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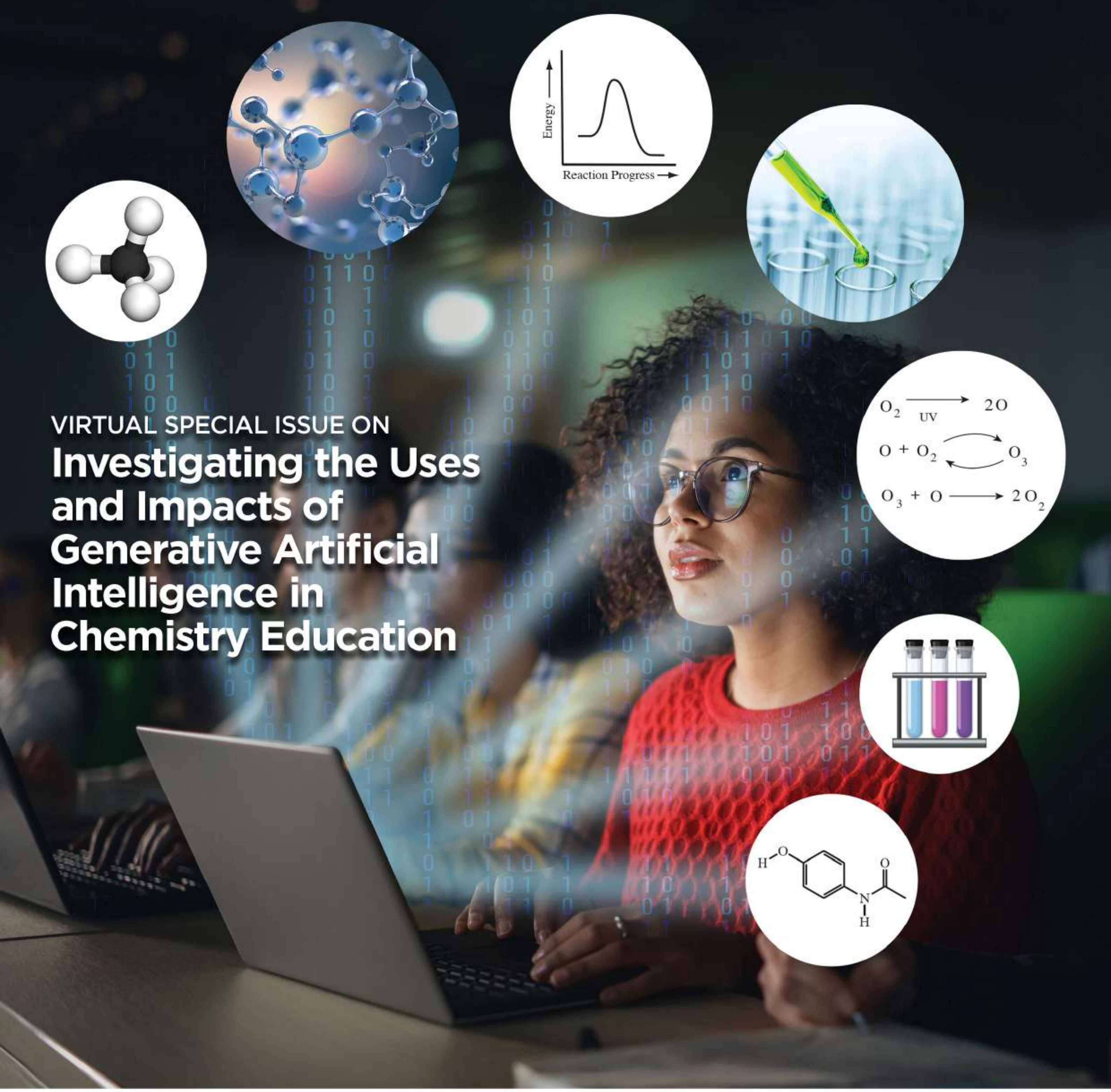

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Judul Artikel	: A Confirmatory and Multigroup Invariance Analysis of the Indonesian Version of the High School Chemistry Self-Efficacy Scale: Gender and Grade Level Overview
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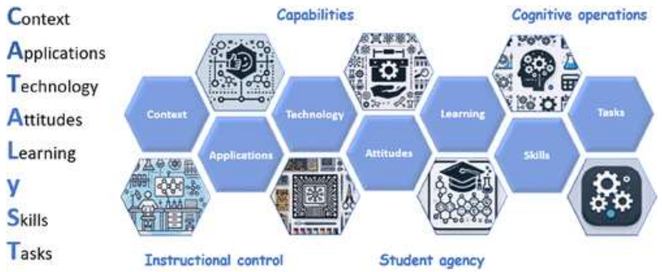

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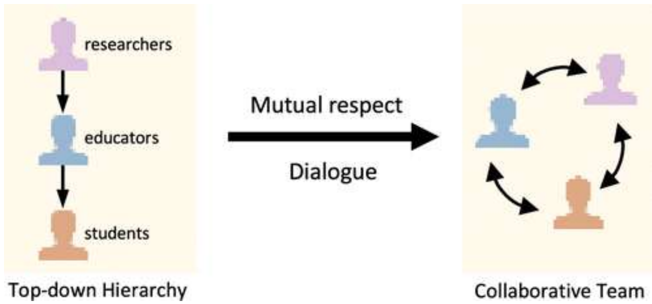

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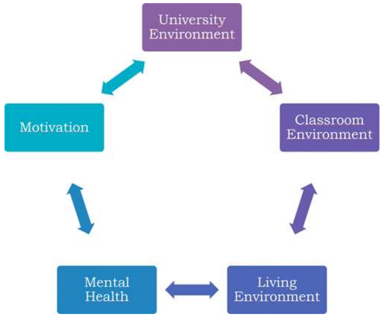

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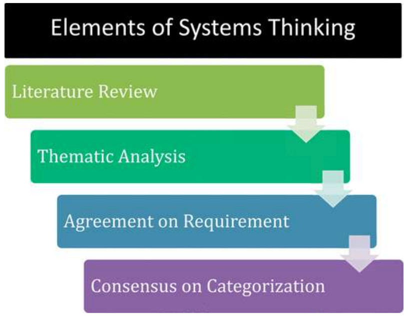

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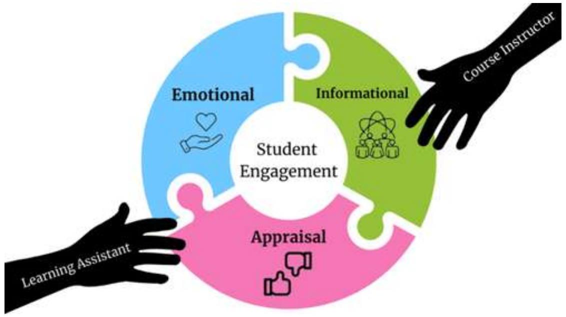

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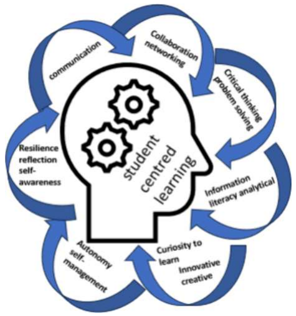

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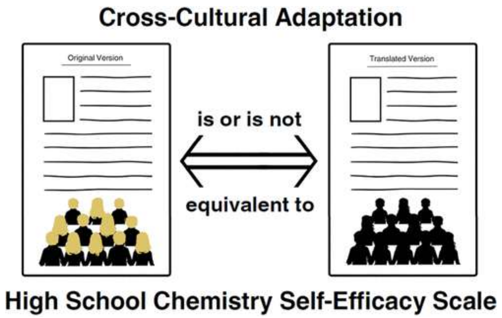

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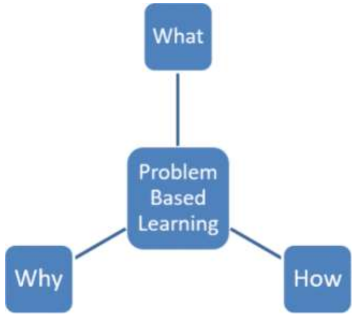

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A Confirmatory and Multigroup Invariance Analysis of the Indonesian Version of the High School Chemistry Self-Efficacy Scale: Gender and Grade Level Overview

