target population.

For the subject-specific anxiety subscale, internal consistency was acceptable. Item-rest correlations were generally adequate, although one item (*"I feel helpless when I have to solve tasks"*) showed a weaker association with the remaining items than the others. Conceptually, this item may reflect perceived lack of control or low competence rather than anxiety more directly, which may explain its weaker fit within the subscale.

The creative thinking anxiety subscale showed strong internal consistency ($\alpha = 0.91$). Item-rest correlations ranged from 0.54 to 0.81, indicating that all items were adequately aligned with the overall scale. The non-creative/control-task anxiety subscale likewise demonstrated strong internal consistency ($\alpha = 0.92$), with high item-rest correlations across all items.

Both IU dimensions demonstrated acceptable internal consistency in the pilot sample. The prospective IU subscale showed $\alpha = 0.80$, but item-level analyses suggested that some items were conceptually weaker and contributed less consistently to the scale. One item was later removed because it

Table 3: Descriptive statistics for the questionnaire scales

Variable	No of items	Mean	SD	95% CI	Skewness	Kurtosis	Cronbach alpha
Subject-specific anxiety							
- In biology	1	2.34	1.08	0.79–1.86	0.55	–0.50	-
- In chemistry	1	3.07	1.40	1.35–3.17	–0.07	–1.40	-
- In geography	1	2.21	1.23	1.03–2.43	0.84	–0.17	-
- In physics	1	3.39	1.32	1.18–2.78	–0.19	–1.25	-
Anxiety in the subject identified by the student as most anxiety-provoking	5	3.02	0.88	0.53–1.25	–0.39	–0.77	$\alpha=0.71$, 95% CI (0.59, 0.84)
- In physics		3.09 (median 3.10)	0.92	2.70–3.48	-	-	-
- In chemistry		2.95 (median 3.00)	0.88	2.46–3.44	-	-	-
Creative thinking anxiety*							
- Creative thinking anxiety	8+4	3.22 (creativ)	0.94	0.60–1.41	–0.05	–0.71	$\alpha=0.91$, 95% CI (0.87, 0.95)
- Control items		2.31 (contr)	1.13	0.87–2.03	0.59	–0.46	$\alpha=0.92$, 95% CI (0.86, 0.97)
Intolerance for uncertainty*							
- Prospective	7+5	3.04 (prosp)	0.81	0.45–1.07	0.09	–0.54	$\alpha=0.79$, 95% CI (0.71, 0.88)
- Inhibitory		3.40 (inhib)	0.78	0.41–0.99	0.10	–0.65	$\alpha=0.71$, 95% CI (0.57, 0.85)
Perceived social support from teacher*	12: 3 each	3.39 (all)	0.79	3.15–3.63	–0.51	–0.16	$\alpha=0.90$, 95% CI (0.86, 0.94)
- Emotional,		3.58 (emot)	1.01	3.28–3.89	–0.63	–0.13	$\alpha=0.90$, 95% CI (0.85, 0.95)
- Informational,		3.79 (inform)	0.88	3.52–4.06	–0.57	–0.10	$\alpha=0.80$, 95% CI (0.70, 0.90)
- Appraisal,		2.95 (appr)	1.00	2.64–3.25	0.34	–0.88	$\alpha=0.76$, 95% CI (0.63, 0.88)
- Instrumental		3.23 (instr)	0.97	2.93–3.52	–0.09	–0.53	$\alpha=0.73$, 95% CI (0.59, 0.872)
Autonomy*	5	2.20	0.73	1.97–2.42	0.39	–0.38	$\alpha=0.74$, 95% CI (0.63, 0.85)
Self-efficacy*	7	3.52 (item 6 reversed)	0.82	3.25–3.79	–0.55	–0.38	$\alpha=0.87$, 95% CI (0.81, 0.92)
Self-perceived knowledge	22:						
-In biology	6	3.39 (bio)	0.77	3.15–3.62	–0.37	0.38	$\alpha=0.84$, 95% CI (0.75, 0.93)
-In chemistry	6	3.26 (chem)	0.94	2.98–3.54	0.03	–0.70	$\alpha=0.86$, 95% CI (0.79, 0.93)
-In physics	6	3.23 (phys)	1.09	2.91–3.56	–0.18	–0.87	$\alpha=0.92$, 95% CI (0.88, 0.96)
In geography	4	3.61 (geo)	0.85	3.35–3.86	–0.94	0.88	$\alpha=0.80$, 95% CI (0.68, 0.91)
Self-perceived skills	16	3.87	0.45	3.74–4.01	0.02	–0.43	$\alpha=0.83$, 95% CI (0.75, 0.90)

