Predictors of Chemistry Learning Achievement: A PRISMA-Guided Systematic Review and Bibliometric Mapping of Cognitive, Affective, and Demographic Factors

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ABSTRACT:
An interplay of cognitive, affective, instructional and demographic variables influences the achievement of chemistry learning. In this paper, we have synthesized literature about predictors of chemistry learning achievement with a special emphasis on prior knowledge, mathematical readiness, spatial ability, self-efficacy, motivation, attitude, attitude causing achievement emotions, belonging, socioeconomic resources, gendered experiences and classroom learning environment. The review is conducted according to PRISMA 2020-apposite search strategy to enhance methodological transparency, clear databases, keywords, inclusion and exclusion rules, screening, quality-appraisal logic, descriptive bibliometric mapping and systematic narrative synthesis are reported. The studies vary in design, so it is not a pooled meta-analysis, but rather, the review designation is based on structured frequency mapping, domain-wise synthesis and patterning of evidence. It is postulated that the achievement in chemistry should be thought of in a model of integration where cognitive readiness and affective engagement interact with the opportunity structures. The best chemistry education involves early diagnostic evaluation, development of mathematical and spatial abilities, affective support, inclusive pedagogy and support of students of disadvantaged background.

Keywords: chemistry achievement, systematic review, PRISMA, bibliometric mapping, self-efficacy, motivation, spatial ability, socioeconomic status

1. Introduction

One of the focal sciences that relates physics, biology, medicine, engineering, agriculture, environmental studies and industrial technology is chemistry. Although it is a very vital subject, chemistry is usually perceived by the students as an abstract subject to be studied, mathematically challenging, complex by symbols, and difficult

emotionally. To study chemistry, the students must be able to switch between macroscopic observations, explanations of particles on submicroscopic level and symbolic representations (equations, structures, graphs and formulae). This representational requirement makes the study of chemistry unlike most other school subjects; and in part explains why the study of chemistry involves more than memorization.

Chemistry learning achievement is the way that students perform in chemistry as shown by their grades, test performances, conceptual knowledge, lab modeling and problem-solving power and application of chemical learning concepts to new situations. The measure of achievement can be in the form of teacher-administered examinations, standardized tests, course marks, diagnostic tests or performance based lab activities. There is nothing that is a single measure of learning. One student can tackle algorithmic numerical tasks and be non-particle-level understanding; another student can have good qualitative intuitions down but fails to get good scores on exams due to anxiety or lack of math fluency. Predictors of chemistry performance must thus be looked at in a multidimensional manner.

There are major groups of predictors evidenced by chemistry education research. Such cognitive predictors as previous success, mathematical preparedness, spatial abilities, metacognition, representational ability and problem solving skills are involved. Emotional predictors are motivation, self-efficacy, attitude towards chemistry, anxiety, emotions of achievement, interest, value of task and goal orientation and sense of belonging. Such demographic and contextual predictors are gender, socioeconomic status, parental education, domestic resources, language background, school type, teacher support and school learning environment. These are variables that are between each other. To illustrate, self-efficacy may be supported by previous success, and persistence may be supported by self-efficacy which subsequently may be supported by future success. Likewise, socioeconomic status can have an effect on access to tutoring, exposure to labs, access to internet and books as well as conducive learning environments.

This paper aims to integrate the evidence on the significant predictors of chemistry learning achievement in cognitive, affective and demographic/contextual realms. In order to tackle transparency in the methodology, the search protocol based on PRISMA 2020, clear inclusion and exclusion criteria, descriptive bibliometric map of the current corpus and systematically synthesised findings are used to structure the review.

2. Methodology: PRISMA-Guided Review Protocol and Bibliometric Mapping

2.1 Review Design

The research was designed to be a systematic literature review with systematic narrative synthesis. The PRISMA 2020 become reports was correlated with PRISMA that focuses on clear identification, screening, and eligibility and inclusion criteria of systematic reviews (Page et al., 2021). The heterogeneity of designs included in the studies used makes the review lacks a pooling of effects sizes using meta-analysis. It instead entertains synthesis without meta-analysis principles to group findings by predictor area, direction of evidence, context and quality of methods (Campbell et al., 2020).

2.2 Databases Searched and Search Strategy

The search strategy was formulated basing on three terms which include chemistry learning achievement, predictor variables and level of education. Scopus, Web of Science Core Collection, ERIC, Education Source, PubMed/PsycINFO (where applicable) and Google Scholar to citation chase are the databases that will be searched to ensure final verification. Highly cited studies and systematic reviews in the field of education in chemistry should be searched with backward and forward citation. The search window proposed is 1980 to 2026 to ensure that both older studies regarding spatial ability foundations and the affective measurement fit within and current chemistry education research fits.