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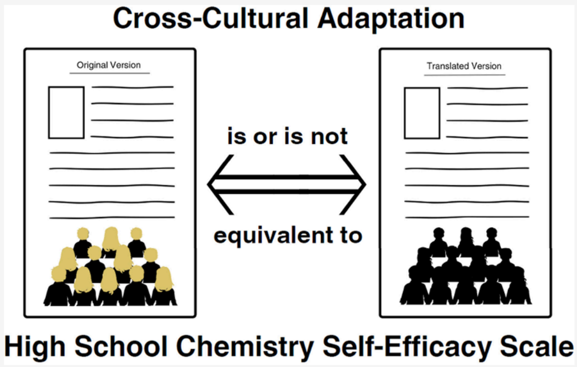
ABSTRACT: Affective measurement tools cannot be uniformly applied across different cultural populations without establishing construct validation and equivalence through cross-cultural studies. This research aims to analyze the cross-cultural validity of the measurement and structural model of the high school chemistry self-efficacy (Aydın et al. *Educ. Psychol. Meas.*, **2009**, *69*(5), 868−880) questionnaire using Indonesian high school students as sample data sets through confirmatory factor analysis. The impact of differences in gender and grade level (grades 10−12) on chemistry self-efficacy in students was also investigated using structured means modeling after a set of invariance tests. A total of 785 respondents (328 males and 457 females) from six high schools in Lampung province, Indonesia, were selected by using cluster random sampling. The confirmatory analysis indicated the best fit for all empirical models toward data sets with high construct validity, internal consistency, and scale stability. Moreover, gender and grade level significantly influenced chemistry self-efficacy, favoring females and the highest-grade students, respectively. However, moving to a higher grade level does not necessarily enhance self-efficacy in students each year, although it does eventually. Probable moderating factors related to gender and grade levels are also discussed.



KEYWORDS: *Chemical Education Research, Testing, Assessment, High School, Introductory Chemistry*

■ INTRODUCTION

Self-efficacy belief is a psychoemotional dimension that is considered the main predictor of academic performance. As a main focus of social cognitive theory, perceived self-efficacy is defined as "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances."[2] These mental attitudes influence academic achievement,[3−6] self-regulation,[7,8] engagement,[9,10] and career choice.[11−13] Fortunately, perceived self-efficacy is not fixed but grows according to the learning experiences of students. Self-efficacy increases with positive experiences and decreases with negative experiences,[14] driven by the main sources of efficacy information: mastery experience, vicarious experience, social persuasion, and psychological states.[15,16]

Specifically in chemistry, multiple-time administration studies with college-level preparatory chemistry students have proven the role of successful experience in enhancing self-efficacy.[14,17] These studies provide empirical evidence that students in higher grades or educational levels are generally more efficacious than those in lower levels, although some studies show the opposite.[18−22] Besides grade levels, gender also plays an important role in self-efficacy belief research. Some studies reveal enhanced self-efficacy in science, technology, engineering, and math (STEM) subjects for males,[1,7,23−29] others for females,[3,17,22,30−34] and quite a few assert no gender effect.[35−42] Furthermore, measuring the roles of grade and gender in self-efficacy beliefs is essential to identifying appropriate learning environments and anticipating declines in academic performance caused by changes in self-efficacy of students over time.

Some chemistry self-efficacy measures have been developed for high school and college students.[1,14,40,41,43−47] Herein, we chose the high school chemistry self-efficacy scale (HCSS). However, the questionnaire was originally developed in Turkish and cannot be directly applied to local participants who differ in language and culture. The original self-reporting measure must undergo a set of procedures widely known in psychometric studies involving cross-cultural adaptation to

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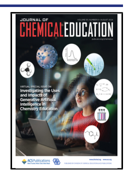

ensure that the instrument is meaningfully applicable and equivalent for use in other cultures. Instruments that measure affective dimensions (attitude, perception, personality trait, etc.) without considering cultural equivalence may cause misinterpretation and bias in this study. Therefore, based on this theoretical background, this research aimed to perform a cross-cultural adaptation of HCSS for an Indonesian sample and investigate the effect of gender and grade levels on chemistry self-efficacy in students.

■ LITERATURE REVIEW

Gender-Based Self-Efficacy in Students for STEM-Related Subjects

Many studies have examined the effect of gender on self-efficacy in subjects such as mathematics and science. However, no consistent findings have emerged regarding which gender has high self-efficacy, owing to various influencing conditions. Dominant literature concludes that men have superior self-efficacy compared with women, but other studies report no gender effect or even stronger self-efficacy in women for certain subjects. Louis and Mistele used multiple tests on various constructs and reported descriptively that men have stronger self-efficacy compared to women, although analysis of variance (ANOVA) showed significant differences between genders in mathematics self-efficacy, not in science.[23] A cross-sectional study by Hong and Lin involving 1,455 Taiwanese senior or vocational high school 11th graders reported that boys had significantly higher self-efficacy scores than girls.[24] Similar results have been found in various research from different countries using different analysis techniques such as descriptive techniques and analysis of variance,[14,23−25] linear regression,[26−28] and structured mean modeling.[1,29]

Focusing on chemistry rather than general science, Garcia used the chemistry attitudes and experiences questionnaire[14] to measure changes in chemistry self-efficacy among college preparatory chemistry students over one semester.[48] Using hierarchical linear modeling at five-time points, it was found that female students had lower self-efficacy in chemistry compared to males at the beginning of the semester but experienced a significant increase by the end, resulting in scores equal to or even higher than those of males from certain races or ethnicities.[17] Another multiple time−point study by Dalgety and Coll measured changes in chemistry self-efficacy among New Zealand students three times during one year. They found that male students were more confident in advanced skills, such as explaining the chemistry content to other students and proposing research questions that could be answered experimentally. Males also become more confident in tasks that involve both theoretical and practical knowledge, such as applying theory and choosing the appropriate formulas to solve problems. Females had lower overall chemistry self-efficacy, and their first-year chemistry experiences impacted these changes.[14] A study by Kan and Akbaş on Turkish high school students found significant differences in chemistry self-efficacy across gender differences, favoring male students.[49]

Kıran and Sungur, using the motivated strategies for learning questionnaire instrument, found no significant mean difference in science between boys and girls among Turkish middle school students.[35,36] Similarly, several studies reported no gender difference in chemistry self-efficacy among first-year college chemistry students in Turkey.[37−40] Furthermore, Tenaw, using an adapted Witt−Rose's self-efficacy questionnaire, revealed no significant gender difference among second-year college students taking an analytical chemistry course.[41] Similarly, İçöz, using the HCSS and two-way ANOVA, concluded that no gender effect was found on chemistry self-efficacy for cognitive skills.[42]

In contrast to the two previous assertions, Sezgintürk and Sungur, using the science learning self-efficacy questionnaire with 461 Turkish middle school students, reported that girls had slightly higher mean scores in higher-order cognitive skills and science communication dimensions of science self-efficacy, while boys had slightly higher mean scores in conceptual understanding and everyday applications.[30,31] Simon et al. explored persistence in STEM programs among 1,309 first-year junior college students (46% male) and found that STEM females had higher self-efficacy than males, indicated by a lower negative affect when they felt competent in STEM.[32] Britner and Pajares also reported that middle school girls had stronger science self-efficacy, self-efficacy for self-regulation, and higher grades in science compared to boys.[3] Several other studies on introductory chemistry courses,[14,17,43] although not disaggregating data by gender, indicated significant increases in chemistry self-efficacy for all students, demonstrating a noticeable rise for females owing to their large contribution to the overall data.[25] A longitudinal study by Whitcomb et al., with three-time points, focused on engineering undergraduate students, examined the simultaneous effects on females or males in four STEM disciplines (mathematics, engineering, physics, and chemistry). Surprisingly, they found that women could only equal or surpass men in grades and self-efficacy in chemistry and not in the other three subjects. In fact, these patterns are consistent across courses within each discipline.[22] In line with this, some researchers,[33,34,50] as cited in Dalgety and Coll, revealed that gender differences in science self-efficacy may suggest females are more confident in natural and life science tasks, while males are more confident in the physical sciences.[14]