n=44. All instruments are measured on a 5-point Likert scale. Analyses of subject-specific anxiety by nominated subjects focused on physics and chemistry, as biology (n=3) and geography (n=2) were selected too infrequently to support meaningful descriptive comparisons in this pilot sample. *In the science subject, chosen as the most anxiety-provoking. SD: Standard deviation, CI: Confidence interval

referred to frustration with unclear teacher explanations rather than uncertainty itself, and another item, referring to always wanting to know the correct solution, showed comparatively weak item-level performance, possibly because it reflected a general preference for clarity common in school settings rather than anxiety-related IU. The inhibitory IU subscale showed comparable reliability ($\alpha = 0.71$) and somewhat more even item functioning.

The perceived teacher support subscale demonstrated strong internal consistency ($\alpha = 0.90$), with subscales ranging from $\alpha = 0.73$ to $\alpha = 0.90$. Most item-rest correlations were moderate to high, although one item showed notably weaker fit ($r = 0.22$). This item referred to the teacher ensuring that students had the necessary materials at school and may reflect a more concrete form of instrumental support that aligned less strongly with the broader support dimension measured by the remaining items.

The self-efficacy and autonomy subscales showed acceptable to strong reliability. For self-efficacy, the pilot item pool initially included two additional belief items. One negatively worded item referring to the idea that ability in the selected subject could not be changed very much was reverse-coded for analysis, but was ultimately removed because it reflected a fixed ability belief rather than self-efficacy more directly. Together with a second malleability-related item, it showed weaker conceptual and statistical coherence with the scale. The revised questionnaire, therefore, retained the five core self-efficacy items aligned with the original instrument. The perceived autonomy subscale showed acceptable internal consistency ($\alpha = 0.74$). Item-rest correlations were mostly moderate, with one item showing a comparatively weaker association with the remainder of the scale ($r = 0.37$). Removal of this item resulted in only a small increase in alpha, suggesting that the subscale was usable in the pilot but may benefit from further refinement.

The subject-specific perceived knowledge scales also showed acceptable to excellent internal consistency in the pilot sample. Reliability estimates ranged from acceptable to excellent across subjects ($\alpha = 0.80$ to $\alpha = 0.92$), supporting their retention for the exploratory correlational analyses. This suggests that students' self-reported knowledge within the four science subjects was measured with sufficient internal consistency for pilot purposes.

The perceived skills scale, developed for this study, showed acceptable internal consistency, although item-rest correlations varied more than in the other subscales, suggesting that the construct may be broader and less homogeneous. Exploratory factor analysis was conducted for descriptive purposes (Costello & Osborne, 2005), but because sampling adequacy was very poor ($KMO = 0.20$), factor extraction was not interpreted, despite a significant Bartlett's test. Instead, the perceived-skills scale was evaluated descriptively through internal consistency and item-level diagnostics. Some items appeared to function less consistently than others, particularly those referring to formulating research questions, connecting

knowledge across science subjects, and using information from graphs and tables. These items may reflect more specific subdomains of science-related competence, such as inquiry, interdisciplinary transfer, and data interpretation, rather than a single homogeneous dimension.

In accordance with the third study aim, preliminary associations among the included constructs in the sample were explored, with attention to whether the observed pattern of relationships was broadly consistent with theoretical expectations. Subject choices and co-occurrence patterns in subject-specific anxiety were examined descriptively (Table 4). Physics was most frequently identified as the most anxiety-provoking science subject (57%, $n = 24$), followed by chemistry (32%, $n = 14$), whereas biology (7%, $n = 3$) and geography (5%, $n = 2$) were selected much less often. At the same time, the co-occurrence patterns showed that students' anxiety was not always limited to a single science subject. Even when one subject was selected as the most anxiety-provoking, some students reported elevated anxiety in multiple science subjects, indicating that subject-specific anxiety may coexist across disciplines rather than occur in isolation.

