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Development of the SMIQ questionnaire measuring interest, sense of self-efficacy and perception of the links existing between mathematics and science in an integrated context

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Résumé de l'article

L'intégration de disciplines scolaires telles que les sciences et la mathématique (S-M) permet de favoriser l'intérêt des élèves et le sentiment d'efficacité personnelle (SEP). Cependant, peu de questionnaires semblent avoir été développés pour mesurer ces variables perceptuelles dans ce type de contexte. Il ne semble pas non plus en exister qui soient adaptés pour les élèves du primaire au sein d'écoles défavorisées et multiculturelles. Cet article rapporte les résultats du processus de validation d'un tel questionnaire comprenant six échelles auprès de 1553 élèves de 5^{e} ou 6^{e} année dans des écoles de la région de Montréal, au Canada. Dans sa version finale, le Questionnaire sur l'intégration de la mathématique et des sciences (QIMS) permet de mesurer six variables perceptuelles : le SEP en sciences, le SEP en mathématique, l'intérêt pour les sciences, l'intérêt pour la mathématique, l'intérêt pour les activités intégrées S-M ainsi que la perception du lien entre sciences et mathématique. À notre connaissance, les deux dernières variables n'ont jamais été mesurées et les échelles proposées pour les mesurer sont inédites.

Development of the SMIQ questionnaire measuring interest, sense of self-efficacy and perception of the links existing between mathematics and science in an integrated context

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Keywords: interest, self-efficacy, disciplinary integration, interdisciplinarity, STEM

The integration of academic disciplines such as science and mathematics (M&S) can help foster students' interest and sense of self-efficacy (S-E). However, few questionnaires appear to have been developed to measure these perceptual variables in this type of context. Nor do any appear to exist that are suitable for elementary students from low-income and multicultural schools. This article reports the results of the validation process of such a questionnaire comprising six scales conducted among 1,553 Grade 5 or 6 students from schools in Canada's Montréal area. In its final version, the Science and Mathematics Integration Questionnaire (SMIQ) measures six perceptual variables: S-E in science, S-E in mathematics, interest in science, interest in mathematics, interest in integrated M&S activities and perception of the links between science and mathematics. To our knowledge, the last two variables have never been measured and the proposed scales to measure them are new.

Mots clés : intérêt, sentiment d'efficacité personnelle, intégration disciplinaire, interdisciplinarité, STIM

L'intégration de disciplines scolaires telles que les sciences et la mathématique (S-M) permet de favoriser l'intérêt des élèves et le sentiment d'efficacité personnelle (SEP). Cependant, peu de questionnaires semblent avoir été développés pour mesurer ces variables perceptuelles dans ce type de contexte. Il ne semble pas non plus en exister qui soient adaptés pour les élèves du primaire au sein d'écoles défavorisées et multiculturelles. Cet article rapporte les résultats du processus de validation d'un tel questionnaire comprenant six échelles auprès de 1553 élèves de 5e ou 6e année dans des écoles de la région de Montréal, au Canada. Dans sa version finale, le Questionnaire sur l'intégration de la mathématique et des sciences (QIMS) permet de mesurer six variables perceptuelles : le SEP en sciences, le SEP en mathématique, l'intérêt pour les sciences, l'intérêt pour la mathématique, l'intérêt pour les activités intégrées S-M ainsi que la perception du lien entre sciences et mathématique. À notre connaissance, les deux dernières variables n'ont jamais été mesurées et les échelles proposées pour les mesurer sont inédites.

Palavras-chave: interesse, sentimento de autoeficácia, integração disciplinar, interdisciplinaridade, STEM

A integração de disciplinas escolares como as ciências e a matemática (C-M) ajuda a fomentar o interesse dos alunos e o sentimento de autoeficácia (SAE). No entanto, poucos questionários parecem ter sido desenvolvidos para medir estas variáveis perceptivas neste tipo de contexto. Nem parecem existir questionários que sejam adequados para os alunos do ensino básico em escolas desfavorecidas e multiculturais. Este artigo relata os resultados do processo de validação deste questionário composto por seis escalas com 1553 alunos dos 5º ou 6º anos nas escolas da região de Montreal, Canadá. Na sua versão final, o Questionário sobre a integração da matemática e das ciências (QIMC) permite medir seis variáveis perceptivas: o SAE em ciências, SAE em matemática, interesse nas ciências, interesse na matemática, interesse em atividades integradas C-M, bem como a perceção da ligação entre a ciência e a matemática. Tanto quanto sabemos, as duas últimas *variáveis nunca foram medidas e as escalas propostas para medi-las são novas.*

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CONTEXT

A necessary integration to meet the needs of the 21st century

The problems facing the scientific community are often complex and interdisciplinary in nature, such as climate change, natural resources management, or pandemic management (Penprase, 2020; Rennie et al., 2012; Thomas & Watters, 2015). With the goal of finding viable solutions to these problems, one must go beyond the traditional disciplinary framework and adopt a more integrated approach (Capraro & Jones, 2013). This is one of the reasons that explain the growing appeal for the integration of disciplines associated with science, technology, engineering, and mathematics (STEM) and the development of students' interest in them (English, 2016; Kelley & Knowles, 2016). It would seem that the more students are interested in STEM, the greater the chances that they will choose to pursue an education and career in that field (Christensen & Knezek, 2017). The integration of two or more school subjects appears to be a fruitful avenue for cultivating this interest (Becker & Park, 2011; Berlin & Lee, 2005; Clark & Wallace, 2015; Margot & Kettler, 2019). As such, Samson et al. (2012) propose to specifically integrate content from mathematics into learning situations of a scientific nature. These can serve as an anchor and provide context for learning mathematics.

Yet, although researchers have been interested in interdisciplinarity (or the integration of disciplines) for over 100 years (Berlin & Lee, 2005; Czerniak & Johnson, 2014), findings about the integration of mathematics with science (M&S) are still considered embryonic by some (English, 2016; Guzey et al., 2014; Honey et al., 2014). There is increasing evidence that the integration of school subjects associated with STEM is related to students' school success (Becker & Park, 2011; Frykholm & Glasson, 2005; Furner & Kumar, 2007; Hurley, 2001; Stinson et al., 2009) through other mediating variables such as interest (Honey et al., 2014) or self-efficacy (S-E) (Becker & Park, 2011). Further work with reliable and adapted measurement tools is necessary to properly measure the relationship between integration and these variables, as research findings can be contradictory and difficult to interpret (Becker & Park, 2011; Honey et al., 2014).

