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Examining the competence and perceptions of teacher candidates in developing the social-emotional skills of preschool children using STEAM technologies

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Abstract

The purpose of this study was to develop a valid and reliable instrument to assess pre-service teachers' competencies and perceptions regarding the use of STEAM technologies to support children's social-emotional learning (SEL) and to identify their competency profiles. The data were collected from 450 pre-service preschool teachers studying at Alikhan Bokeikhan University and Abai Kazakh National Pedagogical University. 94.2% of the participants were female. The construct validity of the scale was examined using exploratory structural equation modeling (ESEM). The 60-item scale, which was initially structured in six dimensions, was refined into a final form comprising four competence factors and a separate perception/attitude dimension.

Content validity was established through a six-member expert panel; item- and scale-level content validity indices (I-CVI, S-CVI) were computed, and the scale-level indices (S-CVI/Ave = .94 to .97) exceeded the recommended threshold. The four-factor ESEM model showed acceptable fit (CFI = .98, TLI = .97, SRMR = .025). The model identified four interpretable factors. These were STEAM and social-emotional skill development, STEAM-SEL integration self-efficacy, technology integration, and classroom management.

Inter-factor correlations ranged from .33 to .78. Discriminant validity was supported by the Fornell-Larcker criterion. The one-factor structure predicted for the perception/attitude section was confirmed (CFI = .99, TLI = .99, SRMR = .062).

Reliability was high across all dimensions, with Cronbach's alpha and McDonald's omega coefficients at the .98 level. Latent profile analysis yielded a three-profile solution with near-perfect classification accuracy (entropy = .97): a high competence-high attitude profile comprising the majority of participants (77.3%), a low competence-low attitude profile (17.3%), and a smaller moderate competence-high attitude profile (5.3%) in which favorable attitudes coexisted with more modest competence perceptions. Profile membership did not differ significantly by grade level (three-step analysis, $p = .46$), suggesting that current teacher education programs may not provide a systematic and progressive pathway toward integrating STEAM and SEL.

The developed scale provides a functional tool for assessing integrated STEAM-SEL competencies and an applicable framework for curriculum development and professional development planning in early childhood teacher education programs.

Keywords: STEAM education, social-emotional learning, scale development, exploratory structural equation modeling, latent profile analysis, early childhood education, teacher competency

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Contribution to the literature

- This study fills a measurement gap by developing an integrated instrument that assesses both the competencies and the perceptions of pre-service preschool teachers regarding STEAM-SEL integration; existing scales have addressed STEM readiness or SEL beliefs separately, but not the combined construct that connects the two domains.
- The combined use of exploratory structural equation modeling and latent profile analysis provides both a variable-centered account of the scale's factor structure and a person-centered account of how teacher candidates group according to their competency and attitude patterns, offering a methodological contribution beyond the confirmatory approaches typically applied in this literature.
- The study extends STEAM-SEL competency research to a Central Asian context; the pre-service preschool teacher population in Kazakhstan has not previously been represented in this literature, which has developed largely around North American, European, and East Asian samples.

INTRODUCTION

The preschool period is a critical phase in which the foundations of children's cognitive, social, and emotional development are established. Social-emotional skills acquired during this period have long-term effects on children's later development. These effects carry over into academic achievement, relationships with others, and overall quality of life (Denham et al., 2012a; Jones & Doolittle, 2017). The STEAM (science, technology, engineering, arts and mathematics) teaching approach has been more and more used at the preschool level in recent years. The potential of this technique for contributing to children's social-emotional development has begun to be examined (Perignat & Katz-Buonincontro, 2019).

Collaboration, problem-solving, patience, and creativity are all abilities that are required in STEAM activities. In this manner they have a natural potential to be integrated with social-emotional learning (SEL). The collaborative for academic, social and emotional learning (CASEL) identifies five fundamental SEL abilities (CASEL, 2020). These are self-awareness, self-management, social awareness, relationship skills, and responsible decision-making. Each can be organically supported during STEAM activities. However, the effective realization of this integration requires teachers to be competent in both STEAM pedagogy and SEL strategies.

Teacher competency is recognized as one of the most determinative factors of educational quality (Darling-Hammond, 2017). Realizing the integration described above therefore depends on whether teachers possess the competencies that bridge STEAM pedagogy and social-emotional facilitation within the same activity. The available instruments, however, address these two domains in parallel rather than in combination. On the STEAM side, recent measures such as the STEAM-TSES capture teachers' self-efficacy for teaching disciplinary content and for integrating subjects, but they do not extend to the social-emotional processes that unfold during inquiry (Stepanović Ilić et al., 2025), and competence frameworks developed for STEAM educators likewise organize roles around teaching methods and disciplinary integration without treating social-emotional facilitation as a component (Spyropoulou & Kameas, 2023). On the SEL side, instruments such as the SECTRS and the scales mapped in recent systematic reviews are anchored almost exclusively in the CASEL competencies and remain silent on disciplinary or technological integration (Grazzani et al., 2024; Martinez-Yarza et al., 2023). This separation is not merely a gap in coverage. Because the embedded and fully integrated models require teachers to plan cognitive and social-emotional goals as a single pedagogical act, an instrument that measures the two capacities in isolation cannot indicate whether a teacher is prepared for the integrated practice itself. It is this intersectional competence, rather than either domain alone, that the present study set out to operationalize.

Building on this gap, the present study set out to develop and validate an instrument that assesses pre-service preschool teachers' competencies and perceptions regarding the development of children's social-emotional skills through STEAM technologies, and to identify the competency profiles that characterize this group. The substantive contribution is twofold. The scale gives empirical form to a construct, integrated STEAM-SEL competence, that has so far been discussed conceptually but not measured as a unified capacity; and the person-centered analysis moves beyond the question of how high candidates score toward the question of how their competencies and attitudes pattern together, which is more directly informative for teacher preparation. The choice of exploratory structural equation modeling (ESEM) (Asparouhov & Muthén, 2009) over traditional confirmatory factor analysis (CFA) follows from both the construct and the data. Conceptually, the facets of an integrated competence are expected to share variance rather than form independent clusters, so the zero cross-loadings imposed by independent-clusters CFA are theoretically implausible. Statistically, constraining such cross-loadings to zero is known to inflate factor correlations and distort fit, whereas ESEM permits cross-loadings and yields more realistic structure and inter-factor estimates (Marsh et al., 2014). Latent profile analysis (LPA) was used to address the person-centered question.

The research questions of this study are as follows:

1. What is the factor structure of the STEAM-SEL competency and perception scale as determined by ESEM?
2. What are the reliability coefficients of the identified dimensions?
3. What distinct STEAM-SEL competency profiles can be identified among pre-service preschool teachers?
4. How are these profiles distributed across demographic variables?

LITERATURE REVIEW

Preschool STEAM as an Integrated and Play-Based Approach

STEAM in early childhood education is usually defined as an integrated approach that brings together science, technology, engineering, arts, and mathematics around meaningful experiences and real problems (Ata-Aktürk & Demircan, 2017; English, 2016; Perignat & Katz-Buonincontro, 2019). In preschool settings, this approach should not be reduced to formal subject teaching. Children learn through play, exploration, talk, movement, and repeated interaction with materials. For this reason, preschool STEAM is strongest when it is hands-on, inquiry-based, and connected to the child's everyday world (DeJarnette, 2018; Fleer, 2021; Wahyuningsih et al., 2020).

Early childhood is widely regarded as a productive period for STEAM precisely because young children already engage in proto-scientific activity. They pose questions, test ideas, build structures, sort objects, notice patterns, and use symbols in play, and these behaviors form a natural base for early science and mathematics learning while also supporting engineering habits such as planning, testing, revising, and explaining (English, 2016; National Research Council, 2012). Understood in this way, preschool STEAM is less concerned with the transmission of isolated facts than with the design of environments in which children observe, compare, communicate, and reflect.