To address the exploratory third aim, descriptive correlations among the included constructs were examined (Table 5). All reported correlations are based on the retained pilot sample ($n = 44$) and should be interpreted cautiously, given the preliminary nature of the study. Mean science anxiety was strongly associated with the high-anxiety count across science subjects ($r = 0.92$, $p < 0.001$) and was moderately related to chosen-subject anxiety ($r = 0.55$, $p < 0.001$) and creative thinking anxiety ($r = 0.51$, $p < 0.001$). Chosen-subject anxiety was positively associated with creative thinking anxiety ($r = 0.54$, $p < 0.001$), prospective IU ($r = 0.48$, $p = 0.001$), and inhibitory IU ($r = 0.66$, $p < 0.001$). Creative thinking anxiety was likewise positively related to both prospective IU ($r = 0.63$, $p < 0.001$) and inhibitory IU ($r = 0.51$, $p < 0.001$). Teacher support was positively associated with self-efficacy ($r = 0.55$, $p < 0.001$) and autonomy ($r = 0.33$, $p = 0.03$). Overall, these descriptive associations suggested that the anxiety-related constructs tended to cluster positively together, whereas teacher support,

Table 4: Students' choices and co-occurrence in subject-specific anxiety

Science class chosen as most anxiety-provoking, %	Co-occurrence of subject-specific anxiety, %			Number of subjects who report high anxiety in
	Science only	Science+ Math		
Biology	7 (3)	32 (14)	27 (12)	0
Chemistry	32 (14)	25 (11)	18 (8)	1
Geography	5 (2)	27 (12)	30 (13)	2
Physics	57 (24)	16 (7)	25 (11)	3 or more

$n=44$. Students rated their anxiety level in science classes and mathematics. On a Likert scale from 1 to 5, answers 4 and 5 were considered "anxious" in data analysis. Students also chose one subject they felt most anxious about from science subjects; math was not an option

Table 5: Correlation coefficients

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. General science anxiety	-											
2. Co-occurrence of subject-specific anxiety	0.92***	-										
3. Chosen subject-specific anxiety	0.55***	0.47**	-									
4. Creative thinking anxiety	0.51***	0.43**	0.54***	-								
5. Control (non-creative thinking) anxiety	0.24	0.20	0.38*	0.17	-							
6. Intolerance of uncertainty (prospective)	0.40**	0.25	0.47**	0.62***	0.22	-						
7. Intolerance of uncertainty (inhibitory)	0.39**	0.33*	0.64***	0.50***	0.33*	0.59***	-					
8. Teacher support	-0.20	-0.19	-0.19	-0.15	-0.48**	-0.11	-0.11	-				
9. Self-efficacy	-0.17	-0.17	-0.18	-0.24	-0.21	-0.10	-0.14	0.49***	-			
10. Autonomy	0.06	0.01	0.10	0.12	-0.04	-0.04	-0.02	0.33*	0.15	-		
11. Perceived subject-specific knowledge in												
- Biology	-0.09	-0.09	0.02	-0.20	0.25	-0.23	-0.32*	-0.28	0.01	-0.02	-	
- Chemistry	-0.44**	-0.31*	-0.23	-0.37*	-0.12	-0.29	-0.24	0.03	0.25	0.25		
- Physics	-0.33*	-0.30	-0.46**	-0.52***	0.11	-0.26	-0.48**	0.31*	0.54***	-0.17		
- Geography	-0.14	-0.04	-0.13	-0.08	0.04	-0.30*	-0.13	0.15	0.21	0.19		

Pearson correlations are reported. High-anxiety count (science) reflects the number of science subjects rated 4–5. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$

self-efficacy, and autonomy appeared somewhat more distinct. For perceived subject-specific knowledge, the correlations tentatively suggested that higher anxiety tended to be associated with lower self-perceived knowledge, although this pattern was not uniform across all subjects. The clearest negative associations emerged for chemistry and physics, where general science anxiety was negatively related to perceived chemistry knowledge ($r = -0.44$, $p < 0.01$) and perceived physics knowledge ($r = -0.33$, $p < 0.05$). A similar pattern was observed for creative thinking anxiety, which was negatively associated with perceived chemistry knowledge ($r = -0.37$, $p < 0.05$), and especially perceived physics knowledge ($r = -0.52$, $p < 0.001$). Chosen subject-specific anxiety was also negatively related to perceived physics knowledge ($r = -0.46$, $p < 0.01$). In contrast, correlations involving perceived biology and geography knowledge were generally weaker and mostly non-significant.