In order to measure perceptual variables, such as interest and S-E, questionnaires with Likert scales are typically used (e.g., Adelson & McCoach, 2011; Fennema & Sherman, 1976; Hasni et al., 2015; Kier et al., 2013; Tezer & Ozcan, 2015; Wininger et al., 2014). In the majority of cases, the questionnaires measure these variables separately and in situations where teaching is done in a compartmentalized way (Guzey et al., 2014; Honey et al., 2014). In rarer cases, researchers have developed questionnaires to measure one variable or the other in integrative contexts (Cunningham & Lachapelle, 2010; Guzey et al., 2014; Tyler-Wood et al., 2010), but the emphasis is placed more so on the relationship between these subjects and STEM-related careers than on learning in school. Moreover, these few studies deserve enrichment as the variables measured are sometimes not well defined, the questionnaires are not always adapted to the target population (Pell & Manganye, 2007) and the integration methods are not systematically specified. Finally, to our knowledge, students' perception of the links that exists between science and mathematics has never been measured using this type of scale.

For example, as of January 15, 2022, the ERIC search engine returns only 50 peer-reviewed results since 2008 (the date of the earliest identified reference) when the keywords "*perception*", "*STEM integration*" and "*student*" are used. None of these writings report results regarding perceptions of the existence of a links between science and mathematics. However, several of these writings address teachers' or prospective teachers' perceptions of STEM integration in school settings or students' attitudes toward careers associated with STEM (e.g., Berlin & White, 2012; Herro & Quigley, 2017; Margot & Kettler, 2019; Sari et al., 2018).

For these various reasons, this article presents the steps in the development and validation process of six scales gathered in a single instrument called the *Science and Mathematics Integration Questionnaire (SMIQ)*. The variables measured by these scales are: 1) student interest in science, 2) interest in mathematics, 3) Interest in integrated M&S activities, 4) Student S-E in science, 5) S-E in mathematics, and 6) students' perception regarding the existence of a links between mathematics and science.

The SMIQ was developed during a research project entitled “Intervention Model for Improving the Perception and Appropriation of Science by Youth from Disadvantaged Areas”, whose objective was to evaluate the efficacy of an educational intervention aimed at fostering students’ interest and S-E in science and mathematics. This study was conducted with elementary students ages 10 to 12 (third cycle of elementary school) whose language of instruction is French and who attend a Québec school in a low-income and multicultural area. This specific population was selected because the final elementary school years are pivotal, they are generally characterized by a decline in students’ interest in science (Potvin & Hasni, 2014), and students from low-income areas are less inclined to pursue careers in science (Fils-Aimé, 2011).

To our knowledge, few measurement instruments exist that have targeted this specific population (Adelson & McCoach, 2011). Students in low-income and multicultural areas have certain characteristics that must be considered. Notably, we have tried like other researchers before to limit the test completion time by using a reasonable number of items (Peixoto et al., 2015) and to propose formulations that are intelligible to students for whom French may not be the first language (MacLeod & Fraser, 2010). In addition, the items were contextualized using the contents of the progression of learning for Cycle 3 of elementary school (MELS, 2009).

CONCEPTUAL BASES

What do the SMIQ scales measure?

Before presenting the development and validation process of the scales, it is pertinent to define the main concepts on which they are based. First, the concepts of *interdisciplinarity* and *disciplinary integration* will be defined as they are often polysemous in the scientific literature (Xie et al., 2015) and not all integrations are equivalent. Next, the six perceptual variables measured in the SMIQ are described and justified.

It is not uncommon for S-E and interest in different school subjects to be measured in parallel, either within the same questionnaire or during the same study. Consistent with Rottinghaus et al.’s (2003) and Lee et al.’s (2014) conclusions, these variables, while correlated, are distinct. According to Rottinghaus et al. (2003), this correlation is moderate. S-E and interest share approximately one third of their variance. Meanwhile, Lee et al. (2014) suggest that these two variables should be considered separately because they do not necessarily appear to be related to school performance in the same way. This echoes Bandura's (1986) statement that a certain degree of S-E is necessary to produce a persistent effect on interest, but he also suggests that the relationship between them is not linear.

Integration and interdisciplinarity

Despite the ongoing interest in interdisciplinarity and integration (Berlin & Lee, 2005; Czerniak & Johnson, 2014), these terms do not possess unequivocal definitions in the scientific literature (English, 2016; Holmlund et al., 2018; Srikoom et al., 2018; Xie et al., 2015). Other terms, such as *pluridisciplinarity, multidisciplinarity or transdisciplinarity*, are also used in contexts that are more or less comparable to represent realities that are more or less similar (Lenoir & Hasni, 2010; Samson et al., 2012). In some cases, interdisciplinarity is also represented as a continuum to assess the effective degree of integration of the disciplines involved (e.g., Brown & Wall, 1976; English, 2016; Lonning & DeFranco; 1997; Rennie et al., 2012). On one side, there is the idea of a discipline taught in an isolated or compartmentalized way, and on the other the idea of teaching where two (or more) disciplines contribute more or less equally to the realization of a learning activity.

While it is important to recognize the importance of this semantic issue, this article does not pursue the goal of proposing a universal definition. Following the lead of several authors (e.g., Holmlund et al., 2018; Honey et al., 2014; Xie et al., 2015), the selected definition is intended primarily to be intelligible and functional. It is also sufficiently general in order to be inclusive of a range of practices and corresponds to the integration model used in the development of the learning activities comprising the pedagogical intervention tested in this research.

Therefore, integration, as proposed by Thouin (2017), is understood as the mobilization of "skills and knowledge from different disciplines to solve a problem" (p. 397). This definition clarifies that integration does not only involve knowledge from the integrated disciplines but also their strategies, abilities and skills as well as the requirement of being situated in a problem-solving context. Regarding these points, we are in agreement with the ideas put forward by other researchers such as English (2016), Kelley & Knowles (2016) and Penprase (2020).

Furthermore, as proposed by English (2016) and Honey et al. (2014), it seems important that the presence of different knowledge, strategies and skills in each of the disciplines should be made explicit so that students can recognize them and perceive the links between them. Finally, the objective of integration is not to eliminate the very idea of "disciplines" or defend the idea that they are outdated. On the contrary, it is about recognizing their input and making evident their respective contributions to the resolution of a problem.