STEAM differs from STEM in that it intentionally incorporates the arts, and this has particular significance for early life. Before children have the formal academic language to express complicated ideas, they often externalize their comprehension through sketching, construction, dramatic play, and dance. Hence the expressive means of the arts are developmentally consistent with the ways in which young children are already thinking. Liao (2016) describes art integration as moving STEAM from a conjunction of subjects to meaningful, student-centered learning. More particularly, Perignat and Katz-Buonincontro (2019) position the contribution of the arts in innovation, adaptability and the ability to frame challenges in integrated tasks. Taken together, these stories demonstrate that the arts are not a fifth field grafted on to STEM, but rather a way to make integration itself accessible to young learners.

These affordances, however, are not consistently realized, and the literature points to several recurring obstacles. The five disciplines are rarely weighted evenly. Science is typically foregrounded at the expense of engineering and technology. Technology is often treated as a ready-made tool rather than as something to be intentionally designed, programmed, or directed at a problem. Implementation is also often less reliant on the written curriculum and more dependent on teachers' confidence in their own ability to enact implementation (Brenneman et al., 2019; DeJarnette, 2018; Park et al., 2017). These are serious issues. Integrated STEAM asks teachers to look for chances to connect learning across all disciplines and to help young people without it becoming a formal lesson.

Evidence from a number of national contexts suggests that these barriers are not exclusive to a single education system. In Turkey, Veziroğlu-Çelik et al. (2026) found that preschool teachers had limited awareness of STEAM, seldom used such activities, and had difficulty accessing materials and planning activities. Similar knowledge and preparedness gap for teaching critical thinking has been reported among Indonesian early childhood educators (Drupadi & Zain, 2025). The two studies locate the constraint mostly in teachers' knowledge, but the large-scale survey of 416 Vietnamese teachers done by Nguyen et al. (2025) moves the focus outward. This study identified managerial support as the strongest predictor of STEAM practice, ahead of domain-specific knowledge and professional attitudes. Material and parental support, by contrast, showed no significant effect. Read together, the studies converge on the existence of a cross-cultural competency gap but diverge on its source, situating it variously in teacher knowledge and in institutional conditions. This divergence is itself instructive, since it implies that valid assessment of integrated practice must capture teacher competence as distinct from the contextual supports that surround it.

When it comes to the positive aspects of STEAM for young children, coding, robotics and digital tools are often emphasized. Research shows that well-structured activities can improve sequencing skills, spatial reasoning, basic math skills, collaboration, and computational thinking (Bers, 2018; Papadakis et al., 2016; Sullivan & Bers, 2016). However, it is also clear that these technologies are only beneficial when they are used in a developmentally appropriate way and when they make learning meaningful and enjoyable for children. The use of technology alone is not sufficient for a quality STEAM education. At this point, teacher mediation is of decisive importance. Teachers need to select appropriate resources, relate activities to children's curiosity and questions, and guide children in explaining the rationale for their activities.

The potential of technology-enriched STEAM practices to support social-emotional outcomes has begun to be grounded in stronger empirical evidence in recent years. In a large-scale experimental study with 450 Korean children aged five to six, Sung et al. (2023) showed that a classroom-based STEAM program supported by developmentally appropriate robotic kits led to significant increases in computational thinking and expressive vocabulary. The study also found a significant gender interaction effect on self-regulation and social behavior. This finding is important as it directly demonstrates that STEAM activities conducted with technological tools can support cognitive development and social-emotional development simultaneously. The main relationship targeted by the measurement tool developed in the current study is based on this integrated structure.

Efforts to provide comprehensive training frameworks for teachers to supply STEAM education in early childhood are also gathering pace. Walshe et al. (2025), based on the experience of early childhood educators, developed a conceptual framework termed "STEAM from the start". The framework focuses on improving knowledge and abilities and also the confidence and willingness of educators to include STEAM into their practice. A bibliometric analysis of STEAM education in preschool demonstrated a significant growth of international interest in this topic but also indicated persistent gaps in assessment tools and teachers' professional development (Florica Tifrea & Felicia Roman, 2025). Wang and Lin (2025) explored early childhood teachers' curriculum design thought processes and implementation self-efficacy in the context of STEAM and found that planning efficacy and perceived self-efficacy are strongly interwoven in practice. All these changes highlight the necessity for measurement instruments that are able to cover the multifaceted structure of STEAM competency in the early childhood context.

Social-Emotional Learning in Early Childhood

SEL refers to the process through which children understand emotions, regulate behavior, build relationships, make responsible decisions, and participate effectively in social life (CASEL, 2020; Weissberg et al., 2015). In early childhood, these abilities are closely tied to school adjustment, participation in classroom routines, and long-term academic and social outcomes (Denham, 2006; Jones et al., 2015). SEL is therefore not an "extra" area of learning. It is part of the foundation that allows children to engage with instruction, peers, and new challenges.

The early childhood SEL literature consistently organizes these capacities around five broad areas: self-awareness, self-management, social awareness, relationship skills, and responsible decision-making (CASEL, 2020). In preschool classrooms, these areas surface as concrete behaviors, as children learn to wait, listen, share materials, recover from frustration, interpret others' feelings, and express their own ideas in socially acceptable ways. Although such behaviors may appear unremarkable, they are central to participation in any collaborative or inquiry-based learning context.

Research also shows that social-emotional competence is linked to early school readiness and later adjustment. Denham et al. (2012b) found that emotion knowledge and self-regulation predict important aspects of early school success. Durlak et al. (2011), in a major meta-analysis, reported positive effects of school-based SEL programs on social behavior, attitudes, and academic performance. Jones and Bouffard (2012) further argue that social and emotional skills should be treated as teachable classroom processes rather than as fixed personal traits. This position is especially relevant in early childhood because classroom routines, teacher responses, and peer interaction strongly shape children's learning opportunities.

The role of the teacher in this process is important. Jennings and Greenberg (2009) define the "prosocial classroom" as an environment where the teacher's own social-emotional competence influences classroom climate, behavior management and student outcomes. Similarly, Hamre and Pianta (2001) show that early relationships between teachers and children have long-term effects on school outcomes. In early childhood education, children acquire SEL not only through direct instruction. The emotional quality of the classroom, the predictability of the daily flow, and the responsive nature of adult-child interactions are also essential components of this learning process. Frameworks such as the pyramid model were developed based on this understanding and centered on a preventive approach, supportive relationships, and intentional teaching of social-emotional skills (Fox et al., 2006; Hemmeter et al., 2016).

A recent review of evidence-based SEL intervention programs for preschool children found that play-based activities, use of puppets and stories, role-playing and family participation were prominent common components of effective programs . It was also found that the majority of these programs focused on problem-solving skills (Aksoy & Gresham, 2024). This review highlights that SEL programs are successful only if the content, process, and delivery are developmentally appropriate. This also applies to SEL approaches entrenched in STEAM environments. In this sense, Devlin et al. (2023) provided a procedure to measure children's active engagement in SEL treatments to assess the integrity of implementation and produced a multidimensional conceptualization that is not based only on the frequency of implementation. This methodological approach is important for the current study. Because it is not only a matter of determining whether teachers have SEL competencies, but also whether these competencies translate into meaningful participation of children during integrated activities.

Considered side by side, STEAM and SEL rest on a common pedagogical base of active participation, guided interaction, and meaningful problem solving. STEAM asks children to investigate, design, experiment, revise, and explain, whereas SEL supports the regulation of emotion, collaboration, persistence, and decision making that allow such inquiry to proceed. Their integration is therefore not merely feasible; in many preschool contexts it is a pedagogically necessary orientation, a claim the following section examines in detail.

Integration of STEAM and SEL

This relationship is perhaps most visible in collaborative design work. When children build a bridge, test a ramp, or program a robot, the activity draws on more than cognitive skill: they negotiate the task, share materials, manage frustration, attend to peers' ideas, and decide jointly how to proceed when a planned solution fails. Within such activities, perseverance, communication, and emotion regulation are constitutive of the learning process rather than secondary elements appended to it. Garner et al. (2018) argue that early STEM education provides a stronger developmental footing when its social-emotional dimensions are deliberately integrated, and research focusing specifically on early childhood STEAM-SEL integration indicates that such activities can support inclusion and sustained engagement when they are designed around explicit social and content goals (Thi Nho & Thi Thiep, 2024).