Table 1. Search strategy for the systematic review

Database/source	Boolean search string or search phrase	Purpose
Scopus / Web of Science	TITLE-ABS-KEY(("chemistry achievement" OR "chemistry performance" OR "chemistry learning achievement") AND (predictor* OR "self-efficacy" OR motivation OR attitude OR anxiety OR "spatial ability" OR "mathematical readiness" OR socioeconomic OR gender))	Core citation-indexed literature
ERIC / Education Source	("chemistry education" AND achievement AND (self-efficacy OR motivation OR attitude OR anxiety OR "spatial ability" OR mathematics OR demographic OR socioeconomic))	Education-focused studies and instrument papers
PubMed / PsycINFO	("science achievement" OR "chemistry achievement") AND (achievement emotions OR self-efficacy OR motivation OR anxiety OR belonging)	Psychological and affective predictors relevant to science/chemistry learning
Google Scholar	"chemistry achievement" "self-efficacy"; "general chemistry" "spatial ability"; "organic chemistry" achievement motivation	Citation chasing and grey-literature checks where appropriate

2.3 Inclusion and Exclusion Criteria

The inclusion criteria were that the studies had to directly address chemistry achievement or relevantly similar science achievement; and had to test one or more cognitive, affective, demographic or contextual predictors. The inclusion criteria comprised empirical studies, validated scale-development articles, meta-analyses and systematic reviews where the constructs of the research were directly related to chemistry achievement. The criteria used to exclude studies included: did not pertain to the learning of chemistry/science, results (achievements/performance) or a specific predicate of significant interest, were opinion pieces with no analytic evidence, or lacked adequate bibliographic information.

Table 2. Inclusion and exclusion criteria

Criterion	Inclusion	Exclusion
Population	Secondary school students, undergraduate chemistry students, or comparable science learners	Samples outside education contexts or unrelated to chemistry/science learning
Outcome	Chemistry achievement, chemistry performance,	Studies without an achievement/performance

	conceptual understanding, grades, test scores or laboratory competence	outcome or transferable science-learning outcome
Predictors	Cognitive, affective, demographic, contextual or instructional predictors	Studies focused only on curriculum description without predictor-outcome relevance
Study type	Empirical research, systematic reviews, meta-analyses, validated measurement studies and theory papers directly supporting predictor interpretation	Editorials, unsourced opinion papers, non-peer-reviewed material lacking analytic detail
Language and access	English-language full text or abstract with sufficient details for coding	Records with insufficient information for eligibility judgement

2.4 Screening and Study Selection

All the records are supposed to be sent to a reference manager where duplicates have to be eliminated and then the records must be screened. The screening can take place in two phases, i. e., title/abstract screening and full-text eligibility screening. All records need to be coded as include, exclude or uncertain. Mixed-up records ought to be sorted out using complete-text examination. The reasons behind the exclusion during full-text level must be recorded under groups like non-chemistry context, no achievement outcome, no predictor variable, duplicate report, inadequate methods or inaccessible full text. The present manuscript will be a synthesis corpus of 34 that it will include; the result counts will be determined as the number of hits on the database, the number of counts duplicates, and the number of Counts of the cases eliminated by full-text need to be completed by journal submission by searching the database and extracting the search results.

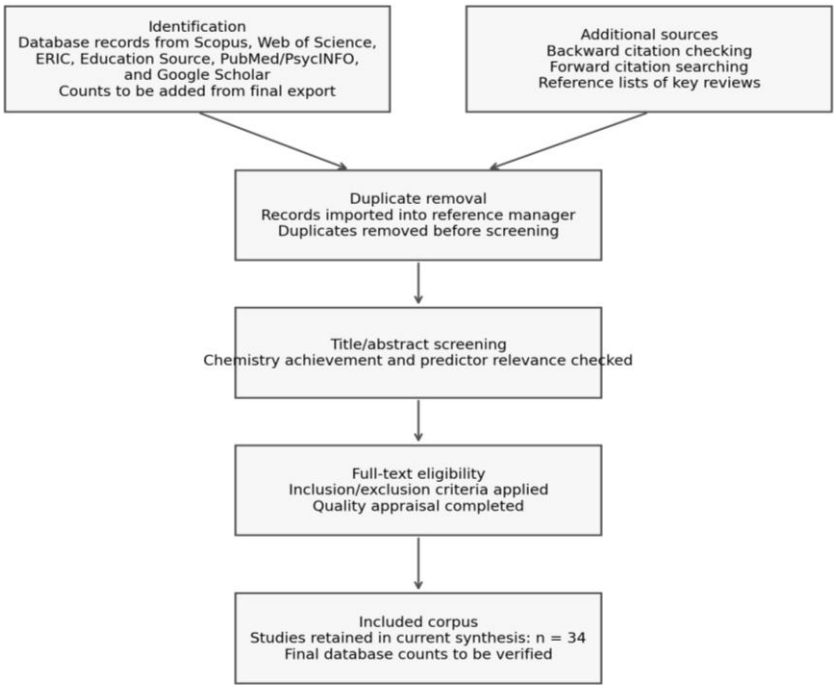

Figure 1. PRISMA 2020-aligned literature selection flow for final verification

2.5 Data Extraction and Quality Appraisal

The extraction sheet must include author, year, country/context, education level, sample, study design, predictor domain, measurement instruments, achievement outcome, analytic method, main finding and limitations, which can be found in every eligible study. Appraisal of quality should be based on clarity of sampling, validity and reliability of instruments, adequacy of statistical analysis, control confounding variables, reporting transparency and relating to chemistry achievement. Systematic searches and meta-analyses are to be evaluated in terms of transparency of the search and synthesis logic. The appraisal is not aimed to filter out all the lower-quality studies automatically instead; it is applied to give a weight on confidence over the synthesis.