Interest in science, mathematics and integrative activities

Like interdisciplinarity and integration, there is no single definition of interest. According to Potvin and Hasni (2014), there are times when interest and other perceptual variables, such as motivation or attitude, are interchangeable. Within the framework of this research, the focus is on the essential criterion that differentiates interest from these other motivational concepts: its inseparability from the school subject. As stated by Gardner (1996), "One cannot simply have an interest: one must be interested in something" (p. 6). Consequently, we define interest in a similar way to Hasni and Potvin (2015) and Hidi and Renninger (2006); that is, as an internal state that drives the student toward the object of interest. In other words, interest corresponds to the more or less stable tendency of the student to engage in tasks that are mathematical in nature, scientific in nature, or scientific in nature where mathematics is integrated (Krapp, 2007; Wininger et al., 2014).

As suggested by Hidi and Renninger (2006), interest develops in relation to the knowledge of the discipline (science or mathematics), the value that the student attributes to it, and the emotions that they feel in reference to these disciplines or this type of activity. Interest is therefore influenced by students' past experiences. It is possible that students have a different interest in situations where mathematics and science are integrated if, for example, some of these experiences have been perceived more positively or negatively than situations involving single-subject content which justifies the development of a scale to measure this interest specifically.

Since interest is a key determinant of school engagement, this perceptual variable is of interest by virtue of the objective pursued by this research; it is also an important factor in the choice of field of study (Kier et al., 2013; Potvin & Hasni, 2014). The chosen definition of this variable is aligned with that proposed by Hasni and Potvin (2015) and Winninger et al. (2014) and served as inspiration when selecting and formulating the items for the scales.

Self-efficacy in science and mathematics

Unlike the previous two concepts, self-efficacy (S-E) has a fairly stable definition in scientific writings. Since it plays a major role in a person's engagement when completing a task, is strongly related to performance and, to a lesser extent, is also related to career choices (Britner & Pajares, 2006; Galand & Vanlede, 2004), S-E appears to be an interesting perceptual variable with respect to the objective of this research. In general, it is also a good predictor of the behaviour (e.g., giving up, rejecting, persevering, cheating, asking for help, etc.) that an individual exhibits when performing a type of task that they are familiar with. It is also a good indicator of the result that person can achieve (Bandura, 2019; Galand & Vanlede, 2004) regardless of their actual skill level (Bandura, 1992).

Thus, according to Bandura (1977, 2019), S-E is defined as a person's belief in their capacity to organize, execute, and accomplish the necessary steps to produce the desired outcomes. This belief can be influenced by a number of aspects, the most important being the individual's interpretation of their past experiences and the context of performing the requested task (Bandura, 2007).

In the context of learning, S-E is of particular importance because a student will be more likely to start, invest in, and persist in a task if their S-E for that type of task is strong. Drawing primarily from Bandura's extensive writings over the past four decades alongside writings on mathematics education (e.g., Skaalvik et al., 2015) and science education (e.g., Kiran & Sungur, 2012), S-E in science is understood as a student's belief in their capacity to engage and succeed in a task of a scientific nature. Analogously, S-E in mathematics is understood as the student's belief regarding their capacity to engage and succeed in a task of a mathematical nature. The definition is consistent with what Britner (2002) and Toland and Usher (2016) propose in their work.

Perception of the links between mathematics and science

The word *perception* seems to be used as much to study the sensations that the senses allow us to feel (e.g., visual perception) as it is to study the conception, opinion or viewpoint that a person has about a given object. Evidently, we are referring to the latter meaning. Despite its frequent usage, no precise definition of this word's meaning was found in the scientific literature consulted. In general, it seems that perception (in this use at least) is of common meaning and is not explicitly defined.

In the absence of a definition from the literature, we define the perception of the existence of a links between mathematics and science as the student's capacity to recognize the presence of connections or reconciliations between the contents of mathematics and science in an integrative learning situation. In keeping with our definition of integration, it is the knowledge, strategies and skills of both disciplines that are considered. In short, when a student perceives the existence of a links between these two subjects, they are conscious of the mobilization of content belonging to these two disciplines. Not only is this definition an interesting contribution of this article, but it also seems that no existing scale has sought to measure this concept.

METHODOLOGY

The *Science and Mathematics Integration Questionnaire (SMIQ)* measures the six concepts defined in the previous section and was developed by following the questionnaire development process proposed by Dussault et al. (2007). This development process involves seven steps: 1) selection of the variables to be measured, 2) creation of an item bank, 3) selection of the format, 4) evaluation of the items by experts, 5) pretesting, 6) testing with the target population, and 7) verification of the factorial structure.

The essence of Steps 1 to 4 is presented in this section, and the results obtained in Steps 5 to 7 are presented in the following section.

Development of the SMIQ: Selection of the preliminary items (Steps 1 to 4)

Step 1 of the process, i.e., the selection of the variables to be measured, has been specified and justified in the previous sections.

The creation of the item bank (Step 2) to measure interest (in science and in mathematics) and S-E (in science and in mathematics) was largely based on existing and previously validated scales. In the preliminary version of the SMIQ, original items were added to Toland and Usher's (2016) S-E in mathematics scale and Britner's (2002) S-E in science scale.

These new items were derived from the progression of learning for science and mathematics in Cycle 3 of elementary school (MELS, 2009). Since the scales for perceptual variables of interest in situations that integrate mathematics and science and perception of the links existing between science and mathematics are unprecedented, the items were prepared by the research team and partially inspired by the model developed by Berlin and White (1994). This model offers general guidelines for understanding integration, and the authors suggest various aspects to consider in order to achieve integration between science and mathematics in the classroom.

All items were also submitted to a group of four field experts (two researchers in science didactics and two researchers in mathematics didactics) to verify their contents and relevance (Step 4). Two teachers working in schools located in low-income areas also ensured that the terms used were suitable for the students involved in our study. Table 1 presents the name of the scale, the origin of the items, the number of items selected and an example of the item for each of the six perceptual variables.

Table 1
Preliminary Composition of each of the SMIQ Scales

Scale	**Reference**	**Number of items (*n* = *52*)**	**Example of item**
Science interest	Adapted from Hasni and Potvin (2015)	8	*We should spend more time doing science in school.*
Mathematics interest	Adapted from Hasni and Potvin (2015) and from Wininger and al. (2014)	10	*If I had the choice, I would not take math class.*
M&S interest	New scale	9	*We should spend more time doing science that includes math.*
Science SE	Adapted from Britner (2002) and three inedited statements	10	*Make appropriate predictions (hypotheses) about what will happen during a laboratory activity.*
Mathematics SE	Adapted from Toland and Usher (2016), plus six new items	9	*How confident are you that you can successfully solve math exercises involving rounding and estimating?*
Perceived links between M&S	New scale	6	*In science, we do math calculations.*

This preliminary version of the SMIQ scales contains a total of 52 items. Regarding the choice of format (Step 3), all items used in the SMIQ (both in its preliminary and final versions) are accompanied by a four-level Likert scale (from “strongly disagree” to “strongly agree”). Each level of the scale is illustrated with an emoji (a face depicting an emotion) allowing students to better visualize their meaning (see Table 2). This number of graduations (which has been reduced compared to the original scales) and graphical representation was chosen because it appears that elementary students from low-income areas may not necessarily have the capacity for proper self-assessment using a scale with six or more levels (Smith et al., 2003). Further, according to Toland and Usher (2016) and Smith et al. (2003), the four-level scale yields results that meet the premises of normal distribution in a similar manner to a scale with six or more levels.