More recent empirical studies have begun to show that an explicit and planned STEAM-SEL integration at the preschool level is feasible. Mahiri et al. (2026) conducted a qualitative study that examined how STEM learning and SEL were supported together in an after-school LEGO robotics program with four- and five-year-olds. The findings revealed that through a project- and play-based pedagogical approach, children developed basic science and mathematics skills while also demonstrating competencies that correspond to the five core domains of CASEL. This study is one of the clearest examples of how young children can develop both cognitive and social-emotional competencies within a single STEAM context if teachers consciously plan for both areas of development.

Findings at the teacher level reinforce this reading while adding a conditional nuance. Monkevičienė et al. (2023) observed that early childhood teachers who deployed social-emotional and cognitive teaching strategies with comparable frequency also implemented integrated STEAM activities more often, whereas those who privileged social-emotional strategies at the expense of cognitive ones engaged in STEAM practice less frequently. The asymmetry suggests that a balanced focus on both strategy groups may be a prerequisite for effective STEAM-SEL integration. This interpretation accords with a structural feature of the present study, in which STEAM pedagogical knowledge and foundational social-emotional skills loaded on a single competence factor. Dignam et al. (2024) extend the discussion, arguing that interweaving STEAM education with self-regulation and mindfulness establishes holistic learning conditions that develop children's cognitive capacities together with the social, emotional, and behavioral capacities that underpin lifelong learning.

The engineering design process builds a functional bridge between these two fields. Defining a problem, proposing possible solutions, deciding between options, testing an idea and developing the design requires both cognitive and interpersonal regulation (English, 2016). Preschool children need support to stay effectively in this cycle. They need to tolerate uncertainty, accept that the first attempt may fail, and work with others towards a common goal. These requirements are closely aligned with the core competencies of SEL. Therefore, STEAM activities can become a concrete and applicable context for teaching skills such as turn-taking, using emotional language, collaborative problem solving and reflective thinking.

This integration can be realized in at least two ways. In the embedded model, the teacher plans a STEAM activity and consciously embeds SEL goals such as collaboration, self-regulation, or respectful communication. In the fully integrated model, social-emotional goals and STEAM goals are constructed together from the beginning of the activity. For example, the teacher might design a building activity that targets the concepts of balance and stability while simultaneously asking children to delegate tasks, discuss conflicts, and evaluate how they react to failure. The literature supports both approaches. However, the success of both models depends on the teacher's knowledge and planning capacity.

Therefore, teacher efficacy stands out as one of the most important themes in the literature. Many early childhood instructors perceive the STEAM approach positively, but are uncertain about material understanding, engineering methods, technology use, and integration into the curriculum (DeJarnette, 2018; Park et al., 2017). The same difficulties are also seen in the research on teacher education. Although pre-service teachers may be in favor of integrated learning at the level of the principle, they may feel unable to create and conduct these experiences in practice (Evagorou, 2024; Menon et al., 2023). This is an important aspect since positive thoughts by themselves do not ensure good classroom practice.

In integrated education settings, teacher knowledge is often addressed through pedagogical content frameworks. Shulman (1987) argued that effective teaching is not only based on content knowledge, but teachers also need to know how to represent content appropriately to learners. Mishra and Koehler (2006) extended this approach with the technological pedagogical content knowledge (TPACK) framework and emphasized the relationship between content, pedagogical approach and technology. These perspectives are particularly relevant for preschool STEAM, because the teacher needs to combine developmental knowledge, content knowledge, material selection and interactional support at the same time. The construct examined here, however, sits at the meeting point of three broader traditions that TPACK alone does not exhaust. The first is the discourse on 21st century competencies, in which collaboration, communication, creativity and self-regulation are treated as learning outcomes that cut across disciplinary content rather than as additions to it; STEAM is frequently positioned as a vehicle for precisely these competencies (Elsayary et al., 2022). The second is the literature on integrated and holistic pedagogy, which holds that cognitive and social-emotional development in early childhood are advanced together within the same activity rather than in separate curricular slots (Monkevičienė et al., 2023). The third is the work on teacher readiness, which distinguishes positive dispositions from the perceived capacity to enact integrated practice and locates the latter as the more proximal condition for classroom implementation (Silva-Hormazábal et al., 2023). Read together, these traditions suggest that the competence required for STEAM-SEL practice is neither STEAM knowledge nor SEL knowledge added side by side, but the readiness to manage conceptual, technological, emotional and relational processes within a single pedagogical act.

Teacher Preparation, Self-Efficacy, and Measurement

Self-efficacy is another fundamental concept in this debate. Bandura (2006) defines self-efficacy as an individual's belief in his/her capacity to organize and implement the actions necessary to accomplish a specific task. In the context of education, teacher self-efficacy affects planning processes, sustained effort in the face of difficulties, openness to new methods, and reactions to classroom problems (Tschannen-Moran & Hoy, 2001). The literature shows that teachers who perceive themselves as more competent in STEAM are more oriented towards integrated practices, use more challenging tasks, and implement innovative practices in a more sustainable manner (Park et al., 2017; Yang et al., 2023). The same situation is thought to be valid for STEAM-SEL integration. When teachers do not feel sufficiently prepared to support collaboration, emotion regulation, and inclusive participation during inquiry-based activities, quality of the practice may be limited.

This issue is even more important for pre-service teachers. They are still in the process of constructing their professional identities. Their beliefs about teaching are shaped by their courses, practicum experiences and previous school experiences (Darling-Hammond, 2006; Korthagen, 2010). At this stage, the perceived efficacy can be a determinant for candidates to avoid or adopt integrated approaches. Even if a teacher candidate finds STEAM and SEL valuable, he/she may prefer teacher-centered routines if he/she finds it difficult to manage open-ended tasks. Therefore, it is not enough for teacher education programs to offer only theoretical content. Design practices, observation, reflection and guided practice opportunities should also be an integral part of these programs.

This preparation problem becomes a measurement problem once one asks how integrated readiness is to be assessed. The instruments currently in use were built for narrower targets: attitudes toward STEM, STEM teaching self-efficacy, or technology-related knowledge (Menon et al., 2023; Yang et al., 2023; Yıldırım & Şahin Topalcengiz, 2018). Each contributes within its own scope, yet none was designed to register what early childhood classrooms actually demand, namely play-based, developmentally appropriate practice in which collaboration, communication, and emotional support are carried out through STEAM tasks rather than alongside them. An instrument that does not represent these features cannot distinguish a candidate who can teach STEAM content from one who can sustain the social-emotional processes that integrated activity requires, and it is the latter distinction that bears on readiness for the practice.

The most recent additions to this literature confirm the pattern while sharpening it. Xiong et al. (2024) validated the teacher social and emotional learning beliefs scale through Rasch analysis and reported fair functioning across gender and education levels, but the instrument is confined to SEL beliefs and does not reach STEAM practice. Conversely, the STEAM competency frameworks proposed for early childhood education students specify disciplinary and pedagogical roles in detail yet leave social-emotional facilitation unrepresented as a distinct component (Anh, 2024). The two lines of work thus advance in parallel and stop short of the same point: the place where STEAM pedagogy and social-emotional competence meet. The present scale was designed to occupy that point rather than to refine either side of it.

Overall, the literature points to several consistent conclusions. First, preschool STEAM is most effective

Table 1. Demographic characteristics of participants

Variable	Category	n	Percentage (%)
Gender	Female	424	94.2
	Male	26	5.8
Class level	1st year	182	40.4
	2nd year	106	23.6
	3rd year	84	18.7
	4th year	78	17.3

when it is play-based, integrated, and connected to children's real experiences. Second, SEL is a foundational part of early learning and strongly shapes classroom participation and later adjustment. Third, STEAM and SEL are naturally linked in collaborative inquiry, design, and problem-solving activities. Fourth, successful integration depends heavily on teacher knowledge, self-efficacy, and pedagogical decision making. Finally, teacher education and assessment tools have not yet fully caught up with the complexity of integrated STEAM-SEL practice in preschool settings.