Grade Level-Based Self-Efficacy in Students for STEM-Related Subjects

Self-efficacy changes with the experiences students face in their academic life, increasing with positive experiences and decreasing with negative experiences. Generally, the higher the level of education or grade level, the better is the self-efficacy. This was empirically proven by Dalgety and Coll, who observed changes in chemistry self-efficacy of students across three survey administrations (start of the academic year, end of the first semester, and end of the second semester) in first-year chemistry.[14] They found that students at the end of the second semester were more efficacious than those at the other two administrations. The low self-efficacy of chemistry students at the start of the academic year may be caused by their learning experiences from secondary school, which they still carry into tertiary education. Moreover, by experiencing university chemistry courses and laboratory classes over two semesters, students' perceptions of their abilities in chemistry improve, although some less confident students may drop out of chemistry classes. As expected, multilevel modeling analysis at multiple-time administration by Villafañe, Garcia, and Lewis showed that trends in chemistry self-efficacy of students have a fairly wide gap at the beginning of the semester, but it gets narrow throughout the semester of college-level preparatory chemistry, achieving similar self-efficacy across gender and ethnicity by the end.[17]

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However, the pattern does not always appear to be a nonlinear development. Other factors, such as prior experiences, influence it. As stated by Dalgety and Coll, "science self-efficacy is related to students' area of science expertise and prior experiences in science, with physics and chemistry majors..."[14] Empirical support was found by Bachman et al., who studied the self-esteem, influenced by self-efficacy, of 8th-, 10th-, and 12th-grade students from various races/ethnicities.[18] In some races/ethnicities and genders, self-esteem does not increase linearly with age. For example, white males, white females, and Asian−African males in 8th grade have stronger self-esteem compared to those in tenth, likely owing to their previous experiences. Similar results were found by Güngören and Güvercin, who reported a decline in the motivational beliefs of students (self-efficacy, intrinsic value, mastery goals, and performance goals) from the sixth to eighth grade. They attributed this decline to factors such as the decontextualization of learning situations, school control, interests in nonacademic activities, mismatches between abilities and instructional strategies of students used in the classrooms, the use of normative assessments, and competitive learning environments.[19,20] Furthermore, research by Diseth, Meland, and Breidablik involving 2,091 Norwegian students in sixth-grade primary (age: 11 years) and eighth-grade lower secondary (age: 13 years) schools found higher self-efficacy and self-esteem in sixth graders compared to eighth graders. These two self-beliefs were still better for sixth graders when compared based on gender.[21]

An interesting study conducted by Whitcomb et al. measured four types of self-efficacy (physics, mathematics, chemistry, and engineering self-efficacy) among students in various engineering majors, such as mechanical, materials science, electrical, computer, civil and environmental, chemical, industrial, and bioengineering. Analysis of data at three-time points (first, second, and fourth year of education) found that all types of self-efficacy increased linearly with study duration, except for chemistry self-efficacy. Chemistry self-efficacy decreased from the first year to the second year across majors and then dramatically increased in the following years.[22]

Chi et al. conducted a specific study on high school chemistry students, diagnosing the progression of students' chemical symbol representation abilities at different grade levels across genders. The results indicated no significant changes in abilities for the four levels of chemical symbol representation in 10th- and 11th-grade students. Further studies found that changes in abilities only occurred for females, not males, with significant changes only occurring in 12th-grade students. For example, from grade 10 to 11, the percentage of students who achieved Level 3 and Level 4 increased by only one percentage point, indicating a slow progression of students' abilities in "understanding and interpreting the transformation between macro- and submicrometer representation of chemical symbols" (Level 3) and "using chemical symbols for reasoning in chemistry problems" (Level 4). This indicates that changes in students' ability to represent chemical symbols require long-term effort.[51] Similarly, developing students' cognitive abilities in chemistry, including self-efficacy, may take time to develop.

Self-Efficacy Instruments

Several researchers have developed questionnaires to measure chemistry self-efficacy at secondary or tertiary levels of education.[1,14,40,41,43−47] Among these instruments, the most famous is the chemistry attitudes and experiences questionnaire.[14,44,45] However, its use in measuring chemistry self-efficacy remains problematic, owing to scalability issues. This instrument accommodates 17 items loaded in a single factor, primarily assessing students' understanding and application of chemistry theory and skills, neglecting specific measurements of self-efficacy in laboratory skills. Understanding chemistry requires mastery of both cognitive and laboratory skills, which are crucial for promoting meaningful science learning in the classroom.[52] In addition, some items in this instrument are overly specific to university-level chemistry courses (e.g., achieving passing grades in a chemical hazards course and a Part Two chemistry course), limiting its applicability across educational levels and/or study programs. Similar limitations are found in other chemistry self-efficacy questionnaires.[43,46,47] As stated by Bandura, "cognitive events are induced and changed most easily by mastery experiences arising from effective performance" (Bandura, 1977, p 191).[96] This indicates that beliefs in cognitive and psychomotor abilities should be integrated into self-efficacy measurements.

In this regard, the search for chemistry self-efficacy instruments led to the development of two key instruments: the HCSS for high school students and the college chemistry self-efficacy scale for college students.[1,40] These questionnaires were chosen based on three main justifications: their underlying construct, ease of survey administration process, and alignment with aspects of self-efficacy and social cognitive theory. The use of HCSS has several advantages. Its dimensionality and validity were explored through the administration of 362 Turkish high school students. The scale accommodates items that assess chemistry self-efficacy in cognitive skills (10 items, α = 0.90) and self-efficacy for chemistry laboratory skills (6 items, α = 0.92). With just 16 items, the HCSS optimizes the administration process, saving time and facilitating facile completion for students to complete. This streamlined approach avoids overwhelming respondents with excessive items, maintaining their focus on basic chemistry contexts applicable to every chemistry class. Upon close inspection at the item level, the HCSS used the operational word "*can*," specifically referring to judgments of capability rather than intention. In contrast, some efficacy measures, such as those used by Baldwin et al. in their biology self-efficacy scale using the operational word "*will*," indicate intention rather than capability (e.g., *How confident are you that you will be successful in this biology course?*).[53] Moreover, the HCSS questionnaire was designed with statements that clearly assess judgments of capability, distinguishing them from assessments of self-worth (self-esteem) or expectations about outcomes (outcome expectancies). In contrast, some science self-efficacy scales, as stated by Uzuntiryaki and Aydın,[40] fail to make this distinction, conflating self-efficacy and outcome expectancy. For example, a math/science self-efficacy scale asked participants "*please indicate your confidence in your ability to complete each of the following mathematics and science courses offered at [name of university] with a B or better.*"[54] Similar characteristics are also found in Tenaw's chemistry self-efficacy scale, where some instruments reflect more on intention and outcome expectancy rather than true self-efficacy (e.g., I think I will receive a better grade in analytical chemistry I).[41]

In the context of domain specification, the HCSS is a context-specific measurement tool for measuring perceived chemistry self-efficacy. Bandura emphasized the importance of using self-efficacy scales that are tailored to content or domain-specific measures, noting in his books and guide for constructing self-efficacy scales, *"the efficacy belief system is not a global trait but a differentiated set of self-beliefs linked to distinct realms of functioning. Scales of perceived self-efficacy must be tailored to the particular domain of functioning that is the object of interest."*[15] However, many existing self-efficacy scales focus broadly on science in general rather than on specific areas of science such as chemistry, physics, and biology. Consequently, global scores resulting from these general self-efficacy scales reflect generalized personality traits rather than context-specific judgments.[55] Conversely, overly specific measures are also less preferred because they may lack generalizability to other skills and contexts.[40] As a result, to the best of our view, considering the underlying construct of the questionnaire, its ease of survey administration process, and alignment with aspects of self-efficacy and social cognitive theory, the HCSS appears to be well suited as a representative measurement tool for chemistry self-efficacy.

■ METHODS

The population in this study was all senior high school students in Lampung province, Indonesia, with a total of 785 from six schools selected as research samples. The participating schools were selected using cluster random sampling with two schools selected from each of three district-level administrative regions (Pesawaran, Tanggamus, and West Lampung). From each selected school, two classes were taken from each grade level as research samples. Inclusion criteria required all participants to be enrolled in chemistry classes and willing to participate in this study. The sample demographics were 41.78% males (n = 328) and 58.22% females (n = 457). In the case of grade levels, 302 were 10th graders (38.47%), 254, 11th graders, and 229, 12th graders. A survey administration process was conducted at the beginning of each semester for each grade level. The sample demographics based on gender and grade levels are presented in Table 1.