Table 3. Data extraction and coding framework

Data-extraction component	Coding details
Bibliographic metadata	Author(s), year, journal, DOI, country/region if available
Study context	Secondary school, general chemistry, organic chemistry, or higher education context
Predictor coding	Cognitive, affective, demographic/contextual, instructional, or mixed-domain
Achievement measure	Test score, course grade, conceptual inventory, laboratory performance or persistence/attrition
Evidence coding	Positive association, negative association, mixed association, indirect/mediated effect, or theoretical support
Quality indicator	Sampling clarity, instrument validity, analytic fit, confounder control and reporting transparency

2.6 Bibliometric and Quantitative Synthesis Procedures

Bibliometric mapping was planned to summarize the publication-year trend, journal distribution, author/source concentration and keyword or predictor-domain clusters. When complete Scopus or Web of Science metadata are available, co-occurrence and source maps may be generated through bibliometrix or VOSviewer (Aria & Cuccurullo, 2017; van Eck & Waltman, 2010). For the current manuscript corpus, descriptive bibliometric mapping is reported using publication year and predictor domain. Quantitative synthesis is presented as frequency mapping by predictor domain and structured evidence patterns rather than as meta-analysis, because included studies differ substantially in sample, level, scale, outcome and design.

3. Cognitive Predictors of Chemistry Learning Achievement

3.1 Prior Knowledge and Former Academic Performance

Prior experience is one of the strongest predictors of future academic success. Prior knowledge in chemistry includes understanding of basic science concepts, mathematics, measurement, atomic structure, chemical symbols, formulae, the mole concept, proportional reasoning and scientific vocabulary. Students with weak background knowledge struggle because chemistry progresses cumulatively. Stoichiometry, for example, requires knowledge of atomic mass, mole ratios, balanced equations, unit conversion and proportional reasoning. A gap in one area can affect later problem solving.

The history of academic performance also reflects broader academic behaviors such as study discipline, reading comprehension, note taking and examination preparation. Research on academic performance in higher education has shown that prior performance, effort regulation, self-efficacy and academic skills are relevant in predicting subsequent performance (Richardson et al., 2012; Schneider & Preckel, 2017). In chemistry, pre-semester assessments and

diagnostic tests have helped identify students likely to struggle in general chemistry (Legg et al., 2001; Wagner et al., 2002). Early diagnostic testing can support remedial instruction, bridge courses, tutoring and skill workshops before failure occurs.

3.2 Mathematical Readiness

Chemistry is conceptually and quantitatively demanding. Students use arithmetic, algebra, logarithms, ratios, proportional reasoning, graph interpretation and, at higher levels, calculus-based reasoning. Mathematical fluency is required for stoichiometry, gas laws, equilibrium, acid-base calculations, electrochemistry, kinetics, thermodynamics and colligative properties. Weak mathematical preparation can therefore become a barrier to chemistry achievement.

Studies in general chemistry have shown relationships between chemistry achievement and arithmetic automaticity or basic mathematics skills (Powell et al., 2020; Williamson et al., 2020). This does not mean that chemistry should be reduced to mathematics. Instead, students need to connect mathematical operations with chemical meaning. For example, equilibrium calculations require students not only to solve for unknown concentration but also to interpret equilibrium position, reaction quotient and system response.

3.3 Spatial Ability and Molecular Representation

Spatial ability is particularly useful in chemistry because chemical phenomena often involve three-dimensional structures represented on two-dimensional surfaces. Students must manipulate molecular geometry, bond angles, stereochemistry, conformations, orbital interactions, crystal structures and reaction mechanisms. Organic chemistry requires mental rotation of molecules, identification of stereochemical relationships and translation among wedge-dash diagrams, Newman projections, chair conformations and three-dimensional models.

Harle and Towns (2011) reviewed spatial ability literature and highlighted its connection to chemistry learning. Pribyl and Bodner (1987) found that spatial ability contributed to organic chemistry performance. Stieff et al. (2012) showed that spatial ability and strategy preference influence spatial problem solving in organic chemistry. These findings suggest that spatial reasoning is not merely an innate talent but a skill that can be supported through molecular model kits, augmented reality, drawing exercises, explicit representation translation and animation.

3.4 Metacognition and Self-Regulated Learning

Metacognition refers to students' awareness and control of their thinking. In chemistry, metacognitive students monitor whether they understand concepts, identify flawed problem-solving steps, select appropriate strategies and adjust their learning habits. Self-regulated learning includes planning, monitoring, effort regulation, help seeking, time management and reflection.

Organic chemistry research has demonstrated that self-regulated learning strategies are related to academic achievement (Lopez et al., 2013). Students who rely only on rereading or memorizing reaction lists may struggle when they must explain mechanisms for unfamiliar molecules. Students who review concepts, explain processes, generate examples and review mistakes tend to learn more deeply. Metacognitive training in general chemistry has also been associated with improved self-efficacy and performance (Graham et al., 2019).

3.5 Conceptual Understanding and Misconceptions

Success in chemistry requires more than correct answers; it requires conceptual understanding. Students often hold misconceptions about atoms, molecules, bonding, equilibrium, acids and bases, thermodynamics and chemical reactions. For example, some students may misunderstand equilibrium as equal concentration, assume bonds store energy in a simplistic way or imagine that atoms expand when heated. Such

misconceptions interfere with learning because new information is interpreted through existing mental models.