Table 2
Likert Scale Levels Used in the SMIQ

1	**2**	**3**	**4**
Strongly disagree 😬	Disagree 🙁	Agree 🙂	Strongly agree 😀

Among the items, five items from two of the scales were only available in English (Wininger et al., 2014; Toland & Usher, 2016). A committee was established to perform the translation (Massoubre et al., 2002). This committee consisted of two bilingual researchers from the team who translated each item without consulting each other. Subsequently, two other bilingual researchers in science didactics each translated the French translation of the items back into English. Finally, the members of this second team compared their translations to arrive at a common wording that was as close as possible to the original English item. The item translations were all found to be similar.

Procedure for taking the SMIQ

This research project received approval from the research ethics boards of all the institutions from which the researchers were based as well as institutional approval from the school boards (now called school service centres) involved in the project before participant recruitment began.

The students recruited to participate in the development of this questionnaire (for both the pretest and the test) came from elementary schools in the Greater Montreal area. The schools are all located in multicultural areas and are considered to be very low-income as their poverty index is 8 or more out of 10 (MEES, 2020). In an effort to improve the homogeneity of the sample, all students were from the third cycle of elementary school (5^{th} or 6^{th} grade) and were therefore between 10 and 12 years old. All students participated in this research on a voluntary basis and could decide to withdraw at any time despite the consent obtained beforehand. No questions were asked and no justification was requested.

After the researchers presented the project, written consent was obtained from a parent or legal guardian for each student. The consent form for the pretest was sent home through the student and was collected in class in the following days. For the test sample, the consent form was mostly signed at the parent meeting at the beginning of the school year where a research assistant visited. Parents were also told that the teacher would not have access to the data from the questionnaire and that refusal to participate in the study would have no impact on their child's school results.

A research assistant was always present when the questionnaires were completed to assist the teacher and to ensure procedural consistency from class to class. The teacher was responsible for reading the questionnaire items to the class. Since the teacher knew their students well, they could anticipate student difficulties, adjust the pace of completion, or ask the research assistant for help. Once all the questionnaires were completed, a student would circulate and collect the anonymized copies from the other students. Then, without looking, the student put them in an envelope and sealed it in front of the class.

The average completion time for the questionnaire was approximately 45 minutes for the pretest and 30 minutes for the test. While the questionnaires were completed, students for whom consent had not been obtained or who did not wish to participate in the research did personal work (e.g., reading, studying, homework, etc.).

Pretest and test sample

The pretest sample consisted of 126 students (54 boys, 71 girls, and 1 student who did not indicate gender) with a mean age of 11.68 years ($SD = 0.73$) from 7 classes in 2 elementary schools in low-income areas.

Of these 126 students, 64 (51%) reported speaking mostly French at home. According to their teacher, all students' French level was sufficient to understand the items in the questionnaire.

The test sample consisted of 1553 students (620 males, 709 females, and 234 students who did not indicate their gender) with a mean age of 11.66 years (*SD* = 0.67) from 96 classes in 19 elementary schools in low-income areas. Of the 1361 students who responded to the question regarding the primary language spoken at home, 734 students (54%) responded that it was French.

Data analysis

All data were entered twice by different research assistants to identify coding errors. They were analyzed using SPSS software (Version 24). Cronbach's alpha coefficients (α) are used to verify the internal consistency of the scales found in the SMIQ. The minimum accepted value is $\alpha = 0.7$, as proposed by Nunnally (1978). In addition, items could be removed if they were not normally distributed (Howell, 2012).

In principal component analyses (PCA), the eigenvalue method is used to determine the number of components to extract. In addition, an item's factorial weight must be greater than 0.3 to be attributed to a component (Field, 2017).

In a PCA, Kaiser-Meyer-Olkin (KMO) indices must be greater than 0.6 and Bartlett's tests of sphericity must be significant ($p < 0.05$) to confirm the relevancy of conducting a PCA (Tabachnick & Fidell, 2019).

For the confirmatory factorial analyses (CFA), CFA parameters were estimated using the maximum likelihood method. The fit indices chosen for CFAs of the sample were conducted using R software (Version 3.6.1) and were taken from Kline's (2019) and Hu and Bentler's (1999) recommendations. Root mean square error of approximation (RMSEA) indices are considered acceptable when they are less than 0.08 and good when they are less than 0.05 (Hu & Bentler, 1999). Comparative fit indices (CFI) are acceptable when they are greater than 0.95 (Hu & Bentler, 1999). Standardized root mean square residual (SRMR) indices are acceptable when they are less than 0.08 and good when they are less than 0.06 (Hu & Bentler, 1999). The use of the Tucker-Lewis index (TLI) as a measure of model fit is contested by Kline (2019), particularly when the sample size is large which is the case in this study. It was therefore not retained for analysis.

RESULTS

The pretest results and the adjustments made to the questionnaire between the preliminary version and the test version are presented first followed by the results of the population test.

Pretest results (Step 5)

In the preliminary version of the SMIQ, a large number of items were deliberately included in order to select those that appeared to be the most relevant following the pretest. Thus, 52 items were pretested with a sample of 126 students from the two schools located in low-income areas. The complete list of items from the preliminary version is available in Appendix 1 (Table 7).

A PCA was performed for each scale because each is considered unidimensional. The KMO indices were all greater than 0.6 and Bartlett's tests of sphericity were routinely less than $p < 0.001$ confirming the relevancy of conducting a PCA (Tabachnick & Fidell, 2019). For each scale, the eigenvalue method extracted a single component. The results for the pretest scales alongside the descriptive statistics are presented in Table 3. Interitem correlation matrices for each of these scales are found in Appendix 1 (Tables 8-13).

Cronbach's alpha coefficients were calculated to verify the internal consistency of each scale in the preliminary version of the SMIQ. The values obtained (0.82-0.93) all exceeded Nunnally's (1978) recommended threshold of 0.7. The component weights are also acceptable as they are all greater than 0.3 (Field, 2017).