These conclusions support the need for focused research on preschool teacher candidates and their perceptions of competence in STEAM-SEL integration. The field now has clear theoretical reasons to connect these areas, but it still needs stronger evidence on how future teachers understand this integration, how confident they feel about implementing it, and which aspects of preparation are still missing. A concise and conceptually clear literature base is important for that next step because it identifies the main constructs, clarifies their relationships, and shows where the empirical gaps remain.

METHOD

Research Design

This study is quantitative research based on scale development methodology. The systematic scale development steps proposed by DeVellis and Thorpe (2022) were followed in the development process.

Participants

The study group consisted of 450 pre-service teachers enrolled in the preschool education departments of Alikhan Bokeikhan University and Abai Kazakh National Pedagogical University, Kazakhstan. Convenience sampling was employed due to the accessibility of the target population. The data collection instrument was distributed as an online questionnaire through university-affiliated student groups. The sample size met the criterion of being at least 5-10 times the number of items recommended for scale development studies (Comrey & Lee, 1992). Demographic characteristics of the participants are presented in **Table 1**.

Ethical Considerations

Ethical approval for this study was obtained from Alikhan Bokeikhan University. At the beginning of the online survey, an informed consent form was presented explaining the purpose of the study, that participation was voluntary, and that participants could withdraw from the study at any time without any sanctions. Only individuals who declared that they agreed to participate were directed at the questionnaire items. Within the scope of the study, no data enabling personal identification was collected, and all responses were stored in a password-protected secure database.

Development of the Data Collection Instrument

The scale items were developed by the researchers on the basis of the theoretical structure summarized above. Drawing on the CASEL (2020) framework, the TPACK model (Mishra & Koehler, 2006), and Bandura's (2006) conceptualization of self-efficacy, an item pool was generated to represent the six hypothesized dimensions. The researchers reached consensus on writing ten items for each dimension, which produced an initial pool of 60 items.

Each item was then read independently by the researchers and reviewed for linguistic clarity and for fit with the dimension to which it had been assigned. This internal review did not result in the addition or removal of any items; the pool remained at 60 items and was subsequently submitted to the expert panel for content validation. The six dimensions were organized into two sections: a 50-item competence section (dimensions 1-5), rated on a 5-point competence scale (1 = not at all competent, 5 = fully competent), and a 10-item perception and attitude section (dimension 6), rated on a 5-point agreement scale (1 = strongly disagree, 5 = strongly agree). The correspondence between the six dimensions, their theoretical grounding, and the supporting literature is presented in **Table 2**.

Following the creation of the initial item pool, the draft instrument was submitted to a panel of six experts for content review. The panel was assembled to represent both academic and applied expertise across the six theoretical dimensions of the scale, comprising four academics specializing in early childhood STEAM pedagogy, educational measurement and SEL, early childhood education, and educational sciences, together with a researcher working in early childhood development and scale development and a preschool teacher. Each expert rated every item on three criteria using a four-point scale: relevance to the intended dimension, clarity of wording, and dimensional fit. The item-level content validity index (I-CVI) was computed as the proportion of experts rating an item 4 or 5 (Polit & Beck, 2006), with values of .83 and above considered acceptable for a six-member panel (Lynn, 1986). A modified kappa statistic adjusting for chance agreement

Table 2. Theoretical mapping of the scale dimensions

Dimension	Items	Theoretical basis	Key references
Dimension 1: STEAM pedagogical knowledge competence	10	Pedagogical content knowledge and its technological extension (TPACK)	Mishra and Koehler (2006), Shulman (1987)
Dimension 2: Social-emotional skill development competence	10	CASEL five-competency framework for social-emotional learning	CASEL (2020), Denham et al. (2012)
Dimension 3: STEAM-SEL integration self-efficacy	10	Self-efficacy theory applied to integrated teaching tasks	Bandura (2006), Tschannen-Moran and Hoy (2001)
Dimension 4: Technology integration competence	10	Technological component of the TPACK framework	Li and Bai (2025), Mishra and Koehler (2006)
Dimension 5: Classroom management and learning environment	10	Prosocial classroom and emotionally supportive learning environments	Hemmeter et al. (2016), Jennings and Greenberg (2009)
Dimension 6: STEAM-SEL perception and attitude	10	Teacher beliefs and attitudes as determinants of instructional practice	Park et al. (2017), Xiong et al. (2024)
Total	60		

Note. Each dimension was operationalized with 10 items, yielding a 60-item pool prior to content validation; items in dimensions 1-5 were rated on a 5-point competence scale; the perception and attitude items (dimension 6) were rated on a 5-point agreement scale

was also calculated (Polit et al., 2007). At the scale level, the average I-CVI (S-CVI/Ave) and the proportion of items rated 4 or 5 by all experts (S-CVI/UA) were reported. Items falling below the threshold were revised considering expert comments and retained for empirical evaluation in the pilot study. Detailed content validity results are presented in the findings section.

Data Analysis

Data analyses were conducted using the SEMLj module in Jamovi software, which provides an interface to the lavaan package (Rosseel, 2012). Since different response formats were used in the two sections of the scale, the analyses were conducted separately for each section.

ESEM approach was adopted in the analysis of the first section (Asparouhov & Muthén, 2009; Marsh et al., 2014). Considering the ordinal structure of the items, a diagonally weighted least squares (DWLS) estimator based on robust standard errors was used. As recommended in the ESEM literature, the oblique Geomin rotation technique was applied, with the epsilon parameter set to .01 to address the numerical instability that produced small negative residual variances under the default value (Marsh et al., 2014; Morin et al., 2013). For the second part, a one-factor CFA model was tested using the same estimation approach.

Model fit was assessed based on the comparative fit index (CFI ≥ .95), Tucker-Lewis index (TLI ≥ .95), root mean square error of approximation (RMSEA ≤ .08) and standardized root mean square residual (SRMR ≤ .05) (Hu & Bentler, 1999). Cronbach's alpha and McDonald's omega coefficients were utilized in the reliability analysis.

LPA was conducted to determine whether the pre-service teachers were divided into different subgroups according to their score patterns across the four competence dimensions and the perception/attitude dimension. The analysis was performed on the five factor scores using the tidyLPA package, and models with different variance-covariance specifications were compared across two to six classes. Bayesian information criterion (BIC), entropy, bootstrap likelihood ratio test (BLRT), minimum profile size, minimum class assignment probability, and theoretical interpretability were considered together when determining the optimal number of profiles (Nylund et al., 2007). The relationship between profile membership and grade level was examined using a three-step approach (DCAT) that accounts for classification error and was cross-checked against an analysis based on modal class assignment.

FINDINGS

Content Validity

Content validity is a fundamental measure of validity that indicates the extent to which a measurement instrument represents the theoretical construct it is intended to measure. The extent to which items exemplify and cover the relevant construct is evaluated through expert judgment and reported using the content validity index (CVI), a quantitative indicator (Lynn, 1986; Polit et al., 2007). In this context, the extent to which the items of the STEAM-SEL competence and attitude scale represent pre-service preschool teachers' self-efficacy and attitudes toward STEAM and SEL was evaluated during the expert review phase, and the item pool was reorganized based on this evaluation.