Conceptual learning improves when instruction connects macroscopic observations, submicroscopic explanations and symbolic representations. Students need opportunities to justify, predict, model and revise their thinking. Diagnostic concept inventories and formative assessments can help teachers identify misconceptions early. Conceptual weakness often predicts poor achievement because later chemistry topics depend on earlier conceptual building blocks.

4. Affective Predictors of Chemistry Learning Achievement

4.1 Chemistry Self-Efficacy

Self-efficacy can be defined as the idea the students have about performing certain actions. Chemistry self-efficacy is not a general confidence; it is chemistry-related confidence which deals with trying to solve problems, comprehend concepts and lab work or succeeding with chemistry tests. According to social cognitive theory, self-efficacy is a cause of effort, persistence, choice of an emotional response and activity (Bandura, 1977). It is one of the most popular affective predictors widely studied in chemistry education.

Uzuntiryaki and Çapa Aydin (2009) created the scale of college chemistry self-efficacy and Çapa Aydin and Uzuntiryaki (2009) created a scale of high school chemistry self-efficacy. Ferrell and Barbera (2015) discovered self-efficacy, interest and efforts beliefs in general chemistry learning are significant. Villafañe et al. (2016) analyzed mutual correlates between self-efficacy and the performance in organic chemistry, which suggests that confidence may have an impact on the performance as well as be affected by it. Self-efficacy is recently connected with mindset, goal orientation, achievement emotions and engagement (Liu et al., 2025; Naibert et al., 2024).

Self-efficacy has an impact on performance since confident students are inclined to tackle challenging tasks, not give up on failure, seek assistance and interpret failure as learning. Avoidance, anxiety, and withdrawal in chemistry pathways may be due to low self-efficacy. Nevertheless, an overconfident ability that lacks skills are also problematic. Mastery experiences, guided practice, feedback and visible progress should thus be used in chemistry teaching to inculcate accurate self-efficacy.

4.2 Attitude Toward Chemistry

Attitude entails how students feel, believe and dispose of the subject of chemistry. Positive attitude can be the pleasure, felt relevance, interest and desire to be able to learn chemistry. Negative attitude can also consist of fear, boredom, dislike or thinking that chemistry is too hard or irrelevant.

Bauer (2008) created a semantic differentiator tool used to gauge attitude towards chemistry whereas Bauer (2005) used chemistry self concept as a component of affective learning. A measure of attitude was refined by Xu and Lewis (2011), and structural equation modeling by Xu et al. (2013) were used to help uncover relationships between attitude, conceptual knowledge and achievement. These articles indicate that the attitude is not a minor affective issue but it is related to involvement and performance.

Attitude can also be influenced by teacher practice, teaching approach, lab work, pertinence of examples, the type of assessment and peer culture. Positive attitudes can be promoted by chemistry related to medicine, food, environment, technology, agriculture, cosmetics, energy and everyday life. Teaching that is too abstract, high levels of rote learning, harsh evaluation and failure to give feedback may result in bad attitudes.

4.3 Motivation, Interest and Value of Task.

Motivation is a reason of why students learn, the amount of efforts they put in and duration they will continue. Intrinsic motivation, career motivation, grade motivation, self-determination and self-efficacy could be considered as some of the motivations of chemistry. The Science

Motivation Questionnaire II has been approved in terms of its validity by Glynn et al. (2011).

The issue of interest is essential since chemistry is regarded as challenging in many cases. The number of students who take interest in asking questions is higher and they are more inclined to get explanations to get to know how chemistry relates to real-life issues. Task value is the perceived significance, usefulness and relevance of learning chemistry. Students who think that chemistry helps in medicine, engineering, pharmacy as well as in environmental science or everyday life might continue to assert themselves more.

Self-determination theory helps us to perceive that motivation is determined by autonomy, competency and relatedness. Black Deci (2000) discovered connections between instructor autonomy support, students autonomy in motivation and learning in organic chemistry. This is important since a significant proportion of students are subjected to chemistry as an obligatory one. Relevance can also transform students who are controlledly motivated into more autonomously motivated ones when teachers support the latter meaningfully through high participation and competence.

4.4 Achievement Emotions and Chemistry Anxiety.

Achievement emotions: These are emotions that are tied directly to academic activity and performance such as enjoyment, hope, pride, anxiety, shame, boredom, anger and hopelessness. Pekrun et al. (2006) have related achievement goals to achievement emotions and have demonstrated that emotions affect learning processes. Emotions particularly apply to chemistry since the subject is usually highly cognitively challenging and pressure to assess as well.

Situation: chemistry anxiety may be present when solving a problem, working in the laboratory, taking a test or making an oral presentation. Anxiety has the potential to minimize working-memory and negatively affect performance. Students prove to be knowledgeable but when they are on the spot, they just falter. Boredom can also decrease attention and effort and even stimulate persistence by positive emotions like enjoyment and hope. Liu et al. (2025) determined that there were direct and indirect relationships between chemistry achievement emotions and achievement, via self-efficacy.