Two items were rewritten as some terms appeared to be ambiguous when the questionnaire was completed by the students. With the goal of reducing the overall size of the questionnaire, 9 items were removed: 2 items in the scale of interest in mathematics, 5 items in the scale of interest in the links between science and mathematics, and 2 items in the scale of the perception of the links between science and mathematics. This is because the results related to these items are not normally distributed.

Study of the correlation matrices between scale items allowed for the finding that certain components contained items correlated with values less than 0.3 (Crocker & Algina, 2006). Nevertheless, in the context of a small pretest sample size ($n = 126$), it was decided not to systematically

Table 3
Fidelity Indices by Scale Based on the Six Principal Component Analyses (PCAs) of the SMIQ (Preliminary Version)

Scale	Number of compo-nents	Number of items	α	KMO	Bartlett test of sphericity	Interval of components score	Explained variance (%)
Science interest	1	8	0.87	0.806	$\chi^2(28)$ = 220.630***	0.57-0.81	52.77
Mathematics interest	1	10	0.92	0.908	$\chi^2(45)$ = 791.838***	0.38-0.90	55.75
M&S interest	1	9	0.93	0.911	$\chi^2(36)$ = 750.746***	0.60-0.92	58.52
Science SE	1	10	0.85	0.819	$\chi^2(45)$ = 222.614***	0.51-0.83	65.50
SEP en math	1	9	0.88	0.856	$\chi^2(36)$ = 359.179***	0.45-0.82	47.30
Perceived links between M&S	1	6	0.82	0.770	$\chi^2(15)$ = 255.882***	0.46-0.81	44.45

Note. *** = $p < 0.001$.

remove such items when, among other things, the internal consistency of the scale was negatively affected (α) or when it was possible to keep the scale from the literature intact (e.g., that of S-E in science).

Population test results (Steps 6 and 7)

This revised version of the SMIQ scales (see Appendix 2, Table 14) contains 43 items and was distributed to 1553 students from 96 classes across 19 schools in low-income areas in the Montreal area.

The sample was first randomly split in half to perform PCAs (n = 778 students) and CFAs (n = 785 students) on distinct parts of the sample. It is possible to conduct these analyses because of the large starting sample size. Table 4 presents the results obtained from these PCAs. The KMO indices (which were all greater than 0.6) as well as Bartlett's sphericity tests (which were all significant) once again confirm the relevancy of conducting PCAs for each of the scales (Tabachnick & Fidell, 2019).

Table 4
Fidelity Indices by Scale Based on the Six Principal Component Analyses (PCAs) of the SMIQ (Final Version)

Scale	**Number of items**	α	**KMO**	**Barlett test of sphericity**	**Interval of components score**	**Explained variance (%)**
Science interest	8	0.79	0.858	$\chi^2(28)$ = 1399.973***	0.45-0.78	41.99
Mathematics interest	8	0.89	0.917	$\chi^2(28)$ = 2811.734***	0.50-0.87	57.39
M&S interest	4	0.89	0.821	$\chi^2(6)$ = 1622.510***	0.81-0.90	74.74
Science SE	10	0.82	0.903	$\chi^2(45)$ = 1538.559***	0.53-0.66	38.71
SEP en math	9	0.81	0.887	$\chi^2(36)$ = 1435.514***	0.56-0.70	40.08
Perceived links between M&S	4	0.77	0.739	$\chi^2(6)$ = 861.287***	0.59-0.87	60.24

Note. *** = $p < 0.001$.

The Cronbach's alpha coefficients of the scales are greater than 0.7 (Nunally, 1978) and are consistent with the values that were previously obtained. Further, the component weights obtained are adequate, as they are all greater than 0.3 (Field, 2017). The correlation matrix between the items on each of the scales is available in Appendix 2 (Tables 15-20). The correlations between each of these scales are presented in Appendix 2 (Table 21).

CFAs were then conducted on the scales. The CFA parameters were estimated using the maximum likelihood method. Table 5 lists the fit indices used to evaluate the quality of the models.

As mentioned in the Methodology, the fit indices chosen to study the SMIQ questionnaire scales were derived from Kline's (2019) and Hu and Bentler's (1999) recommendations. The Root Mean Square Error of Approximation (RMSEA) indices are all less than 0.08 which is an acceptable fit (Bentler, 2006) for each factor. The Comparative Fit Index (CFI) are also acceptable because they are systematically greater than 0.95 (Hu & Bentler, 1999). As for the Standardized Root Mean Square Residual (SRMR) index s, they are good as they are all below 0.06 (Hu & Bentler,

Table 5

Adjustment Indices by Model Following the Confirmatory Factor Analysis of the SMIQ (Final Version)

Models	**Number of Factors**	**Model fit indices**		
		RMSEA [IC 90%]	**CFI**	**SRMR**
Science interest	1	0.054 ∈ [0.039, 0.070]	0.972	0.031
Mathematics interest	1	0.071 ∈ [0.056, 0.086]	0.975	0.029
M&S interest	1	0.000 ∈ [0.000, 0.079]	1.000	0.010
Science SE	1	0.049 ∈ [0.037, 0.062]	0.958	0.037
Mathematics SE	1	0.035 ∈ [0.019, 0.050]	0.987	0.025
Perceived links between M&S	1	0.000 ∈ [0.000, 0.071]	1.000	0.005

1999). Although the CFI value is equal to 1 for the models of interest in the links and perception of the links between science and mathematics, they are not saturated as the SRMR is non-zero and the RMSEA has a confidence interval.

Scores on the scales

The six scales that comprise the SMIQ are measured using Likert scales graduated from 1 (strongly disagree) to 4 (strongly agree). The scores presented in Table 6 correspond to the average calculated from all items on each of the scales.

Table 6

Mean of the Descriptive Scores for each Scale

Scale	***Mean***	***ESDT***
Science interest	3,40	0,51
Mathematics interest	3,31	0,68
M&S interest	2,73	0,91
Science SE	3,03	0,51
Mathematics SE	3,14	0,58
Perceived links between M&S	3,22	0,71

Note. The mean and the standard deviation were computed from the results of 1457 students who answered all the items of the six scales. The correlations between the different scales are presented in Table 21 of Appendix 2.

The mean scores on each of the three interest scales are above the median value (2.5) which signifies that on average students have a good interest in science, mathematics, and in situations that integrate mathematical content with learning situations of a scientific nature. Students also possess strong S-E in both science and mathematics. Finally, they also perceive, on average, the links that exists between science and mathematics.

DISCUSSION

The objective of this article was to report the validation process results of the six scales in the *Science and Mathematics Integration Questionnaire (SMIQ)*.