The expert panel was composed of six experts selected to represent domain knowledge related to the scale's six dimensions from various perspectives. The panel included four academics from the fields of early childhood STEAM pedagogy, assessment, and SEL, as well as early childhood education and educational sciences, along with a researcher working in early childhood development and scale development, and an early childhood teacher. This composition allowed for the joint evaluation of the scale's theoretical foundations

Table 3. Composition of the expert panel

No	Field of expertise	Position	Note
1	Early childhood STEAM pedagogy	Academic	-
2	Educational measurement and SEL	Academic	-
3	Early childhood education	Academic	-
4	Educational sciences	Academic	-
5	Scale development and STEAM-SEL research	Academic	Specialized in early childhood development
6	Early childhood teaching (field)	Lead preschool teacher	18 years of experience

Note. N = 6 & the panel was constructed to ensure both content and applied expertise across the six theoretical dimensions of the scale

Table 4. Dimension- and scale-level content validity indices

Dimension	n items	I-CVI (relevance)	I-CVI (clarity)	I-CVI (dimensional fit)	κ* (relevance)
1. STEAM pedagogical knowledge	10	1.00	.98	1.00	1.00
2. Social-emotional skill development	10	.98	.95	.98	.98
3. STEAM-SEL integration	10	.98	.98	.97	.98
4. Technology integration	10	.87	.93	.97	.86
5. Classroom management	10	1.00	.98	.95	1.00
6. Perception and attitude	10	.83	.98	.97	.81
Scale-level S-CVI/Ave	60	.94	.97	.97	-
Scale-level S-CVI/UA	60	.88	.83	.87	-

Note. I-CVI: Item-level content validity index (proportion of experts rating an item 4 or 5); S-CVI/Ave: Average I-CVI across items; S-CVI/UA: Proportion of items rated 4 or 5 by all experts; & κ*: Modified kappa adjusted for chance (Polit et al., 2007)

from both academic and practical perspectives. The experts' profiles are presented in **Table 3**.

The experts were asked to evaluate each item based on three criteria: the item's suitability for measuring the relevant dimension, the clarity of the item's wording, and the item's consistency with the dimension to which it was assigned. The I-CVI was calculated as the proportion of experts who rated each item 4 or 5 (Polit & Beck, 2006). In line with Lynn's (1986) recommendation, an I-CVI value of .83 or higher is expected in a six-expert panel; items falling below this threshold were further examined in light of expert comments. To assess chance agreement, the modified kappa statistic proposed by Polit et al. (2007) was calculated, and values of .74 or higher were considered excellent. At the scale level, the S-CVI/Ave (calculated as the average of the item I-CVI values) and the S-CVI/UA (calculated as the proportion of items rated 4 or 5 by all experts) were reported.

In the first round of expert evaluation, 55 out of 60 items achieved an I-CVI value of .83 or higher based on the acceptability criterion; the remaining five items (M19, M34, M46, M52, M55) fell below this threshold. The validity I-CVI value was calculated as zero for items M34 and M55, and .33 for M52; the modified kappa coefficients for these three items were also found to be below the acceptable range. Although items M19 and M46 showed values close to the threshold, expert reviews indicated that they contained dual structures and that their dimensional assignments needed to be reconsidered. Dimension-based average I-CVI values and scale-level indices are presented in **Table 4**.

In light of expert feedback, the wording of items falling below the threshold was revised and retained in the item pool. This decision was made to avoid narrowing the scale's conceptual scope and to ensure that the final psychometric decision regarding the items is based on factor analysis findings following the pilot study. In Item M19, the statement combining two separate concepts was adapted to the preschool developmental level and reduced to concrete daily choices; in Item M34, the use of augmented and virtual reality tools was framed within a conditional structure, adding an emphasis on age-appropriate design. In Item M46, a statement more consistent with the classroom management dimension was preferred, while in Items M52 and M55, attitude statements with a limited scope were used instead of categorical generalizations. The revised items and their justifications are presented in **Table 5**.

When examining the scale-level results, it was observed that the S-CVI/Ave values were calculated as .94, .97, and .97 for the criteria of fit, clarity, and dimensionality, respectively. The S-CVI/UA values, based on the proportion of items agreed upon by all experts, were found to be .88, .83, and .87, respectively. As suggested by Polit and Beck (2006), an S-CVI/Ave value of .90 or higher indicates excellent content validity at the scale level; the values obtained in this study exceed this threshold for all three criteria. When examined by dimension, the highest average I-CVI values were obtained for the STEAM pedagogical content knowledge and classroom management dimensions, while the lowest average value was observed for the perception and attitude dimension, which includes the two attitude items with revised wording. These findings indicate that the items of the developed scale generally achieved high content validity during the expert review phase.

Table 5. Revised items based on expert feedback

Item	I-CVI (R/C/D)	Original wording (OW)/revised wording (RW)	Basis for revision
M19	.83/.67/.83	OW: I can create situations that support children's making responsible and ethical decisions./RW: I can create situations that support children's responsible choices in daily activities (e.g., sharing, taking turns).	Double-barreled item; "ethical decision" abstract for preschool level.
M34	.00/.83/.83	OW: I can use AR/VR tools in preschool activities./RW: I can use AR/VR tools in preschool activities when they are designed appropriately for the age group.	Conditional framing added; absolute pedagogical claim softened.
M46	1.00/1.00/.67	OW: I can respond sensitively to children's emotional reactions during STEAM activities./RW: I can adapt the pace and arrangement of STEAM activities based on children's emotional reactions.	Dimensional realignment toward classroom management.
M52	.33/1.00/1.00	OW: I believe technology use in preschool positively affects children's development./RW: I believe technology used for educational purposes supports children's development.	Categorical generalization narrowed to a defensible domain.
M55	.00/.83/.67	OW: I think STEAM technologies support children's empathy and social awareness./RW: I think the STEAM-SEL approach develops children's empathy and social awareness.	Overlap with technology dimension removed; reframed around the construct.

Note. I-CVI values reflect the first round of expert review; R: Relevance; C: Clarity; D: Dimensional fit; & Revised items remained within their original dimensions and were re-examined empirically in the pilot study

Construct Validity: Exploratory Structural Equation Modeling

The factor structure of the items comprising the competence section of the scale (section I; 50 items) was examined using ESEM. ESEM is an approach that combines the flexibility of exploratory factor analysis with the model fit framework of CFA, allowing items to load on more than one factor (Asparouhov & Muthén, 2009). Due to the five-point Likert scale format of the items, estimation was performed using the DWLS method with robust standard errors; the geometric (oblique) rotation method was used for rotation. The analysis was conducted on data obtained from 450 participants.

To determine the number of factors, three-, four-, five-, and six-factor solutions were compared. While the five- and six-factor solutions yielded lower fit indices, they produced empty factors with no items loading significantly; in the three-factor solution, dimensions expected to be theoretically distinct merged into a single cluster. The four-factor solution was identified as the only interpretable solution without empty factors. In this solution, the initial five competency dimensions were reduced to four; items related to STEAM pedagogical knowledge and basic social-emotional skills were grouped under a single factor.

The item simplification process was conducted step-by-step on the four-factor solution. During this process, six items (M2, M3, M24, M40, M45, M47) were removed from the scale after evaluating items that yielded low or meaningless primary loadings, loaded similarly on multiple factors, or overlapped in content with other items. To address numerical instability in the Geomin rotation that led to small negative residual variances, the Geomin epsilon value was set to .01. Following the simplification, a final four-factor solution comprising 44 items was obtained (**Appendix A**). The fit indices of this solution are at an acceptable level (CFI = .98, TLI = .97, SRMR = .025). Although the RMSEA value appears relatively high, this is a known characteristic of the WLSMV/DWLS approach under conditions involving a large number of indicators, high factor loadings, and categorical estimates, and it has been reported that under these conditions, the RMSEA reflects model fit worse than it actually is (Kenny et al., 2015; Shi et al.,).

In the final solution, all items loaded strongly and significantly on their primary factors. The first factor (STEAM and social-emotional skill development competence) consists of 14 items, the second factor (STEAM-SEL integration self-efficacy) 13 items, the third factor (technology integration competence) nine items, and the fourth factor (classroom management and learning environment organization competence) eight items. Standardized factor loadings and factor names are presented in **Table 6**.

Table 6. Standardized factor loadings of the four-factor ESEM solution

Item	F1 STEAM-SEL pedagogy	F2 integration self-efficacy	F3 technology integration	F4 classroom management
M1	.675			
M4	.699			
M5	.729			
M6	.715			
M7	.728			
M8	.730			
M9	.746			
M10	.779			
M11	.965			
M12	.914			
M13	.968			
M14	.991			

Table 6 (Continued).