Table 1. Sample Demographics Showing the Number of Students at Each Grade Level Across Gender

District	School Name[a]	Grade Level[b]	Distribution by Gender	
			Males	Females
Pesawaran	PHS A	X A1	12	22
		X A2	11	18
		XI A1	8	15
		XI A2	8	15
		XII A1	7	15
		XII A2	9	10
	PHS B	X B1	8	13
		X B2	8	14
		XI B1	10	11
		XI B2	10	11
		XII B1	6	11
		XII B2	5	12
Tanggamus	PHS C	X C1	10	17
		X C2	10	16
		XI C1	9	13
		XI C2	9	13
		XII C1	8	12
		XII C2	7	11
	PHS D	X D1	9	19
		X D2	10	16
		XI D1	13	7
		XI D2	12	8
		XII D1	7	10
		XII D2	6	11
West Lampung	PHS E	X E1	16	8
		X E2	14	9
		XI E1	15	7
		XI E2	14	8
		XII E1	10	15
		XII E2	8	17
	PHS F	X F1	6	15
		X F2	6	15
		XI F1	9	10
		XI F2	8	11
		XII F1	5	11
		XII F2	5	11
Total			328	457

[a]PHS = Public High School. [b]X, XI, and XII are 10th, 11th, and 12th grade levels, respectively.

Research Design and Procedures

This survey research was conducted over 6 months. A literature search was conducted to obtain an overview of existing questionnaires related to chemistry self-efficacy as the initial step. The next steps were the translation and adaptation processes of the original instrument into Bahasa as a target language. A translator with extensive experience in translation and proofreading ensured fluency in both source and target languages. The researcher coordinated with the translator to ensure a clear understanding of the measurement objectives, subscales, and specific chemical terms used in the instrument. Additionally, each author independently created a translated version based on their knowledge and expertise regarding the HCSS instrument. Beyond professional English translators, Indonesian language experts were involved to verify syntactic and semantic equivalence and ensure the overall language quality of the translated instrument.

The following stage was a synthesis and review committee composed of researchers, professional English translators, and Indonesian language experts. They convened to review all initial drafts, resolve discrepancies, and collectively refine each item based on consensus. At this stage, a prefinal version was produced, ensuring clarity (misinterpretation) in the translation results and eliminating any writing errors. This group discussion resulted in several revisions of the survey items. The results of the first group discussion included changes to words or sentences that were less effective and led to multiple interpretations, such as "*Seberapa baik Anda dapat menulis laporan laboratorium yang meringkas hasil penelitian utama?*" was revised to "*Seberapa baik Anda mampu menulis laporan hasil praktikum kimia di laboratorium?*" Another example was "*Seberapa baik Anda dapat memilih persamaan yang tepat untuk memecahkan permasalahan-permasalahan kimia?*" which was changed to "*Seberapa baik Anda mampu memilih rumus yang tepat dalam menyelesaikan soal kimia?*"

Next, a small-scale survey was administered to 40 nonsample high school science students to assess their understanding of the prefinal questionnaire items. They were asked to grade the extent of their understanding of the instrument (from did not understand [1] to fully understood [5]), identify any unclear words or sentences, and provide suggestions for possible revisions of words or sentences. Moreover, 10 students were interviewed to explore their interpretations of each question

Table 2. Question Items of the Original and Translated Versions of HCSS

Label	Questionnaire Items	
	English (Original Version)	*Bahasa* (Translated Version)
Q1	To what extent can you explain chemical laws and theories?	*Sejauh mana Anda mampu menjelaskan hukum−hukum dan teori−teori kimia?*
Q2	How well can you choose an appropriate formula to solve a chemistry problem?	*Seberapa baik Anda mampu memilih rumus yang tepat dalam menyelesaikan soal kimia?*
Q3	How well can you carry out experimental procedures in the chemistry laboratory?	*Seberapa baik Anda mampu menjalankan prosedur-prosedur praktikum di laboratorium kimia?*
Q4	How well can you use the equipment in the chemistry laboratory?	*Seberapa baik Anda mampu menggunakan peralatan di laboratorium kimia?*
Q5	How well can you establish the relationship between chemistry and other sciences?	*Seberapa baik Anda mampu menghubungkan ilmu kimia dengan ilmu sains lainnya?*
Q6	How well can you describe the structure of an atom?	*Seberapa baik Anda mampu mendeskripsikan*[b] *struktur dari sebuah atom?*
Q7	How well can you interpret data during the laboratory sessions?	*Seberapa baik Anda mampu menginterpretasi*[a] *data yang diperoleh pada saat praktikum?*
Q8	How well can you describe the properties of elements by using periodic table?	*Seberapa baik Anda mampu mendeskripsikan*[b] *sifat−sifat unsur dengan menggunakan tabel periodik?*
Q9	How well can you read the formulas of elements and compounds?	*Seberapa baik Anda mampu membaca rumus unsur dan rumus senyawa?*
Q10	How well can you interpret chemical equations?	*Seberapa baik Anda mempu menginterpretasi*[a] *persamaan kimia?*
Q11	How well can you explain the particulate nature of matter?	*Seberapa baik Anda mampu menjelaskan sifat partikel materi (atom, molekul, dan ion)?*
Q12	How well can you construct a laboratory apparatus?	*Seberapa baik Anda mampu merangkai peralatan laboratorium?*
Q13	How well can you define the fundamental concepts in chemistry?	*Seberapa baik Anda mampu mendefinisikan konsep−konsep dasar dalam kimia?*
Q14	How well can you interpret graphs/charts related to chemistry?	*Seberapa baik Anda mampu menginterpretasi*[a] *grafik/bagan yang berkaitan dengan kimia?*
Q15	How well can you collect data during the chemistry laboratory?	*Seberapa baik Anda mampu mengumpulkan data saat praktikum di laboratorium kimia?*
Q16	How well can you write a laboratory report summarizing main findings?	*Seberapa baik Anda mampu menulis laporan hasil praktikum kimia di laboratorium?*

[a]Menginterpretasi adalah menafsirkan; memberikan kesan, pendapat, atau pandangan teoretis terhadap sesuatu. [b]Mendeskripsikan adalah memaparkan; menguraikan; menggambarkan dengan kata−kata yang jelas dan terperinci.

item and their perception of chemistry self-efficacy, confirming suggested revisions to wordings and sentences. The results of the pretesting and interviews were discussed again in a focus group involving all authors and English translators to address the feedback on each item comprehensively. These insights were integrated into the prefinal product to produce the final version of the instrument.

The small survey and student interviews produced suggestions for improving clarity by revising several words that were deemed "ambiguous" or led to multiple interpretations. Student feedback on ambiguous terms such as "*menginterpretasikan*" and "*mendeskripsikan*" was thoroughly discussed and considered in a subsequent group discussion. Ultimately, it was decided to retain these words but provide additional clarifying information based on their definitions from the Indonesian dictionary. In the final stage, after the questionnaire had been prepared, the final version of the questionnaire was distributed for a two-point survey administration, spaced one month apart. During administration, instructors asked participants to read question items carefully to ensure thoughtful completion of the questionnaire.

Instrument

A four-point Likert scale (ranging from very poorly to very well) was used in this research for the HCSS questionnaire. The original version of the HCSS consisted of 16 question items that measure two dimensions of chemistry self-efficacy: chemistry self-efficacy for cognitive skills (CSCS; 10 items) and self-efficacy for the chemistry laboratory (SCL; 6 items). CSCS measures self-efficacy in cognitive abilities related to chemistry, such as "to what extent can you explain the laws and theories of chemistry?" The SCL measures self-efficacy specifically in chemistry laboratory settings, for example, "How well did you carry out practical work in the chemistry laboratory?" The measurement items of the HCSS in both English and the translated version are presented in Table 2.