The development of these scales was necessary because of gaps identified in the scientific literature, notably the lack of instruments to measure the perceptual variables under study (interest and S-E) in the context of elementary school education with students from low-income areas. This tool also responds to the growing need to evaluate interventions that propose an integration of mathematics and science.

The approach proposed by Dussault et al. (2007) was chosen to develop and guide the validation process for the scales that comprise the SMIQ. This choice proved to be judicious as this approach lends greater precision to the process and allows the inferences made from the data obtained with the developed scales to be supported. The scales possess good theoretical foundations insofar as a review of existing questionnaires was conducted and a committee of field experts reviewed the selected items. Moreover, the statistical tools used in the different stages of statistical analysis (Cronbach's alpha, correlation matrices, PCAs and CFAs, etc.) allow us to conclude that the questionnaire scales have good psychometric qualities.

Analysis of the results provides valid evidence supporting the internal structure of each SMIQ scale. The results obtained for the scales separately measuring S-E and interest in each discipline are consistent with those obtained by researchers who have developed similar questionnaires (Britner, 2002; Hasni & Potvin, 2015; Toland & Usher, 2016; Wininger et al., 2014). A few new items for the two S-E scales were proposed using the list of learning contents found in the Quebec school program (MELS, 2009). They allow the questionnaire to be better contextualized in terms of the learning that Quebec students actually do at the end of elementary school, but they are also general enough to be transferrable to other contexts. For example, for S-E in mathematics, an item was added to verify if students are able to make a prediction or a hypothesis about a mathematical exercise. Similarly, for S-E in science, a few items were added, such as an item verifying if students can propose an explanation for a scientific problem. The results obtained for these items appear to indicate that they are relevant and that they belong to the correct scale.

In the SMIQ, two new scales are proposed: one allowing for the measurement of students' interest in situations that integrate mathematics into situations of a scientific nature and one allowing for the measurement of the perception of the links that exists between these two disciplines. Each of these two scales contains four original items, such as "*Doing science and mathematics together in the same activity makes me happy*". Since these are new scales, they were adjusted the most in the validation process. The results indicate that these new scales present good psychometric qualities and measure their respective perceptual variables well. To our knowledge, this is the first questionnaire allowing for the measurement of these perceptual variables.

The scores obtained from these scales at the time of the test with the target population (Step 6 of the development process) allow us to believe that students have an interest in this type of learning situation and that they are capable of perceiving the links that exist between the two disciplines. Although more research is needed to confirm this with greater certainty, the important thing at this point is to note that the values obtained are not extreme and that an intervention could eventually modify students' perceptions significantly. The score for interest in science is the highest but it is similar to results obtained for the same age group in other research (Lamb et al., 2012; Potvin & Hasni, 2014). Finally, the respective scores for interest in science and interest in mathematics may also appear high but they are similar to those obtained by other researchers (Ganley & Lubienski, 2016; Potvin & Hasni, 2014).

LIMITATIONS AND OPPORTUNITIES

The SMIQ is well suited to the specific population for which it was developed, i.e., students aged 10 to 12 attending a Québec francophone school in a low-income and multicultural area. In this sense, the sample used within the scope of this research is appropriate as it is a good size.

Naturally, it is a sample of convenience and may not be fully representative of the target population. It would no doubt be possible to use the SMIQ or one of its scales with students of other age groups or sociodemographic backgrounds but this would require a validation process. The preliminary version of the SMIQ scales intentionally contained many items ($n = 52$). The final questionnaire containing 43 items allowed us to limit the completion time to approximately 30 minutes, which seems reasonable considering that the questionnaire contains 6 different scales.

In addition to the research avenues already mentioned in the Discussion, it would be interesting to verify whether S-E specific to activities that integrate mathematics and science also exists and, if so, if it is possible to develop a scale to measure it. It would also be relevant to verify the usefulness of the SMIQ in the context of an intervention or evaluation of a program that proposes activities of a scientific nature in which mathematics is integrated.

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APPENDIX 1

Preliminary Version of the Pretest Questionnaire

Table 7

Items of the SMIQ Preliminary Version (n = 52)

Scale	Identification Number for Correlation Matrices	Items
Science interest	Q1	I look forward to the next science activities.
	Q2	Science at school is fun.
	Q3	Science at school is boring.
	Q4	Science at school is interesting.
	Q5	I'm not really interested in what we study in science class.
	Q6	We should spend more time doing science in school.
	Q7	If I had the choice, I would not take science class.
	Q8	I enjoy performing experimental tasks in science.
Mathematics interest	Q1	Math is "cool".
	Q2	Math at school is fun.
	Q3	Math at school is boring.
	Q4	Math at school is interesting.
	Q5	**I like math.**
	Q6	**I'm not really interested in what we study in math class.**
	Q7	We should spend more time doing math in school.
	Q8	If I had the choice, I would not take math class.
	Q9	*We spend too much time doing math in school.*
	Q10	*What I learn in my math class is useful.*
M&S interest	Q1	I enjoy doing activities that link science and math.
	Q2	When science and math come together in the same activity, I am glad.
	Q3	Doing science and math in the same activity makes me happy.
	Q4	We should spend more time doing science that includes math.
	Q5	*I am good at doing science that involves math.*
	Q6	*In class, math helps me understand science.*
	Q7	*I don't like doing math when I am doing science.*
	Q8	*Learning something when math is used in science is easy.*
	Q9	*I learn science better when math is involved.*

Scale	Identification Number for Correlation Matrices	Items
Science SE	Q1	Correctly follow directions to complete a laboratory activity.
	Q2	Make appropriate predictions (hypotheses) about what will happen during a laboratory activity.
	Q3	Use laboratory equipment correctly.
	Q4	Make accurate measurements during a laboratory activity.
	Q5	Make appropriate observations during a laboratory activity.
	Q6	Identify sources of error that might affect the results of a laboratory activity.
	Q7	Describe how the laboratory activity is related to everyday life.
	Q8	Provide an explanation or solution to a scientific problem.
	Q9	Speak with correct use of science vocabulary.
	Q10	Build something to solve a problem in science (e.g., a bridge or a mechanism to transport an object).
Mathematics SE	Q1	How confident are you that you can successfully solve math exercises involving… decimals?
	Q2	How confident are you that you can successfully solve math exercises involving… fractions?
	Q3	How confident are you that you can successfully solve math exercises involving… rounding and estimating?
	Q4	Carry out a math exercise in which there are units of measurement to convert (cm-m-km, g-kg).
	Q5	Make a prediction (hypothesis) about an exercise in math.
	Q6	Speak using math vocabulary correctly.
	Q7	Provide an explanation or solution to a math problem.
	Q8	Make a mathematical reasoning.
	Q9	Use math in other subjects.
Perceived links between M&S	Q1	When I do a science experiment, I need to use math.
	Q2	I use math when I do science.
	Q3	In science, we do math calculations.
	Q4	In science class, I don't do math.
	Q5	*I have never done science activities that involves math.*
	Q6	*I don't do science during math class.*