Item	F1 STEAM-SEL pedagogy	F2 integration self-efficacy	F3 technology integration	F4 classroom management
M15	.898			
M16	.897			
M17		.768		
M18		.776		
M19		.867		
M20		.802		
M21		.877		
M22		.773		
M23		.808		
M25		.885		
M26		.925		
M27		.807		
M28		.799		
M29		.793		
M30		.840		
M31			.694	
M32			.841	
M33			.850	
M34			.836	
M35			.924	
M36			.868	
M37			.900	
M38			.859	
M39			.905	
M41				.904
M42				.909
M43				.928
M44				.945
M46				.992
M48				.977
M49				.968
M50				.953

Note. N = 450; Estimator: DWLS with robust standard errors; Geomin (oblique) rotation, epsilon = .01; Only primary loadings are displayed; cross-loadings were all below $|.25|$. F1: STEAM and social-emotional skill development; F2: STEAM-SEL integration self-efficacy; F3: Technology integration; & F4: Classroom management and learning environment

Inter-factor correlations range from .33 to .78, and it was observed that the technology integration dimension showed a relatively lower relationship with the other three dimensions.

Reliability and Convergent/Discriminant Validity

The internal consistency coefficients for the four factors were calculated using Cronbach's alpha and McDonald's omega. Both coefficients were found to be at the .98 level for all dimensions (**Table 7**). To assess convergent validity, the average variance explained (AVE) and composite reliability (CR) values were calculated for each dimension. AVE values range from .68 to .90, while CR values range from .96 to .99; all values exceed the recommended thresholds of .50 (AVE) and .70 (CR). While these high coefficients reflect the strong internal consistency of the dimensions, they also indicate that there may be content overlap among some items. Discriminant validity was examined using the Fornell-Larcker criterion. According to this criterion, the square root of the AVE value for each dimension must be greater than the correlations of that dimension with the other dimensions. As shown in **Table 8**, the square root of the AVE for each of the four dimensions is higher than the correlations of that dimension with the other dimensions; therefore, the discriminant validity condition is met. However, the relatively narrow difference between the first and second dimensions and between the second and fourth dimensions indicates that these dimensions represent distinct yet closely related constructs.

Table 7. Reliability and convergent validity indices

Dimension	k	α	ω	AVE	CR
F1 STEAM-SEL pedagogy	14	.985	.985	.679	.967
F2 integration self-efficacy	13	.986	.986	.682	.965
F3 technology integration	9	.981	.981	.731	.961
F4 classroom management	8	.984	.984	.897	.986
Part II perception-attitude	10	.976	.976	.902	.989

Note. k: Number of items; α: Cronbach's alpha; ω: McDonald's omega; & the last row reports the single-factor perception-attitude dimension (part II)

Table 8. Discriminant validity (Fornell-Larcker criterion)

Dimension	F1	F2	F3	F4
F1 STEAM-SEL pedagogy	.824			
F2 integration self-efficacy	.734	.826		
F3 technology integration	.407	.418	.855	
F4 classroom management	.703	.776	.326	.947

Note. Diagonal values are the square roots of AVE; off-diagonal values are inter-factor correlations & discriminant validity is supported when the square root of AVE exceeds the correlations in the corresponding row and column

Perception and Attitude Dimension: Confirmatory Factor Analysis

Since the perception and attitude section of the scale (section II; 10 items) was designed as a unidimensional structure, this section was tested using CFA. The suitability of the single-factor structure was examined beforehand using principal component analysis; the Kaiser-Meyer-Olkin value was .947, the Bartlett sphericity test was significant ($\chi^2 = 7063$, $p < .001$), and all items loaded onto a single component with loadings ranging from .88 to .92. These results supported the section's unidimensional structure.

CFA was conducted using DWLS estimates and robust standard errors for ordinal items, consistent with Section I. The one-factor model fit all ten items well (CFI = .99, TLI = .99, SRMR = .062). Although the RMSEA value appears high, model fit was primarily evaluated through incremental indices and SRMR due to the tendency of this index to inflate under conditions of few indicators and high factor loadings (Kenny et al., 2015). The standardized loadings of the items ranged from .88

Table 9. Factor means across the three latent profiles

Factor	Profile 1 (n = 78, 17.3%)	Profile 2 (n = 348, 77.3%)	Profile 3 (n = 24, 5.3%)
F1 STEAM-SEL pedagogy	2.21	3.97	3.27
F2 integration self-efficacy	2.03	3.96	3.20
F3 technology integration	2.09	4.02	2.85
F4 classroom management	1.53	4.08	3.23
F5 perception-attitude	1.79	4.03	4.03

Note. Profile 1: Low competence-low attitude; Profile 2: High competence-high attitude; Profile 3: Moderate competence-high attitude; Values are mean factor scores on a 1-5 metric; Entropy = .97; & Minimum class assignment probability = .95

to .98. The internal consistency of the dimension is high (α = ω = .98); the AVE was .90, and the composite reliability was calculated as .99.

Latent Profile Analysis

LPA was conducted to determine whether teacher candidates could be grouped based on patterns in the four competency dimensions and the attitude dimension. The analysis was performed using the tidyLPA package on five-factor scores, and models with different variance-covariance structures were compared across two to six classes. In the model where variances and covariances were assumed to be equal (Model 3), the three-class solution provided the highest classification accuracy.

Three- and five-class solutions were also compared. Although the five-class solution yielded the lowest BIC value, it was deemed unstable due to the inclusion of two very small classes (n = 16 and n = 19), lower entropy (.85), and a weak minimum assignment probability (.60). The three-class solution, however, was adopted as the final solution because it provided nearly perfect classification accuracy (entropy = .97; minimum assignment probability = .95) and achieved unambiguous convergence. The bootstrap likelihood ratio test also supported the three-class solution (BLRT p = .01).

The factor means for the three profiles are presented in **Table 9**. The second profile, which comprises the vast majority of participants (n = 348; 77.3%), was named the high competence-high attitude profile because it exhibited high means across all competence dimensions and attitude. The first profile (n = 78; 17.3%) exhibited low means across all dimensions and was defined as the low competence-low attitude profile. The third and smallest profile (n = 24; 5.3%) exhibited moderate average scores across competency dimensions while showing a positive average score in the attitude dimension that was on par with the high competency profile (4.03); this pattern indicates a profile where, despite a relatively low perception of competence, the attitude toward STEAM-SEL remains high, and it was named the moderate competence-high attitude profile.

The relationship between profile membership and pre-service teachers' grade level was examined using the three-step (3-step) DCAT approach, which accounts for classification error. The omnibus test was not significant (χ^2 = 5.65, df = 6, p = .46, V = .08); none of the pairwise comparisons reached significance after multiple comparison correction (all pBH > .65). This result is consistent with the analysis based on modal assignment (χ^2 = 5.12, p = .53). These findings indicate that profile membership is independent of the teacher candidates' grade level. However, it should be noted that the statistical power of this comparison is limited due to the small size of the third profile.

DISCUSSION

This study set out to develop and validate an instrument for assessing pre-service preschool teachers' competencies and perceptions regarding the use of STEAM technologies to support children's social-emotional development, and to identify the competency profiles that characterize this group. The findings carry implications for both assessment practice and teacher preparation in an area where validated tools remain scarce.

A notable result is that the item pool, initially organized around five separate competence dimensions, resolved into four empirically distinct factors. STEAM pedagogical knowledge and foundational social-emotional skills converged on a single factor (STEAM and social-emotional skill development). Advanced integration capacities formed a second factor (STEAM-SEL integration self-efficacy). Technology integration and classroom management emerged as two further, separable factors. The merging of the first two theoretical domains, rather than indicating measurement failure, points to how pre-service teachers experience these competencies in practice. For a teacher preparing to work with young children, planning a STEAM activity sits alongside helping children recognize emotions, build empathy, or communicate. These may not be experienced as separate tasks. They function instead as intertwined components of the same pedagogical action. This reading aligns with research emphasizing that effective early childhood pedagogy combines cognitive and social-emotional dimensions (Jennings & Greenberg, 2009).