4.5 Belonging and Identity

Belonging is a feeling that one is accepted, respected and is involved in the learning environment. Participation, persistence and performance in courses of chemistry are affected by belonging. Even able students may check out when they get opportunities to study chemistry when they think it is not a subject that people like them can study. Fink et al. (2020) demonstrated that first-year undergraduates performance and retention were predicted by belonging in general chemistry.

Chemistry identity is defined as the perspective students will hold the claim of being a competent learner of chemistry, or a future professional in science. Teacher recognition, the experience of success, support of peers, role models and representation shape identity. Inclusive teaching is hence not a social rather than an academic success issue.

5. Demographic and Contextual Predictors

5.1 Gender

Gender differences in chemistry achievement are complex and context-dependent. Some studies find no consistent achievement difference by gender, while differences in self-efficacy, anxiety, participation and identity may be more visible. Turner and Lindsay (2003) examined gender differences in cognitive and noncognitive factors related to organic chemistry achievement. Wang and Degol (2017) reviewed gender gaps in STEM and emphasized that achievement differences cannot be interpreted separately from stereotypes, expectations, confidence and schooling environments.

Gender should not be used as a biological explanation for achievement variation. Rather, gendered experiences may affect encouragement, confidence, classroom participation, role-model

exposure and sense of belonging. For example, female students may perform equally well but report lower confidence in some STEM environments. Chemistry educators should monitor classroom interaction, group work, feedback and representation.

5.2 Socioeconomic Status and Home Educational Resources

Socioeconomic status is a major contextual predictor of academic achievement. Sirin's (2005) meta-analysis found a medium-to-strong association between SES and academic achievement. In chemistry learning, SES may affect access to textbooks, laboratories, private tutoring, internet resources, quiet study space, parental academic support and school quality. Students from low-resource backgrounds may have fewer supports rather than lower ability.

Home learning resources include books, digital programs, internet access, educational software, study space and parental involvement. TIMSS-based evidence links science achievement with home resources and attitudes (Addido et al., 2025). In chemistry, resource gaps can affect homework completion, simulation access, laboratory preparation and examination practice. Schools and colleges should provide libraries, open laboratory practice, electronic materials, peer mentoring and remedial services.

5.3 Parental Education and Language Background

Parental education has the potential to impact achievement in the form of academic expectations, academic support of study, educational planning and familiarity with school system. Nonetheless, parental schooling has to be viewed with a considerable amount of caution since first-generation students will be able to achieve success provided that the institutions can guide and help them. Such students can be helped with explicit communication of the expectations in the academic level, office hours, strategies of studying and career opportunities with professional training in chemistry.

In addition, language background is an important factor. Special vocabulary, use of symbols and thick textbook explanations are used in chemistry. Learning chemistry as a second language, students might not accomplish as easily not due to ineffective scientific thinking but because the processing of the language and primary meaning is required in those situations. Glossaries, visual representations, writing-to-learn and bilingual-where-and-where-appropriate examples are some of the ways that teachers can facilitate the development of the language.

5.4 Type of school, quality of the teachers and classroom environment.

Demographic impacts usually take place via institutional context. Students at well-equipped schools can possess such resources as laboratories, trained teachers in chemistry, small classes and technology. Learners in low resource education can experience deficit of teachers, insufficient practical experiences and teaching which is based on examinations. The quality of a teacher, climate in the classroom setting, assessment and instruction design may decrease or expand achievement gaps.

Inquiry learning, guided inquiry, process-oriented guided inquiry learning, collaborative problem solving and active learning can be well implemented to enhance engagement and learning. But the active learning should be organized in such a way that no students who had greater knowledge of a subject should tyrannize. An efficient teaching method is both explanatory and practical with feedback and evaluations of formative assessment and interactive learning.

6. Bibliometric and Quantitative Synthesis of the Literature that is included.

It includes 34 sources which are included in the current corpus. A bibliometric profile displaying all literature produces the descriptive profile of the literature being foundational studies of the 1980s to the modern chemistry education research. The last sources are clumped in Chemistry Education Research and Practice and Journal of Chemical Education, which shows that the review is grounded in the chemistry education research but relied on the evidence available in the area of educational psychology and science education in general.