For perceived science-related skills, correlations with the anxiety variables were generally weak and non-significant. One exception was a moderate negative association with inhibitory IU ($r = -0.41$, $p < 0.01$). Perceived skills were positively related to perceived subject-specific knowledge, with the strongest associations found for geography ($r = -0.57$, $p < 0.001$), and biology ($r = 0.48$, $p < 0.001$) and a smaller but significant association for physics ($r = 0.37$, $p < 0.05$). No significant association emerged between perceived skills and perceived chemistry knowledge.

DISCUSSION

This pilot study had three aims: To develop and pilot a multidimensional instrument for assessing science-related anxiety, to examine its preliminary psychometric properties, and to explore initial associations among the included constructs. Overall, the findings suggest that the instrument functioned adequately in this pilot sample. Most

subscales showed acceptable to strong internal consistency (α s = 0.73–0.92), and the observed pattern of associations was broadly in line with theoretical expectations. At the same time, the pilot also identified several items and one broader scale requiring refinement before further data collection. Regarding the first aim, the findings provide preliminary support for the use of the instrument as a multidimensional measure. The questionnaire made it possible to assess both subject-specific anxiety and related cross-cutting dimensions within a single framework, and most subscales demonstrated acceptable to strong internal consistency in this pilot sample. At the same time, the pilot nature of the study means that the instrument should be regarded as provisional and in need of further refinement and validation in a larger sample.

From a preliminary instrument-development perspective, the pilot findings were broadly compatible with a multidimensional approach that combines subject-specific anxiety with broader cross-cutting constructs relevant to science learning. Several subscales showed internal consistency estimates that were sufficient for pilot purposes, whereas others appeared workable but in greater need of further refinement. These findings should not be interpreted as evidence of validation, but rather as an initial indication that the multidimensional structure of the questionnaire was feasible to pilot and sufficiently coherent to inform subsequent revision. At the same time, the pilot served an important developmental function by identifying weaker items. In the subject-specific anxiety subscale, one item referring to helplessness appeared to reflect low perceived control or competence more than anxiety directly. In the prospective IU section, one item referred to frustration with unclear teacher explanations and was therefore conceptually distinct from uncertainty intolerance, while another item about always wanting to know the correct solution may have reflected a more general preference for clarity common in school settings. In the self-efficacy section, two belief items were removed because they reflected fixed or malleable ability

beliefs rather than task-specific self-efficacy. The perceived skills scale also appeared broader and less homogeneous than the other scales, and its internal structure could not be interpreted with confidence in the pilot sample. This interpretation is supported by the very poor KMO value, which indicates inadequate sampling adequacy for stable factor extraction (Kaiser, 1974; Kaiser and Rice, 1974).

The exploratory findings also provided a meaningful descriptive picture of science anxiety in this sample. Physics and chemistry were much more frequently identified as the most anxiety-provoking science subjects than biology or geography. This pattern is broadly consistent with Rozgonjuk et al. (2024), who likewise approached science anxiety as subject-specific rather than evenly distributed across science disciplines. At the same time, the co-occurrence patterns (Table 4) indicated that anxiety was not always confined to a single subject. Even when one subject was nominated as the most anxiety-provoking, some participants also reported elevated anxiety in multiple science subjects. In some cases, participants rated all science subjects at the lowest anxiety level but were still required to nominate one subject as relatively most anxiety-provoking. Importantly, because all students were required to nominate one most anxiety-provoking science subject, this forced-choice step reflects a relative judgment. The subsequent five-item subject-specific anxiety subscale, therefore, served as an additional check on the absolute level of anxiety in the selected subject. This supports the rationale for examining both subject-specific anxiety and broader science-related anxiety profiles within the same instrument.