This integrated experience of competence finds support in recent training research. Fatwikiningsih and Ismaeil (2025) showed that STEAM-based instructional training improved both knowledge scores and teaching performance when delivered as a holistic package. This finding suggests that teachers encounter these competencies as interconnected rather than modular. Such evidence lends weight to the empirical convergence observed here. It is also consistent with the TPACK framework (Mishra & Koehler, 2006), which treats content, pedagogy, and technology as interacting rather than independent constructs. On this view, the framework can be extended to incorporate social-emotional facilitation in the preschool STEAM context.

The pattern of inter-factor correlations refines this interpretation in an important way. The correlations ranged from .33 to .78, and the technology integration factor showed consistently weaker associations with the other three (.33 to .42), a separation confirmed by the Fornell-Larcker criterion. The earlier expectation that STEAM-SEL competence would behave as an essentially unidimensional construct therefore holds only in part. The pedagogical, integration, and classroom-management facets are closely related and may reflect a common underlying readiness, but technology integration operates with greater independence. A plausible reading is that handling digital tools draws on a distinct skill set that pre-service teachers do not automatically fold into their broader pedagogical and relational competence. This more differentiated picture cautions against treating STEAM-SEL competence as a single global capacity and is itself informative for instrument design, since it indicates that the technology dimension warrants separate attention.

Whether the three closely related factors are best modeled as facets of a higher-order construct remains an open question that the present design cannot settle. Marsh et al. (2023) demonstrated through Bayesian structural equation modeling that bifactor models with global factors can represent such data better than single-factor alternatives. Wei et al. (2025) applied bifactor ESEM to the UWES-S-9 with Chinese undergraduates. They found that a general factor accounted for the bulk of common variance, while specific-factor reliabilities were negligible. These precedents suggest that future iterations of the scale could benefit from bifactor or higher-order examination. Such work would determine whether a general STEAM-SEL competence factor coexists with a distinguishable technology component, and it would help establish the most defensible scoring structure.

The decision to adopt ESEM rather than independent-clusters CFA is supported both by the structure of the construct and by the methodological literature. When the facets of a competence are theoretically interrelated, constraining cross-loadings to zero forces shared variance onto primary loadings and inflates factor correlations. This distorts the structure obtained (Marsh et al., 2014; Morin et al., 2020). Recent advances support this view. Prokofieva et al. (2023) provided a step-by-step ESEM guide demonstrating how allowing cross-loadings prevents artificially inflated correlations. Swami et al. (2023) provided a detailed guide for ESEM and bifactor-ESEM applications. Marsh and Alamer (2024) introduced set-ESEM as a way to balance flexibility and parsimony. Pawlak et al. (2024) demonstrated that ESEM provides a realistic representation of the data in cases where a confirmatory model produces inflated correlations and an unacceptable fit. Taken together, these developments support the present approach and the broader recommendation that scale-development studies in education routinely consider ESEM where constructs are expected to be interrelated.

The LPA yielded three profiles with near-perfect classification accuracy (entropy = .97). The largest, comprising more than three-quarters of the sample (77.3%), combined high competence with positive attitudes across all dimensions. A second profile (17.3%) was uniformly low on both competence and attitude. The third and smallest profile (5.3%) was distinctive: competence scores were only moderate, yet attitudes toward STEAM-SEL were as favorable as those of the high-competence group. This configuration, in which enthusiasm outpaces perceived capability, is pedagogically significant. It identifies a subgroup of pre-service teachers who value integrated STEAM-SEL practice but do not yet feel equipped to enact it, and who may therefore benefit most from targeted, practice-oriented professional development rather than from further efforts to improve attitudes. The low-competence, low-attitude profile, by contrast, may require more foundational support before integrated practice becomes feasible. Reading the profiles in this way moves the analysis beyond an ordering of overall competence toward differentiated implications for teacher preparation.

Person-centered findings in adjacent literatures help situate these profiles. Wang et al. (2026), in an LPA of 1,783 Chinese pre-service preschool teachers, identified a dominant profile (60.5%) marked by low self-efficacy and negative reactivity, a pattern that contrasts with the predominantly high-competence majority observed here. This divergence is most plausibly attributable to contextual differences between teacher education systems, which is one reason the generalizability of the present profiles across countries should be treated cautiously. Uras et al. (2025), examining pre-service mathematics teachers, recovered three profiles differing mainly in level rather than shape, a finding broadly consistent with the largely parallel competence scores observed across the first two profiles in the present study. The distinctive third profile, however, indicates that the present data are not reducible to a simple high-to-low ordering, since attitude and competence diverge within it.

The relationship between profile membership and grade level was examined using a three-step approach that accounts for classification error. The omnibus test was non-significant ($\chi^2 = 5.65$, df = 6, p = .46), and no pairwise comparison survived correction for multiple testing, a result corroborated by the modal-assignment analysis. Within the present context, profile membership thus appears unrelated to year of study. One interpretation is that current teacher education programs may not provide a systematic, progressive pathway toward integrated STEAM-SEL competence, since final-year candidates were distributed across profiles in much the same way as first-year candidates. This reading is consistent with Darling-Hammond's (2017) emphasis on practice-based, competency-oriented teacher preparation, though it should be advanced tentatively. The cross-sectional design precludes developmental inference, the small size of the third profile limits statistical power, and any apparent stability across cohorts could reflect curricular content, cohort differences, or the way perceived competence is reported rather than an absence of growth.

The absence of meaningful variation across grade levels resonates with findings from other teacher education contexts. Alan (2025) conducted a mixed-methods LPA of 247 Turkish pre-service teachers. Participants attributed their limitations to theory-laden preparation that neglected practical teaching, and they reported the least competence in areas requiring hands-on experience. Li and Bai (2025) similarly used multilevel LPA to examine preschool teachers' self-regulated learning and technological integration competency. Their findings reinforce the value of person-centered approaches for locating gaps in early childhood teacher preparation. The convergence of these findings across competency domains and cultural settings strengthens the argument that teacher education curricula may need structural attention. Without it, integrated STEAM-SEL competencies are unlikely to develop cumulatively and may instead remain static across the program.

The reliability and validity evidence was generally strong, though it warrants a measured reading. Internal consistency was high across all dimensions, with Cronbach's alpha and McDonald's omega at the .98 level, and average variance extracted and composite reliability comfortably exceeded conventional thresholds. Coefficients of this magnitude, however, may signal content overlap as much as measurement precision, since items with very similar wording can inflate internal consistency without adding distinct information (Streiner, 2003). The combination of very high reliability, substantial inter-factor correlations among three of the four factors, and closely similar descriptive patterns suggests that future versions of the scale could be shortened through item reduction without sacrificing measurement quality, yielding a more economical instrument. Such short-form development would need to proceed carefully: rather than simply retaining the items with the highest factor loadings, item selection could draw on item-discrimination or item-response theory information indices to identify items that best differentiate respondents across the full range of each construct, while deliberately keeping at least one item per theoretically distinct facet within each factor. This would allow the instrument to become more efficient for applied and repeated-measurement use without collapsing the conceptual breadth the current 44-item version was designed to capture. The single-factor model for the perception and attitude section fit well on incremental indices and SRMR (CFI = .99, TLI = .99, SRMR = .062). Its elevated RMSEA reflects a well-documented artifact of models with few indicators and high loadings rather than a substantive problem (Kenny et al., 2015; Xia & Yang, 2019), so fit was evaluated primarily through the incremental indices and SRMR.