Data Analysis

Construct validation involved analyzing how well the data set aligned with the constructed model of high school chemistry self-efficacy. Fit data testing encompassed two empirical models, namely, the measurement model and the structural model, to analyze dimensionality, the internal consistency of the scale, and convergent validity.[56−58] Discriminant validity was not included in this research owing to the expected high correlation among scales.[59] Confirmatory factor analysis with maximum likelihood discrepancy was applied to elicit the estimated model parameters and goodness-of-fit indices using AMOS software. Furthermore, results were compared against the recommended range for acceptable fit indices: χ^2/df < 3, TLI ≥ 0.90, comparative fit index (CFI) ≥ 0.90, NFI ≥ 0.90, standardized root-mean-square residual (SRMR) ≤ 0.08, 0.05 ≤ root-mean-square error of approximation (RMSEA) ≤ 0.08, and RFI and GFI ≥ 0.90.[60−64] The estimated model parameters, such as factor loading, variance, and squared multiple correlations, were extracted from the proposed model. Criteria for model validity included standardized factor loadings of all items above 0.6, composite reliability exceeding 0.7, and the extracted variance ideally surpassing 0.5.[57]

Besides the internal consistency of the scale, stability analysis of the scale was conducted by using test−retest reliability. This involved repeating the survey to the same sample at two separate time points, with the estimated interclass correlation coefficient used to validate the stability of the scale over time. Furthermore, multigroup confirmatory factor analysis (MG-CFA) was applied to analyze how gender and grade levels affect chemistry self-efficacy. Before MG-CFA was applied, a set of invariance tests across groups was executed, including configural invariance, metric invariance, and scalar invariance. Measurement invariance is a statistical method derived from validating the internal structure of the instrument that characterizes the latent variables being measured.[65−67] Educational measurement standards require evidence of internal construct validity and invariance testing before using instrument scores for group comparisons.[66,68] Changes in the p-values and the CFI were identified to detect the equivalence of the proposed model across groups. Next, structured means modeling was applied to analyze the impact of gender and grade levels on high school chemistry self-efficacy. Latent factor means generated from this procedure enable comparisons between two or more groups if a scalar invariance is established. This statistical technique has also been used in several survey studies related to the area of chemistry education.[69−71]

RESULTS AND DISCUSSION

Confirmatory Factor Analysis

The confirmatory analysis applied in this research involved examining two empirical models: the measurement model (comprising two intercorrelated first-order factors) and the structural model (with one second-order factor and two first-order factors) of the HCSS. Confirmatory factor analysis is a multivariate statistical technique used to test how well the measured variables represent the number of constructs. Before conducting confirmatory analysis and considering the sensitivity of this analysis technique to the data set (N = 785), it was important to consider multivariate normality. Normal data distribution was indicated by measuring skewness and kurtosis, with cutoffs of ±1 and ±3, respectively. The skewness and kurtosis values are presented in Table 3 (ranging from −0.486 to 0.158 and −1.603 to −1.379, respectively), suggesting that non-normality was not a problem in this research data.

Table 3. Skewness and Kurtosis

Variable	M	SD	Skew	Kurtosis
Q1	2.88	0.950	0.033	−1.519
Q2	2.90	0.980	−0.020	−1.566
Q3	3.19	0.926	−0.486	−1.429
Q4	3.15	0.931	−0.383	−1.561
Q5	2.80	0.998	0.005	−1.379
Q6	2.88	0.992	−0.036	−1.508
Q7	2.97	0.955	−0.118	−1.551
Q8	2.95	0.956	−0.091	−1.533
Q9	3.05	0.958	−0.225	−1.603
Q10	2.84	0.927	0.158	−1.532
Q11	2.98	0.948	−0.124	−1.557
Q12	2.98	0.955	−0.129	−1.564
Q13	2.91	0.969	−0.037	−1.540
Q14	2.81	0.956	0.106	−1.429
Q15	3.04	0.938	−0.203	−1.561
Q16	3.13	0.941	−0.362	−1.549

Furthermore, to assess the suitability of the model to the data set, it is important to consider fit indices across three classes: incremental, parsimonious, and absolute. It is recommended that fit indices from more than one class be evaluated.[72] Incremental fit indices, such as the CFI and the Tucker−Lewis index (TLI), compare the data fit of the proposed model to that of a null model. Higher values closer to 1 indicate a perfect fit of the proposed model to the data. Next, parsimonious fit indices include the RMSEA, which evaluates how well the hypothesized model approximates the perfect model considering model complexity. A low RMSEA value closer to 0 indicates a minimal difference between the hypothesized and actual models. Lastly, absolute fit indices such as the SRMR measure the average difference between observed and expected correlations as an absolute fit criterion (model).

Both empirical models exhibited excellent fit with the observed data, where the goodness-of-fit indices value reached the threshold.[61] For the measurement model, fit index values are as follows: χ^2/df = 5.860, TLI = 0.932, CFI = 0.942, NFI = 0.931, SRMR = 0.037, RMSEA = 0.079, RFI = 0.920, and GFI = 0.905. Similarly, the fit index values for the structural model are as follows: χ^2/df = 5.860, TLI = 0.932, CFI = 0.942, NFI = 0.931, SRMR = 0.037, RMSEA = 0.079, RFI = 0.920, and GFI = 0.906.

In addition to assessing model fit indices, another property that is taken into account to guarantee the quality of the model is the unidimensionality of the subscales. This property is important because the calculation of a composite score depends on each item demonstrating acceptable unidimensionality. Standardized factor loadings for CSCS ranged from 0.76 to 0.85 and, for SCL, 0.68 to 0.75 (see Supporting Information), confirming the unidimensionality of the subscale. Consequently, all resulting composite scores reflect the properties of their respective latent factors. Apart from that, both models demonstrated convergent validity, with a composite reliability of more than 0.9 and average variance extracted from the constructs of more than 0.5. Thus, in this cross-cultural study, the constructs of the HCSS showed unidimensionality, convergent validity, and internal consistency of the scale toward the data set. Moreover, the test−retest reliability generated an interclass correlation coefficient of 0.91 after repeating the survey twice within a month. The high test−retest reliability score indicates that the instrument is repeatable and remains stable over time.[73] The estimated model parameters of the measurement model are presented in Table 4.

CSCS is significantly correlated with SCL, with a correlation coefficient of 0.87. Moreover, CSCS accounted for 52.5% of the variance (SE = 0.038, t-value = 10.409, p < 0.001), while SCL accounted for 39.7% of the variance (SE = 0.042, t-value = 12.470, p < 0.001) in predicting chemistry self-efficacy among high school students. The connectivity between cognitive and laboratory skills (psychomotor) can be theoretically well explained through meaningful learning principles. Novak posited that individuals derive meaning from experiences through a combination of thoughts, feelings, and actions. A person chooses to act a certain way based on how they think and feel about the experience.[74] How students choose to act (psychomotor) in the undergraduate teaching laboratory also depends on their thinking (cognitive) and emotional (affective) responses to laboratory experiences.[75] Long-term studies by Hofstein in chemistry laboratory developments, implementation, and research support the idea that well-structured laboratory activities can effectively enhance cognitive skills in chemistry education.[76] Effectively organized activities have great potential to develop attitudes and cognitive growth.[77,78] Chandran, Treagust, and Tobin revealed that cognitive factors such as formal reasoning ability

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Table 4. Estimated Model Parameters of the Measurement Model[a]

Construct	Item Labels	Unstd. Factor Loading	SE	*t*-value	*p*	Std. Factor Loading	SMCs	CR	AVE
CSCS	Q1	1.000				0.763	0.582	0.935	0.589
	Q2	1.046	0.045	23.050	*b*	0.774	0.599		
	Q5	1.074	0.046	23.282	*b*	0.681	0.608		
	Q6	1.100	0.046	24.092	*b*	0.780	0.645		
	Q8	1.016	0.044	22.975	*b*	0.803	0.594		
	Q9	0.905	0.045	19.996	*b*	0.770	0.469		
	Q10	1.117	0.042	26.809	*b*	0.685	0.764		
	Q11	0.949	0.044	21.355	*b*	0.874	0.527		
	Q13	1.073	0.045	24.089	*b*	0.726	0.645		
	Q14	1.116	0.044	25.626	*b*	0.803	0.716		
SCL	Q3	1.000				0.846	0.464	0.89	0.576
	Q4	1.063	0.058	18.476	*b*	0.720	0.518		
	Q7	1.154	0.060	19.091	*b*	0.762	0.581		
	Q12	1.059	0.060	17.587	*b*	0.700	0.490		
	Q15	1.137	0.059	19.318	*b*	0.765	0.585		
	Q16	1.123	0.059	18.892	*b*	0.753	0.566		

[a]Square multiple correlations, SMCs; composite reliability, CR; average variance extracted, AVE. [b]$p < 0.001$.