Note. The 9 items in italics were removed from the final version of the SMIQ. The 2 items in bold were slightly modified in the final version of the SMIQ in to improve students understanding

Interitem Correlation Matrices for Each Scale Measured During the Pretest PCA

Table 8
Science Interest Scale

	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**
Q1								
Q2	0.546***							
Q3	0.506***	0.457***						
Q4	0.501***	0.414***	0.215					
Q5	0.636***	0.463***	0.373***	0.530***				
Q6	0.483***	0.471***	0.473***	0.479***	0.357**			
Q7	0.511***	0.440***	0.534***	0.545***	0.568***	0.500***		
Q8	0.448***	0.423***	0.132	0.469***	0.345**	0.301**	0.366**	

Note. *** = $p \leq 0.001$; ** = $0.001 < p \leq 0.005$.

Table 9
Mathematics Interest Scale

	Q1	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**
Q1										
Q2	0.814***									
Q3	-0.787***	-0.827***								
Q4	0.637***	0.657***	-0.728***							
Q5	0.739***	0.752***	-0.714***	0.642***						
Q6	-0.551***	-0.618***	0.672***	-0.609***	-0.520***					
Q7	0547***	0.538***	-0.508***	0.517***	0.575***	-0.502***				
Q8	-0.607***	-0.583***	0.703***	-0.632***	-0.617***	0.613***	-0.534***			
Q9	-0.394***	-0.439***	0.483***	-0.351***	-0.469***	0.445***	-0.525***	0.462***		
Q10	0.246**	0.305***	-0.273***	0.392***	0.368***	-0.300***	0.168	-0.348***	-0.264**	

Note. *** = $p \leq 0.001$; ** = $0.001 < p \leq 0.005$.

Table 10
M&S Interest Scale

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Q1									
Q2	0.563***								
Q3	0.488***	0.781***							
Q4	0.549***	0.755***	0.834***						
Q5	0.466***	0.629***	0.761***	0.813***					
Q6	-0.427***	-0.629***	-0.694***	-0.565***	-0.526***				
Q7	0.573***	0.682***	0.716***	0.671***	0.605***	-0.582***			
Q8	0.340***	0.412***	0.547***	0.569***	0.572***	-0.252**	0.479***		
Q9	0.429***	0.451***	0.558***	0.550***	0.517***	-0.393***	0.595***	0.567***	

Note. *** = $p \leq 0.001$; ** = $0.001 < p \leq 0.005$.

Table 11
Science Self-Efficacy Scale

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Q1										
Q2	0.241*									
Q3	0.276*	0.122								
Q4	0.434***	0.211	0.312**							
Q5	0.510***	0.502***	0.311**	0.487***						
Q6	0.320**	0.258*	0.265*	0.254*	0.194					
Q7	0.194	0.293*	0.406***	0.337**	0.218	0.494***				
Q8	0.408***	0.364**	0.343**	0.494***	0.521***	0.436***	0.477***			
Q9	0.554***	0.215	0.427***	0.450***	0.454***	0.397***	0.312**	0.498***		
Q10	0.175	0.549***	0.268*	0.232	0.301*	0.309***	0.494***	0.289***	0.327***	

Note. *** = $p \leq 0.001$; ** = $0.001 < p \leq 0.005$; * = $0.005 < p \leq 0.05$.

Table 12
Mathematics Self-Efficacy Scale

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Q1									
Q2	0.556***								
Q3	0.403***	0.401***							
Q4	0.473***	0.403***	0.372***						
Q5	0.324***	0.328***	0.237**	0.181					
Q6	0.306***	0.418***	0.238**	0.185	0.403***				
Q7	0.382***	0.443***	0.326***	0.206	0.359***	0.657***			
Q8	0.401***	0.453***	0.343***	0.379***	0.459***	0.486***	0.587***		
Q9	0.304***	0.381***	0.294***	0.272***	0.279***	0.495***	0.425***	0.389***	

Note. *** = $p \leq 0.001$; ** = 0.001< $p \leq 0.005$.

Table 13
Perception of the Links between Science and Mathematics Scale

	Q1	Q2	Q3	Q4	Q5	Q6
Q1						
Q2	-0.247**					
Q3	-0.336***	0.668***				
Q4	-0.351***	0.585***	0.602***			
Q5	0.504***	-0.592***	-0.482***	-0.399***		
Q6	0.226*	-0.367***	-0.263**	-0.272***	0.449***	

Note. *** = $p \leq 0.001$;** = 0.001< $p \leq 0.005$; * = 0.005 < $p \leq 0.05$.

APPENDIX 2

Final Test Questionnaire

Table 14
Items, Source and Overview of the Results of the Analysis of the 43 Statements of the Final Version

Item	Original wording (if applicable)	PCA	CFA
Interest in science (adapted from Hasni and Potvin [2015])			
Indicate to what extent you agree or disagree with these statements. Circle only one answer per statement.			
I look forward to the next science activities.	n/a	0.723	0.749
Science at school is fun.	n/a	0.736	0.778
Science at school is boring.	n/a	0.547	0.592
Science at school is interesting.	n/a	0.642	0.717
I'm not really interested in what we study in science class.	n/a	0.360	0.451
We should spend more time doing science in school.	n/a	0.661	0.706
If I had the choice. I would not take science class.	n/a	0.556	0.590
I enjoy performing experimental tasks in science.	n/a	0.519	0.529
Interest in mathematics (adapted from Hasni and Potvin [2015])			
Indicate to what extent you agree or disagree with these statements. Circle only one answer per statement.			
Math at school is fun.	*Science at school is fun.*	0.828	0.839
Math at school is boring.	*Science at school is boring.*	0.835	0.867
Math at school is interesting.	*Science at school is interesting.*	0.586	0.744
I'm not really interested in what we study in math class.	*I'm not really interested in what we study in science class.*	0.782	0.777