CONCLUSION

This study developed and validated an instrument for measuring pre-service preschool teachers' competencies and perceptions regarding the use of STEAM technologies to support children's social-emotional development. ESEM-based analyses reduced a construct initially specified across five competence dimensions to a 44-item scale comprising four competence factors and a separate perception and attitude factor. The empirical merging of theoretically distinct domains suggests that pre-service teachers experience pedagogical and social-emotional competence as intertwined components of a single pedagogical action, while the relative independence of the technology integration factor indicates that working with digital tools draws on a more distinct capacity.

The LPA identified three profiles. A high-competence, high-attitude profile encompassed most of the sample, a low-competence, low-attitude profile a smaller share, and a third, distinctive profile combined moderate competence with notably positive attitudes. Profile membership did not differ significantly by grade level, which raises the question of whether current teacher education programs support a systematic and progressive development of integrated STEAM-SEL competence. The third profile, in which favorable attitudes coexist with more modest perceived competence, points in particular to a group whose readiness might be advanced through targeted, practice-based support.

Several limitations qualify for these conclusions. The sample was drawn from a single province through convenience sampling, so the profile distributions and the structure recovered here should not be generalized to other settings, teacher education systems, or cultural contexts without further evidence. The data are self-reports of perceived competence rather than observations of classroom performance, and perceived and enacted competence need not coincide. The cross-sectional design likewise precludes any developmental interpretation of the grade-level findings.

These limitations indicate clear directions for further work. The measurement invariance of the scale across gender, grade level, and cultural settings should be tested, and its structure cross-validated on independent samples through multi-group analysis before the instrument is used comparatively. Linking scale scores to external competency indicators, such as ratings of observed teaching practice during practicum, would help establish criterion and predictive validity and address the gap between perceived and enacted competence. Bifactor and higher-order models could clarify whether STEAM-SEL competence is best represented as a general construct with a distinguishable technology component, and item reduction could yield a more economical form. The present study is best understood as an initial attempt to operationalize integrated STEAM-SEL competence; situating teacher preparation as the proximal lever, its findings suggest that curriculum designers, teacher educators, and policy makers may need to embed practice-oriented STEAM-SEL experiences from the early stages of preschool teacher education rather than assuming that such competence develops on its own over the course of a program.

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APPENDIX A

Table A1. Items

No	Item statement	Factor
M1	I can design science activities appropriate to the developmental level of preschool children.	STEAM and social-emotional skill development
M4	I can integrate art activities with other STEAM disciplines (science, mathematics, technology).	STEAM and social-emotional skill development
M5	I can design questions that stimulate children's curiosity and sense of discovery in STEAM activities.	STEAM and social-emotional skill development
M6	I can plan basic coding and algorithmic thinking activities for the preschool period.	STEAM and social-emotional skill development
M7	I can meaningfully combine different STEAM disciplines within a single project.	STEAM and social-emotional skill development
M8	I can effectively use play-based learning approaches in STEAM activities.	STEAM and social-emotional skill development
M9	I can design open-ended activities that encourage children's creative thinking in STEAM projects.	STEAM and social-emotional skill development
M10	I can assess the outcomes of STEAM activities using methods appropriate to children's developmental level.	STEAM and social-emotional skill development
M11	I can help children identify and label their own emotions.	STEAM and social-emotional skill development
M12	I can teach children strategies for coping with negative emotions such as anger, sadness, and frustration.	STEAM and social-emotional skill development
M13	I can plan activities that develop children's empathy skills.	STEAM and social-emotional skill development
M14	I can support children's cooperation skills during group work.	STEAM and social-emotional skill development
M15	I can help children develop effective communication skills with their peers.	STEAM and social-emotional skill development
M16	I can implement strategies to support children's impulse control and self-regulation skills.	STEAM and social-emotional skill development
M17	I can teach children to find constructive solutions in conflict situations.	STEAM-SEL integration self-efficacy
M18	I can organize activities that support children in developing self-confidence and a positive self-concept.	STEAM-SEL integration self-efficacy
M19	I can create situations that support children's responsible choices in daily activities (e.g., sharing, taking turns).	STEAM-SEL integration self-efficacy
M20	I can encourage children to respect differences and behave inclusively.	STEAM-SEL integration self-efficacy
M21	I can make interventions to support children's social-emotional skills during STEAM activities.	STEAM-SEL integration self-efficacy
M22	I can use a science experiment simultaneously to develop cooperation and sharing skills.	STEAM-SEL integration self-efficacy
M23	I can help children manage emotional experiences such as frustration and patience during the engineering design process.	STEAM-SEL integration self-efficacy
M25	I can develop children's relationship skills through teamwork in STEAM projects.	STEAM-SEL integration self-efficacy
M26	I can set both academic and social-emotional learning objectives together in my STEAM activity plans.	STEAM-SEL integration self-efficacy
M27	I can guide children in developing patience, perseverance, and cooperation skills in coding and robotics activities.	STEAM-SEL integration self-efficacy
M28	I can offer choices that support children's responsible decision-making skills in a STEAM project.	STEAM-SEL integration self-efficacy
M29	I can transform conflicts among children into learning opportunities in group STEAM projects.	STEAM-SEL integration self-efficacy
M30	I can develop original curriculum materials that integrate STEAM and SEL.	STEAM-SEL integration self-efficacy

Table A1 (Continued).

No	Item statement	Factor
M31	I am familiar with educational technologies (robotic kits, tablet applications, etc.) that can be used in the preschool period.	Technology integration
M32	I can select age-appropriate digital tools (Bee-Bot, ScratchJr, Osmo, etc.) and integrate them into activities.	Technology integration
M33	I can combine robotics and coding tools with social-emotional learning activities.	Technology integration
M34	I can use AR/VR tools in preschool activities when they are designed appropriately for the age group.	Technology integration
M35	I can use digital storytelling tools for children's emotional expression.	Technology integration
M36	I can ensure children's screen time management and digital safety when using technology.	Technology integration
M37	I can troubleshoot problems encountered with technological tools and generate alternative solutions.	Technology integration
M38	I can design activities that enable children to use technology as a creative tool.	Technology integration
M39	I can evaluate the pedagogical appropriateness of technological tools used in the preschool period.	Technology integration
M41	I can make safe and child-friendly physical arrangements in the classroom for STEAM activities.	Classroom management
M42	I can provide an emotionally warm and supportive environment for children during STEAM activities.	Classroom management
M43	I can create seating arrangements that facilitate interaction among children in group STEAM work.	Classroom management
M44	I can constructively manage conflicts that arise among children during STEAM activities.	Classroom management
M46	I can adapt the pace and arrangement of STEAM activities based on children's emotional reactions.	Classroom management
M48	I can create a learning atmosphere that supports children's curiosity and sense of discovery in STEAM activities.	Classroom management
M49	I can implement strategies to support children in coping with challenges they face in STEAM activities.	Classroom management
M50	I can adjust time management in STEAM activities according to children's attention spans and emotional needs.	Classroom management
M51	I believe that STEAM activities contribute to the social-emotional development of preschool children.	Perception and attitude
M52	I believe technology used for educational purposes supports children's development.	Perception and attitude
M53	I believe that addressing STEAM and social-emotional learning together is the most effective approach for children.	Perception and attitude
M54	I think that STEAM activities naturally develop children's cooperation and teamwork skills.	Perception and attitude
M55	I think the STEAM-SEL approach develops children's empathy and social awareness.	Perception and attitude
M56	I believe that more emphasis should be placed on STEAM-SEL integration in teacher education programs.	Perception and attitude
M57	I think that STEAM activities contribute to the development of children's self-confidence and self-efficacy.	Perception and attitude
M58	I think that STEAM activities enrich children's emotional expression skills.	Perception and attitude
M59	I believe that STEAM-SEL integration better prepares children for the future.	Perception and attitude
M60	I think it is important to collaborate with families to extend STEAM-SEL activities to the home environment.	Perception and attitude

Note. The final scale comprises 44 competence items across four ESEM-derived factors and 10 perception/attitude items (part II); six items (M2, M3, M24, M40, M45, M47) were removed during item simplification; original item numbers are retained for traceability; & items M19, M34, M46, M52, and M55 are shown in their revised wording following expert review