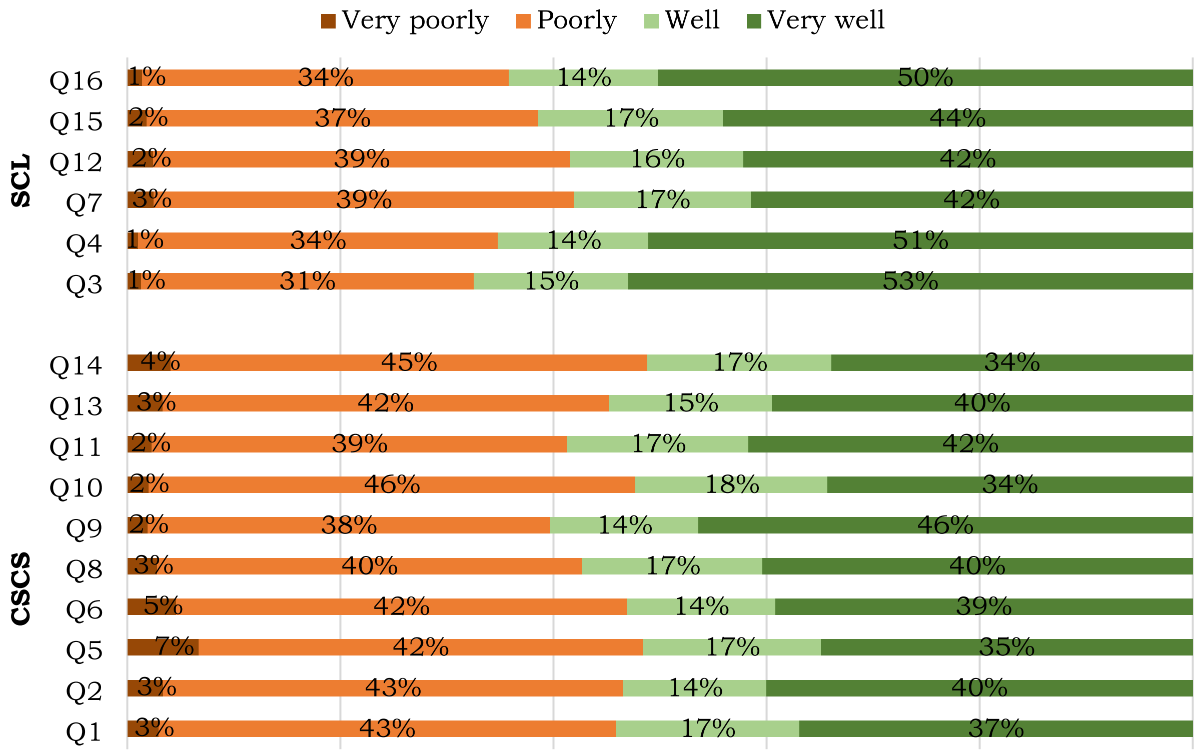

Figure 1. Descriptive analysis.

and prior knowledge significantly correlated with the achievement measures of laboratory application.[79] In short, cognitive abilities in chemistry influence students' chemistry laboratory skills and vice versa within the context of self-efficacy beliefs. Exploratory and confirmatory studies related to chemistry self-efficacy across various countries consistently show a positive and significant relationship between psychomotor and cognitive self-efficacy beliefs in chemistry.[40,80−82] Students who believe in their intellectual abilities in chemistry also tend to have strong beliefs about their ability to accomplish laboratory tasks.

Analysis of student responses revealed a slightly higher score for chemistry laboratory self-efficacy compared with cognitive skills, as shown in Figure 1. This result confirms that high school students in Indonesia tend to feel negative self-efficacy toward chemistry cognitive skills. The percentage of positive responses (light and dark green) for each item in the SCL dimension outweighs those in the CSCS dimension. Although the gap between positive and negative responses is not drastic, we suppose that perceived chemistry self-efficacy in chemistry cognitive skills contributes to the low academic performance in chemistry among Indonesian high school students,[83] despite the importance of self-efficacy in laboratory tasks not being negligible.

CSCS explains students' beliefs about their intellectual abilities in chemistry, while SCL concerns their confidence in handling laboratory tasks. As shown in Figure 1, the three most positive responses (which also means the fewest negative

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Table 5. Estimated Parameter of Invariance Testing across Gender

Type	χ^2	df	CFI	$\Delta\chi^2$	Δdf	[a]Sig	ΔCFI
Configural invariance	745.608	206	0.936				
Metric invariance	758.361	220	0.937	12.753	14	0.5460	0.001
Scalar invariance	786.512	234	0.935	28.151	14	0.0136	−0.002

[a]Significance at $\alpha = 0.01$

responses) were found for item Q3 (how well can you carry out experimental procedures in the chemistry laboratory?), item Q4 (how well can you use the equipment in the chemistry laboratory?), and item Q16 (how well can you write a laboratory report summarizing the main findings?), which are all SCL factor items. Conversely, the three fewest positive responses were found for item Q5 (how well can you establish the relationship between chemistry and other sciences?), item Q10 (how well can you interpret chemical equations?), and item Q14 (how well can you interpret graphs/charts related to chemistry?), which are all CSCS factor items. These findings indirectly show that specific intellectual abilities in chemistry, such as integrating chemicals with other branches of science, interpreting chemical equations, and interpreting graphs, have not yet been adequately emphasized or taught in high school chemistry education in Indonesia. Consequently, students have low cognitive self-efficacy for these abilities.

Gender Effect toward High School Chemistry Self-Efficacy

Investigations into gender and grade effects on chemistry self-efficacy cannot simply rely on mean scale scores without first establishing whether the data set is equivalent (invariance) across groups. Mean scores treat each item as having an equal contribution to the overall mean, which contradicts the actual structure, where factor loadings vary. To address this, researchers suggest applying structured means modeling to obtain the equivalent of *t*-tests and ANOVAs with their constructs. This latent variable approach requires the establishment of measurement invariance across groups before examining mean differences.[84] Invariance testing in this research involves configural invariance (unconstrained model), weak (metric) invariance, and strong (scalar) invariance. Configural invariance allows all parameters to vary freely, serving as a baseline with chi-square and CFI values. Furthermore, metric invariance constrains factor loadings to be equal across groups, while scalar invariance extends this to both loading and intercepts being proportionally equal across groups. Comparisons of hierarchical chi-square and CFI values determine whether equality constraints significantly change the model across the groups.

All invariance models demonstrated an acceptable model fit with the following details: [for configural invariance, χ^2/df = 3.619, TLI = 0.926, CFI = 0.936, NFI = 0.915, SRMR = 0.0473, RMSEA = 0.058, and RFI = 0.900; for metric invariance, χ^2/df = 3.447, TLI = 0.931, CFI = 0.937, NFI = 0.913, SRMR = 0.048, RMSEA = 0.056, and RFI = 0.905; for scalar invariance, χ^2/df = 3.361, TLI = 0.933, CFI = 0.935, NFI = 0.910, SRMR = 0.049, RMSEA = 0.055, and RFI = 0.908]. Based on the information in Table 5, there was no statistically significant reduction ($p > 0.01$) in the model fit upon imposing equality constraints. This finding is also supported by the minimal change in CFI values when equality constraints were applied.[85] Consequently, the measurement model passed invariance testing across gender.

Next, following the confirmation of scalar invariance, the statistical analysis continued with latent mean measurements. This involved setting the latent mean score to zero for the female group and allowing free estimation for the male group. Results showed a significant mean difference between the chemistry self-efficacy of males and females, where females showed higher levels of both cognitive efficacy and laboratory efficacy compared to males (Table 6). This gender difference

Table 6. Latent Mean Difference

	Male (N = 328)		Female (N = 457)			
Factor	Latent Mean	SD	Latent Mean	SD	Cohen's d	Sig[a]
CSCS	−0.22	0.735	0	0.70	0.306	0.00
SCL	−0.30	0.678	0	0.557	0.483	0.00

[a]Significance at $\alpha = 0.01$.

also shows a moderate effect on high school chemistry self-efficacy.[86] The latent means analysis is also supported by the distribution of students' responses as depicted in the violin plot (see Figure 2). Violin plot analysis showed that more than 50% of female responses were concentrated at higher scale levels for almost all items, whereas males seemed to appear more dispersed across lower scale levels.