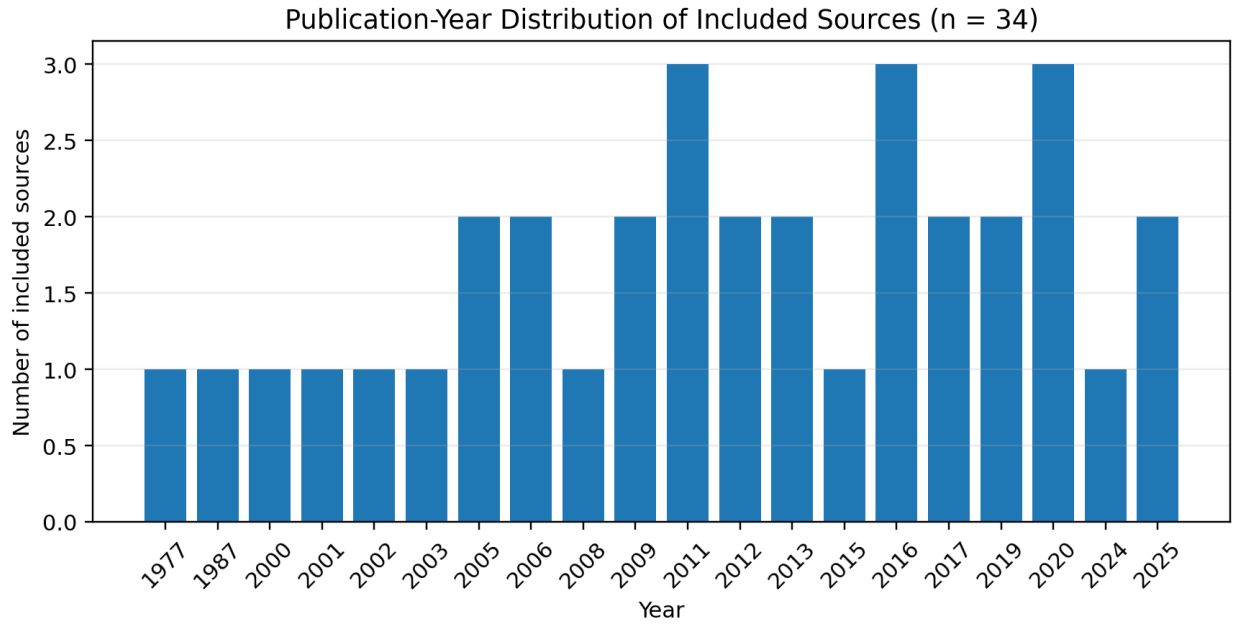

Figure 2. Publication-year distribution of the included sources

Domain-wise mapping shows that affective predictors are the most frequently represented in the corpus, especially self-efficacy, motivation, attitude, achievement emotions and belonging. Cognitive predictors are strongly represented through prior achievement, mathematical readiness, spatial ability and self-regulated learning. Demographic/contextual predictors appear less frequently but remain central for interpreting opportunity structures and equity-related achievement gaps.

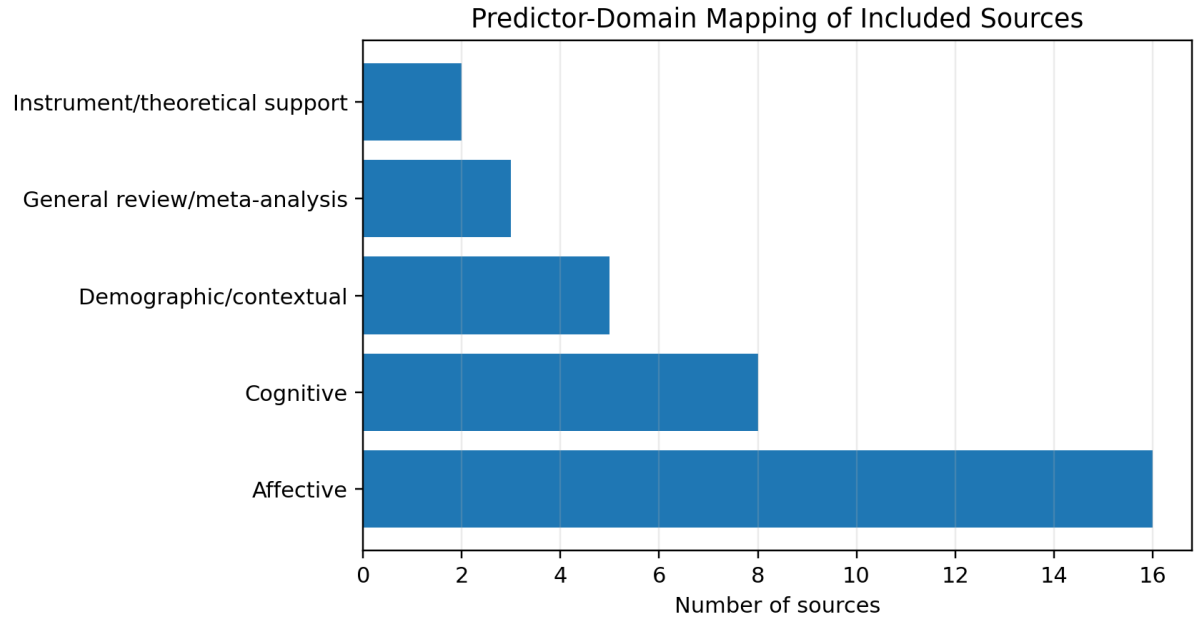

Figure 3. Predictor-domain mapping of the current synthesis corpus

Table 4. Quantitative domain-wise mapping of included literature

Domain	No. of sources	Representative variables	Evidence pattern
Affective predictors	16	Self-efficacy, motivation, attitude, achievement emotions, belonging	Generally positive links with achievement through effort, persistence, engagement and anxiety reduction
Cognitive predictors	8	Prior knowledge, mathematical readiness, spatial ability, metacognition	Strong direct relevance for chemistry problem solving and conceptual understanding
Demographic/contextual predictors	5	SES, gendered experience, home resources, language and classroom context	Indirect and opportunity-mediated effects; important for equity-focused interventions
General reviews/meta-analyses	3	General higher-education achievement and SES-achievement literature	Supports interpretation of predictor strength across educational contexts
Instrument/theoretical support	2	Self-efficacy theory and motivation/self-determination theory	Provides theoretical foundation for interpreting affective predictors

This quantitative mapping does not replace a meta-analysis. Rather, it makes the synthesis more transparent by showing which predictor families dominate the literature and which areas require further empirical attention. The limited number of demographic/contextual studies suggests a need for more culturally responsive, longitudinal and mixed-method research on how opportunity structures shape chemistry learning achievement.