Item	Original wording (if applicable)	PCA	CFA
We should spend more time doing math in school.	*We should spend more time doing science in school.*	0.409	0.495
If I had the choice. I would not take math class.	*If I had the choice. I would not take science class.*	0.748	0.738
I enjoy doing math tasks.	*I enjoy performing experimental tasks in science.*	0.660	0.704
I look forward to the next math activities.	*I look forward to the next science activities.*	0.811	0.831
Interest in integrated S&M learning situations (new scale)			
Indicate to what extent you agree or disagree with these statements. Circle only one answer per statement.			
I enjoy doing activities that link science and math.	n/a	0.842	0.844
When science and math come together in the same activity. I am glad.	n/a	0.905	0.903
Doing science and math in the same activity makes me happy.	n/a	0.898	0.896
We should spend more time doing science that includes math.	n/a	0.705	0.811
SE science (adapted from Britner [2002] with new items indicated in italics)			
Indicate how certain you are that you can perform the following actions:			
Correctly follow directions to complete a laboratory activity.	n/a	0.535	0.589
Make appropriate predictions (hypotheses) about what will happen during a laboratory activity.	n/a	0.522	0.631
Use laboratory equipment correctly.	n/a	0.411	0.527
Make accurate measurements during a laboratory activity.	n/a	0.606	0.628
Make appropriate observations during a laboratory activity.	n/a	0.538	0.610
Identify sources of error that might affect the results of a laboratory activity.	n/a	0.646	0.652

Item	Original wording (if applicable)	PCA	CFA
Describe how the laboratory activity is related to everyday life.	n/a	0.533	0.591
Provide an explanation or solution to a scientific problem.	n/a	0.629	0.657
Speak with correct use of science vocabulary.	n/a	0.570	0.646
Build something to solve a problem in science (e.g.. a bridge or a mechanism to transport an object).	n/a	0.548	0.624
SE mathematics (adapted from Toland and User [2002] with new items indicated in italics) *Indicate how certain you are that you can perform the following actions:*			
How confident are you that you can successfully solve math exercises involving decimals	n/a	0.596	0.663
How confident are you that you can successfully solve math exercises involving fractions	n/a	0.525	0.559
How confident are you that you can successfully solve math exercises involving rounding and estimating	*n/a*	0.586	0.621

Item	Original wording (if applicable)	PCA	CFA
Carry out a math exercise in which there are units of measurement to convert (cm-m-km. g-kg).	n/a	0.565	0.622
Make a prediction (hypothesis) about an exercise in math.	n/a	0.625	0.588
Speak using math vocabulary correctly.	n/a	0.599	0.666
Provide an explanation or solution to a math problem.	n/a	0.752	0.688
Make a mathematical reasoning.	n/a	0.735	0.701
Use math in other subjects.	n/a	0.536	0.572
Perceived mathematics-science links (new scale)			
Indicate to what extent you agree or disagree with these statements. Circle only one answer per statement.			
When I do a science experiment, I need to use math.	n/a	0.804	0.848
I use math when I do science.	n/a	0.783	0.869
In science, we do math calculations.	n/a	0.580	0.770
In science class, I don't do math.	n/a	0.433	0.586

Note. n/a. = non applicable

Interitem Correlation Matrices for Each Scale Tested with the PCA

Table 15
Science Interest Scale

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Q1								
Q2	0.52***							
Q3	0.29***	0.48***						
Q4	0.44***	0.52***	0.33***					
Q5	0.27***	0.23***	0.24***	0.32***				
Q6	0.46***	0.50***	0.35***	0.39***	0.14***			
Q7	0.39***	0.34***	0.18***	0.31***	0.21***	0.39***		
Q8	0.37***	0.26***	0.21***	0.30***	0.16***	0.29***	0.25***	

Note. *** = $p \leq 0.001$.

Table 16
Mathematics Interest Scale

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Q1								
Q2	0.74***							
Q3	0.54***	0.62***						
Q4	0.59***	0.65***	0.45***					
Q5	0.27***	0.37***	0.33***	0.38***				
Q6	0.59***	0.56***	0.47***	0.51***	0.30***			
Q7	0.53***	0.53***	0.53***	0.44***	0.28***	0.43***		
Q8	0.68***	0.54***	0.62***	0.62***	0.32***	0.56***	0.53***	

Note. *** = $p \leq 0.001$.

Table 17
M&S Interest Scale

	Q1	Q2	Q3	Q4
Q1				
Q2	0.70***			
Q3	0.51***	0.54***		
Q4	0.32***	0.36***	0.31***	

Note. *** = $p \leq 0{,}001$.

Table 18
Science Self-Efficacy Scale

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Q1										
Q2	0.28***									
Q3	0.38***	0.22***								
Q4	0.30***	0.33***	0.29***							
Q5	0.29***	0.31***	0.31***	0.29***						
Q6	0.32***	0.33***	0.24***	0.35***	0.33***					
Q7	0.34***	0.33***	0.27***	0.37***	0.27***	0.39***				
Q8	0.29***	0.34***	0.25***	0.34***	0.33***	0.30***	0.34***			
Q9	0.24***	0.33***	0.24***	0.32***	0.37***	0.39***	0.36***	0.35***		
Q10	0.27***	0.42***	0.21***	0.30***	0.31***	0.39***	0.33***	0.34***	0.40***	

Note. *** = $p \leq 0.001$.

Table 19
Mathematics Self-Efficacy Scale

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Q1									
Q2	0.37***								
Q3	0.44***	0.27***							
Q4	0.40***	0.28***	0.33***						
Q5	0.26***	0.23***	0.25***	0.27***					
Q6	0.32***	0.26***	0.31***	0.33***	0.35***				
Q7	0.32***	0.29***	0.29***	0.31***	0.37***	0.45***			
Q8	0.36***	0.30***	0.39***	0.32***	0.38***	0.42***	0.45***		
Q9	0.26***	0.25***	0.26***	0.31***	0.27***	0.30***	0.37***	0.30***	

Note. *** = $p \leq 0.001$.

Table 20
Perception of the Links between Science and Mathematics Scale

	Q1	Q2	Q3	Q4
Q1				
Q2	0.69***			
Q3	0.65***	0.80***		
Q4	0.58***	0.62***	0.63***	

Note. *** = $p \leq 0.001$.

Cross-Scale Correlation Matrix

Table 21
PCA Interscale Correlation Matrix

	Science interest	Math interest	M&S interest	Science SE	Math SE	Perceived links between M&S
Science interest						
Math interest	0.13***					
M&S interest	0.41***	0.59***				
Science SE	0.54***	0.15***	0.39***			
Math SE	0.19***	0.57***	0.55***	0.44***		
Perceived links between M&S	0.28***	0.26***	0.46***	0.29***	0.35***	

Note. *** = $p \leq 0.001$.