The current latent structure analysis supports stronger chemistry self-efficacy among females compared to males in both cognitive (*t*-value = 4.2529; 95% CI: − 0.32163 to −0.11837; $p < 0.01$) and laboratory skills ($t = 6.7909$; 95% CI: − 0.38679 to −0.21321; $p < 0.01$). This result prompts a discussion on the effects of gender-related moderating on students' self-efficacy. According to Dalgety and Coll, science self-efficacy may not be inherently gender-based but rather influenced by various underlying variables.[14] Factors contributing to these gender differences in self-efficacy include learning environment, socialization, stereotypes, minority status, discrimination, and access to role models, which collectively influence the sources of self-efficacy positively or negatively. Analysis of the sample demographics and insights from teacher interviews suggest that differences in self-efficacy between males and females are likely caused by the learning environment and the composition of males and females in a classroom (minority status and stereotype threat). Information about the demographic sample reveals that females dominate the composition of almost every classroom. Different gender compositions can impact self-efficacy in mathematics and science, as supported by Inzlicht and Ben-Zeev, which is consistent in the areas of minority status and stereotype threat. They found female deficits in math performance with an increase in the relative number of males in their environment, which did not occur in males. In essence, female deficits in math were proportional to the number of males in their group.[87]

Besides minority status, differences in male and female students' self-efficacy can also stem from teaching methods and

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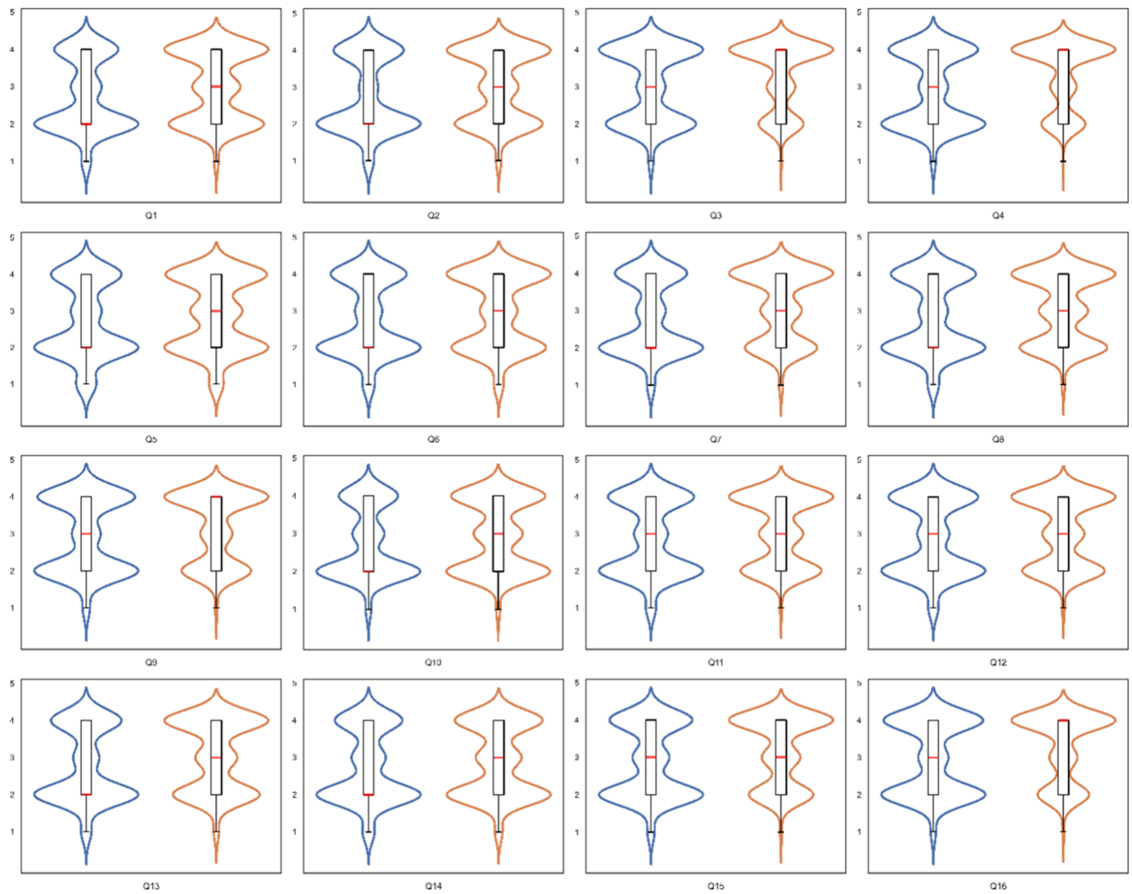

Figure 2. Distribution of responses for all items (Q1−Q16) by gender, with male and female responses represented by blue and yellow, respectively.

Table 7. Estimated Parameters of Invariance Testing Across Grade Level

Type	χ^2	df	CFI	$\Delta\chi^2$	Δdf	Sig[a]	ΔCFI
Configural invariance	913.743	309	0.928				
Metric invariance	944.413	337	0.927	30.67	28	0.3319	−0.001
Scalar invariance	984.574	365	0.926	40.161	28	0.063975	−0.001

[a]Significant at level 0.01.

classroom learning processes. Interviews with teachers revealed that almost all chemistry teachers across grade levels predominantly use traditional teaching methods, such as presentations, and very rarely conduct laboratory experiments owing to the limited availability of apparatus and chemicals. The less competitive learning environment has the potential to significantly reduce self-efficacy among male students while providing a favorable condition for female students.[88] As mentioned in many literature sources,[88−94] girls perceive their learning environment more positively compared to boys. Stressful, threatening, and competitive learning circumstances degrade women's interest in learning. Concerning chemistry self-efficacy, Boz, Yerdelen-Damar, Aydemir, and Aydemir state that female students' more positive perceptions of their learning environment lead to stronger overall chemistry self-efficacy compared to males. A nonthreatening and friendly environment allows female students to feel more relaxed and active in their learning, which enhances their physiological and emotional states.[95]

Grade Effect on High School Chemistry Self-Efficacy

This test evaluated whether the chemistry self-efficacy of high school students increases with years of education. Invariance testing across grade levels was established with the generated parameter presented in Table 7. The measurement model has excellent fit indices across grade-level differences under equality constraints with the following details: [for configural invariance, χ^2/df = 2.957, TLI = 0.916, CFI = 0.928, NFI = 0.895, SRMR = 0.0318, RMSEA = 0.050, and RFI = 0.878; for metric invariance, χ^2/df = 2.802, TLI = 0.922, CFI = 0.927, NFI = 0.891, SRMR = 0.0329, RMSEA = 0.048, and RFI = 0.884; for scalar invariance, χ^2/df = 2.697, TLI = 0.927, CFI = 0.926, NFI = 0.887, SRMR = 0.0326, RMSEA = 0.047, and RFI = 0.888]. The *p*-value and CFI changes showed no inequality problems in this research.

After passing invariance testing, structured means modeling was performed with the latent mean score of the 10th graders as a baseline. The results showed that the 12th-grade students had the highest latent mean score, followed by the 10th-grade students, with the 11th-grade group scoring the lowest. ANOVA among the three groups of means showed that

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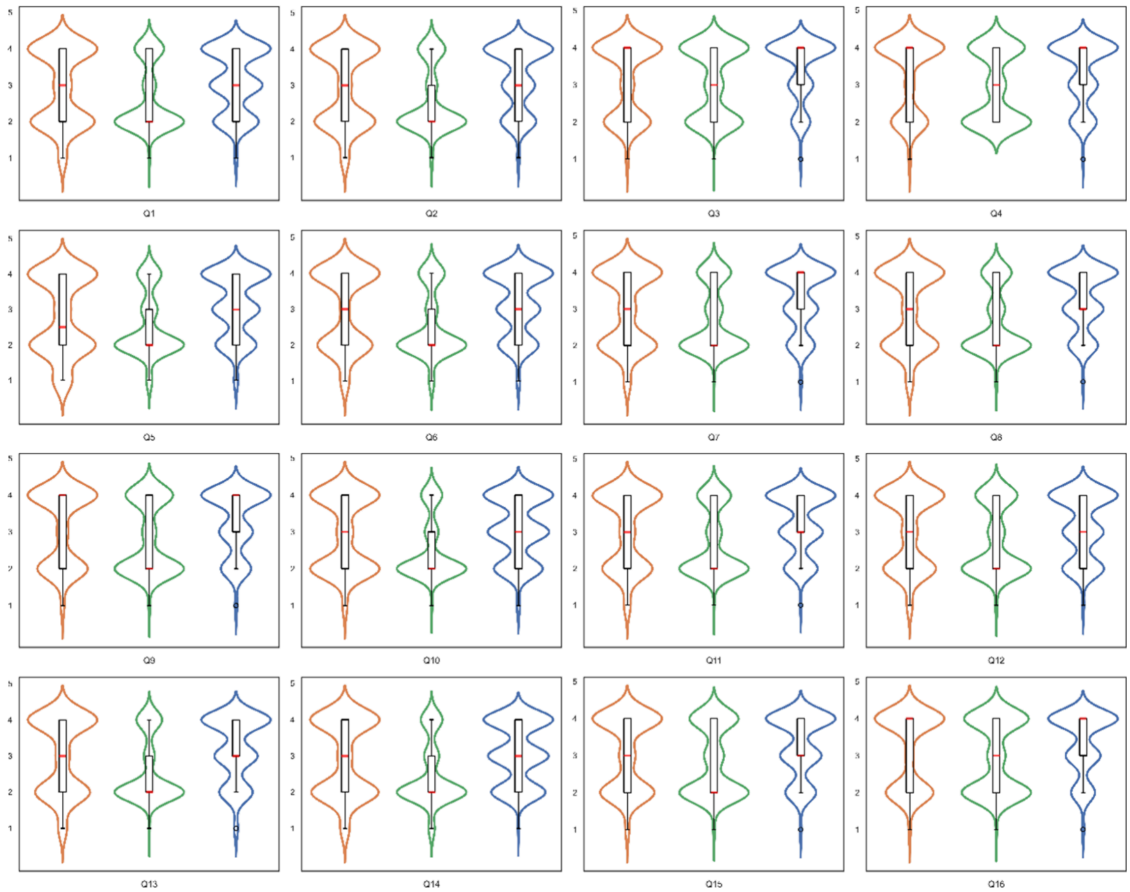