7. Synthesis of Key Predictors

The major predictors of chemistry learning achievement can be grouped into cognitive, affective, demographic and contextual domains. Table 5 summarizes the central predictors, their influence on achievement and classroom implications.

Table 5. Major predictors of chemistry learning achievement

Predictor domain	Specific predictor	How it influences achievement	Example implication
Cognitive	Prior chemistry knowledge	Supports understanding of advanced topics	Use diagnostic tests and bridge modules
Cognitive	Mathematical readiness	Enables quantitative problem solving	Integrate math review with chemistry examples

Cognitive	Spatial ability	Supports molecular structure reasoning	Use models, drawings, AR and visualization practice
Cognitive	Metacognition	Improves strategy use and error correction	Teach reflection and exam-wrapper activities
Cognitive	Conceptual understanding	Reduces misconceptions and supports transfer	Use concept inventories and formative assessment
Affective	Self-efficacy	Increases effort, persistence and help-seeking	Provide mastery experiences and constructive feedback
Affective	Attitude	Shapes engagement and willingness to learn	Connect chemistry to real-life applications
Affective	Motivation	Influences effort and persistence	Support autonomy, relevance and competence
Affective	Achievement emotions	Affect attention, confidence and performance	Reduce anxiety and promote positive challenge
Affective	Belonging	Supports participation and persistence	Build inclusive classroom culture
Demographic	Gendered experience	Influences confidence, identity and participation	Use equitable feedback and representation
Demographic	SES/home resources	Affects access to academic support	Provide institutional resources and mentoring
Demographic	Language background	Affects comprehension of technical vocabulary	Use visual, linguistic and scaffolded support
Contextual	Teacher/classroom environment	Shapes opportunity to learn	Use active, guided and inclusive pedagogy

8. Integrated Conceptual Framework

The product of Interactive relationships between student preparedness, affective involvement, context of learning is chemistry achievement. The cognitive variables give a basis to the cognition and the resolution of a problem. The emotional elements dictate whether students will take up and persist into a challenging situation. Access, experiences related to identity and opportunity are determined by demographic variables. These relationships are mediated by instructional quality since teaching may enhance or diminish the impact of predictors.

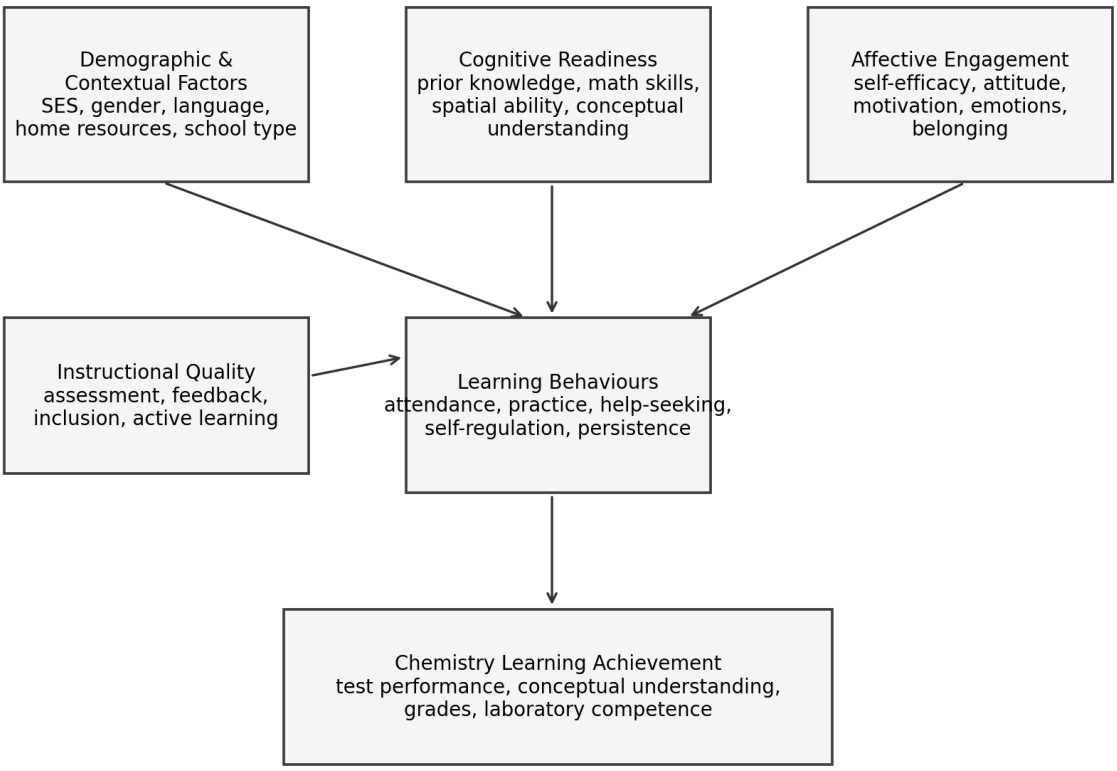

Figure 4. Conceptual model of predictors of chemistry learning achievement

This model indicates the demographic factors do not have the deterministic factors. Their impact on achievement is primarily in the areas of resource access, the quality of instruction and affective experiences. On the same note, there is nothing like fixed cognitive abilities. Through the proper support, students are able to achieve mathematical fluency, spatial reasoning and conceptual understanding and self-regulation.