The correlational results were also broadly consistent with the conceptual framework of the instrument. Chosen-subject anxiety, general science anxiety, creative thinking anxiety, and both dimensions of IU were positively interrelated, supporting the view that these constructs represent connected but non-identical aspects of science-related anxiety. The link between science-related anxiety and IU is theoretically plausible, as uncertainty is considered a core feature of anxiety and is closely tied to worry and maladaptive responses to ambiguous situations (Buhr and Dugas, 2002; Koerner and Dugas, 2006; Williams, 2013). In this respect, the present findings suggest that students' anxiety in science may be related not only to subject content but also to how they respond to ambiguity, open-endedness, and uncertain outcomes. Teacher support, self-efficacy, and autonomy formed a partly separate cluster, with teacher support showing a clear positive association with self-efficacy. This is in line with earlier findings that anxiety and self-efficacy are closely intertwined in science learning, and that anxiety may undermine the positive role of self-efficacy in achievement-related contexts (Burns et al., 2021). Perceived social support from teachers has been shown to reduce math anxiety (Wang and Ramel, 2023), while in the current study, perceived support from the subject teacher was in negative correlation with non-creative thinking anxiety. Furthermore, social support from teachers has been shown to act as a protective factor influencing student academic

engagement (Wang et al., 2024). Together, these results support the inclusion of both anxiety-related and support- or agency-related constructs in a multidimensional science-anxiety instrument.

These findings should be interpreted in light of several limitations. First, the sample was small, which restricted the stability of some analyses, particularly exploratory factor analysis, and precluded meaningful evaluation of the questionnaire's internal structure. Accordingly, the present results should be interpreted only as preliminary evidence regarding feasibility, internal consistency, and item functioning. Second, the participants were university students reflecting retrospectively on their upper secondary school experiences, rather than members of the intended target population. This limits direct generalizability to current gymnasium students and introduces the possibility of recall bias. Although the participants were not members of the intended target population, they were relatively recent school leavers, and the questionnaire was designed for use with upper-secondary students across different grade levels. This made the sample a practical option for preliminary piloting for item clarity, response patterns, and preliminary reliability. Nevertheless, retrospective pilot data cannot substitute for validation in the target population, and the questionnaire requires further refinement and testing with current upper-secondary students before stronger conclusions can be drawn. More broadly, retrospective designs can offer useful preliminary insights, but they require cautious interpretation and do not support strong generalization or causal inference (Talari and Goyal, 2020).

A further limitation concerns the questionnaire design itself. The pilot instrument combined existing scales with newly developed components. For the adapted scales, the modifications involved converting original response formats to a common 5-point scale, rewording items to refer to the chosen science subject, and, in some cases, retaining only selected parts of broader original instruments. For example, only teacher support was retained from a broader social support measure, and only autonomy-given items were retained from a broader autonomy framework. Details of the scale-specific modifications are provided in Table 2. Although these adaptations were intended to improve coherence and contextual specificity, they also limit direct comparability with the original instruments and mean that the present results should be interpreted only in relation to this pilot version of the questionnaire. In addition, students were required to nominate a single most anxiety-provoking science subject and complete the remaining subject-specific sections with that subject in mind. Although this increased contextual specificity, it also introduced a relative-choice element, as even students with generally low anxiety were required to select one subject. The additional five-item subject-specific anxiety subscale partly addressed this issue by allowing the absolute level of anxiety in the selected subject to be examined, but the design nevertheless complicates interpretation and should be refined in future work.

In addition, the pilot relied on self-report measures only, and several constructs were explored descriptively rather than tested in a fully confirmatory way. Despite these limitations, the pilot provided an important foundation for subsequent data collection. It supported retaining most of the multidimensional structure of the instrument, while also highlighting specific areas for refinement, particularly within the prospective IU, self-efficacy, and perceived skills sections. Overall, the pilot suggests that the instrument is a starting point for assessing science anxiety as a multidimensional phenomenon that is both subject-specific and shaped by broader cognitive-affective processes.

CONCLUSION

This pilot study developed and preliminarily examined a multidimensional questionnaire for assessing science-related anxiety across both subject-specific and broader process-related dimensions. The findings suggest that the questionnaire was feasible to administer and that most subscales showed acceptable to strong internal consistency in the pilot sample. The results also identified specific areas for refinement, particularly within the prospective intolerance of uncertainty, self-efficacy, and perceived skills sections.

Descriptive findings indicated that science anxiety was not experienced uniformly across subjects, with physics and chemistry most often identified as the most anxiety-provoking science subjects. Preliminary associations among the constructs suggested that subject-specific anxiety, creative thinking anxiety, and intolerance of uncertainty were positively related, while teacher support, autonomy, and self-efficacy appeared partly distinct. Overall, the study provides an initial basis for further refinement of the questionnaire and its future validation with current upper-secondary students.

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