Figure 3. Distribution of responses for all items (Q1−Q16) by grade levels, with 10th, 11th, and 12th grader responses represented by yellow, green, and blue lines, respectively.

Table 8. Latent Mean Analysis Across Grade Differences

	X (N = 302)		XI (N = 254)		XII (N = 229)				
Factor	Latent Mean	SD	Latent Mean	SD	Latent Mean	SD	F	η^2	[a]Sig
CSCS	0	0.837	−0.36	0.583	0.19	0.600	39.506	0.092	0.00
SCL	0	0.735	−0.21	0.529	0.18	0.520	24.468	0.059	0.00

[a]Significant at level 0.01.

grade has a significant impact ($p < 0.01$) on high school chemistry self-efficacy. Moreover, effect size analysis with partial eta-squared (η^2) scores[86] revealed a moderate to high impact of grade level on the growth of high school chemistry self-efficacy. This finding was also supported by the distribution of students' responses by the violin plot (Figure 3). The violin plot showed that more than 50% of the 11th graders tended to concentrate at lower scale levels for almost all items, whereas the 12th graders concentrated at higher scale levels. Responses from the 10th graders appeared evenly split between lower and higher levels.

The highest chemistry self-efficacy scores observed among the 12th graders can be attributed to their perceived mastery of chemistry concepts at this level. However, a unique finding was that 11th graders exhibited no better, and even lower, chemistry self-efficacy compared to 10th graders (Table 8). This indicates that the length of study time in high school education does not guarantee an improvement in students' chemistry self-efficacy over time. Prior experiences of students are an important contributing factor in the development of self-efficacy.

This trend can theoretically be explained based on the sources of self-efficacy, including mastery experience, vicarious experience, and social interactions. The highest chemistry self-efficacy among senior students can be attributed to Bandura's opinion that mastery experience is the most influential source of academic self-efficacy.[96] The more academic experience a student has, the more confident he will be about his abilities. Conversely, the higher chemistry self-efficacy observed in 10th graders compared to 11th graders likely stems from their prior experience in junior high school, a point explained by Dalgety and Coll.[14] In Indonesia, science education in junior high school combines chemistry with biology and physics as a part of basic science. Consequently, chemistry appears less complex in junior high school compared with senior high school. Transitioning to senior high school, where chemistry becomes a distinct subject, may induce a "content shock" for 11th graders, potentially lowering their chemistry self-efficacy.

■ CONCLUSION

The covariance structure analysis presented in this study successfully validated high school chemistry self-efficacy among

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Indonesian students. All questionnaire items grouped into two subscales significantly predicted chemistry self-efficacy in both cognitive and psychomotor dimensions. The unidimensionality of each subscale has been proved. Test−retest reliability shows that this instrument is repeatable on the same sample at multiple time-point measurements. Descriptively measuring perceived self-efficacy beliefs in chemistry reveals low chemistry self-efficacy among Indonesian high school students, particularly in cognitive and psychomotor skills, which are slightly more negative than the others. Furthermore, after gender invariance testing, structured mean modeling revealed significant mean differences between male and female chemistry self-efficacy in favor of female students. This benefit is attributed to their majority status in classrooms and their less competitive learning environment. Furthermore, an investigation of the grade-level effect revealed that 12th graders had the strongest chemistry self-efficacy, surpassing students in the 10th and 11th grades, which was in line with the increasing mastery experiences students had. However, this development is not always a year-to-year linear development where, in the case of this research findings, 10th graders showed higher chemistry self-efficacy than 11th graders. This trend, as also found by other researchers, is thought to be caused by prior experiences and "content shock" during the learning of chemistry.

The empirical findings of this research contribute to the literature, especially highlighting the superiority of scales for cross-cultural adaptation and the efficacy of powerful statistical analyses in achieving research objectives. This research also emphasizes the importance of rigorous instrument validation in cross-cultural studies. Merely translating existing instruments without adequate validation can lead to significant cultural biases, as terms or concepts may not align with local contexts or may be misinterpreted. In many general cases, practitioners will prefer to use previously validated instruments by simply translating the questionnaire from the original English version into the targeted language. Using an assessment tool in this way can cause potential problems in terms of cultural equality, because an instrument suitable in one situation may not be in another. Simple translation alone is insufficient. Questionnaire items may include words or phrases that refer to specific objects that are not part of a culture or that function differently and may not be recognized or may be misinterpreted. Thus, assessment tools must be both translated and revalidated for local participants in the target language. Cross-cultural validation is essential to ensure that the questionnaire items are culturally equivalent and that those participants interpret each question item correctly. This study serves as a model for other researchers engaged in cross-culturally related studies, especially in the instrument adaptation process. Moreover, the Indonesian-version instrument generated in this research can be applied by practitioners who want to assess the chemistry self-efficacy of high school students with similar social and cultural backgrounds.

Limitation

There are at least two limitations of this research. First, the research sample involved three districts within one province, while Indonesia is a pluralistic country that is very rich in ethnic and cultural diversity. Indonesia is an archipelagic country with more than 278 million inhabitants, 300 ethnic groups, and 38 provincial-level administrative regions. A wide and highly diverse sample would provide a richer understanding of the suitability of the self-efficacy questionnaire in the Indonesian context. Second, this research fully applies a quantitative assessment of chemistry self-efficacy, which can introduce biases into data analytics. This technique must be combined with cognitive interviewing to produce complete information regarding how students perceive their chemistry abilities. Conducting interviews in cross-cultural studies is important for confirming the accuracy of translation results and quantitative analysis.

Implication

For researchers, cross-cultural research is synonymous with the use of instruments that are translated from the original language to the target language. Therefore, it is important to meticulously manage the step-by-step language transfer of each instrument and rigorously test its construct validity. A group discussion between researchers, English translators, and Indonesian language experts is highly recommended to reach a consensus regarding potential modifications during the language transfer process and align student responses with the instrument. Prior to survey deployment, initiating confirmatory factors is essential, ensuring adherence to model suitability criteria and seriously addressing validity, internal consistency, and scale stability. Researchers should also conduct invariance testing across groups if the research aims to compare two or more groups.

For practitioners, teachers who intend to use this instrument are advised to conduct a paper-and-pencil survey and ensure thorough student comprehension of each question item. We also suggest that teachers collaborate with researchers for the adaptation process before using the instrument and throughout the process of evaluating/assessing students' chemical self-efficacy. Teachers should also be aware of classroom gender composition and commit to creating a well-designed participatory learning environment that positively influences students' self-efficacy and the quality of chemistry learning. Regarding grade-level effects, teachers should proactively monitor shifts in students' self-efficacy from grade 10 to 11, anticipating any potential declines in student self-efficacy toward chemistry and intervening accordingly.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.3c01332.

Parameters including model fit summary and scalar estimates for measurement and structural models (PDF; DOCX)

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Notes

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■ NOTE ADDED AFTER ASAP PUBLICATION

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