9. Discussion

According to the literature, it is not the interaction of one single predictor but an interactive mechanism that results in chemistry achievement. Previous success and intellectual preparedness are noteworthy yet no longer than adequate explanations. Anxiety, poor belonging support or poor instructional support might still be the cause of a student with a good performance in the past. In time a student who has lower effectiveness can be able to achieve through better self efficacy, encouragement by the teacher and learning plans.

Self-efficacy seems to be the most powerful one of affective variables, as it is what connects cognitions, emotion and action. Students who have a greater sense of self-efficacy in chemistry have increased chances of persevering through difficult topics. However, genuine skills development and not honorable praise should lead to self-efficacy development. To facilitate the teaching personality towards self-efficacy can involve simplifying and enhancing a difficult task into smaller manageable parts, timely feedback, role modeling and promoting revision.

The attitude and motivation are also important as chemistry is thought to be hard, abstract and unrelated to everyday life. Medicine, food chemistry, environmental pollution, material science, cosmetics, agriculture and energy are examples that can be effective in improving attitude. Task value is reinforced by relevance and your persistence by your task value.

The area of space and readiness to mathematics is an area that needs particular attention due to its frequent obscurity as a hindrance. The problem may be pro rata reasoning, reading graphs or

visualization of three dimensional structures, and this may result in students being labeled weak in chemistry. Achievement improvement, especially with the aid of targeted visualization and mathematics as opposed to general mathematics, can thus be realized.

Demographic predictors will help educators to remember that opportunity structures are connected with differences in achievement. They can be gender, socioeconomic status, language background and school type, as they can affect their learning experiences. Student blame should not be based on these factors. They ought to instead inform equity-based interventions like open educational resources, structured study groups, language support, mentorship and increased access to laboratory.

10. Educational Implications

Firstly, early diagnoses assessments are recommended to detect any lapses in existing knowledge, mathematics and representation aptitudes among the chemistry teachers. There should be low-stakes diagnostic assessment and associated with support.

Second, conceptual, mathematical and representational learning should be incorporated in the teaching of chemistry. Students must be able to work out problems that are quantitative and to justify the chemical sense of their values.

Third, the scaffolded problem solving, formative feedback, peer instruction and opportunity to observe progress should be developed by teachers intentionally to develop chemistry self-efficacy.

Fourth, courses in chemistry ought to decrease superfluous worry and keep them scholastic. Fear can be minimized by giving well-understood expectations, practice tests, safe laboratory training and positive feedback.

Fifth, it needs to have an inclusive pedagogy. The use of examples, role models, group work and feedback should assist all students in making them feel like they fit within chemistry.

Sixth, response to demographic obstacles by the institutions should happen by provision of tutoring, digital access, and lab opportunities, mentoring, language support and financial aid where possible.

11. Future Research Directions

Future studies must go beyond single-predictor studies, and explore predictor interactions across cognitive predictors, affective predictors and demographics as time goes by. Longitudinal investigations are required to help in explaining the predictive nature of self-efficacy related to achievement, achievement related to self-efficacy or a combination of the two processes. Mixed-method research is able to clarify why there are good students with low numbers of resources whose performance was so good and those students with good performance who dropped chemistry.

The variation in culture in predictors of chemistry achievement should also be analyzed through further research. The instruments created in one country are not likely to operate in the same way in another country unless it is confirmed as valid. Qualitative interviews and culturally responsive frameworks, measurement invariance testing are required. Lastly there is a need to have more intervention studies. Predictors are important to identify, however, evidence-based interventions that enhance performance and decrease inequities are essential to chemistry education.

12. Conclusion

There are cognitive, affective and demographic/contextual predictors which determine performance on chemistry learning. Cognitive preparation such as prior knowledge, mathematical ability, spatial skills, conceptual learning and metacognition, will aid in learning chemistry. Engagement and persistence are affected by the affective factors including self-efficacy, attitude, motivation, feeling of achievement and belonging. Opportunities to learn are determined by demographic and contextual variations including gendered experience and socioeconomic status, as well as language background, home resources, the type of school and teacher support.

The synthesis indicates that chemistry success ought to be considered in a balanced system as opposed to a result of detached foretellers. The presence of cognitive tools, motivation and emotional support, as well as equal access to resources and high quality of learning opportunities allow students to excel in chemistry. Enhancement of achievement in chemistry thus cannot be done by just delivery of content. It needs to be diagnosed, affectively supported, representation-filled teaching, mathematically scaffolded, institutionally equitable and comprehensive pedagogy.

Ethics Declaration: This study is a systematic review and bibliometric analysis based solely on published literature and publicly accessible bibliographic databases. No human participants or animals were involved; therefore, ethical approval and informed consent were not required.

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