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ASSESSING THE READINESS OF FUTURE TEACHERS IN KAZAKHSTAN FOR TRANSDISCIPLINARY EDUCATION IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

Abstract. This study explores the readiness of future teachers in Kazakhstan for transdisciplinary education within the context of underutilized STEM/STEAM frameworks. Using a quantitative approach, survey data were collected from 166 students across five Kazakhstani universities: Korkyt Ata Kyzylorda University, Kyzylorda Bolashak university, Alikhan Bokeikhan University in Semey, Karaganda Buketov university and Eurasian National University named after L.N.Gumilyov in Astana. The survey instrument, based on transdisciplinary frameworks by Piaget and Nicolescu, demonstrated high reliability (Cronbach's Alpha = 0.978). Transdisciplinarity refers to a holistic approach that transcends disciplinary boundaries, aiming to integrate knowledge into a unified system of understanding. Data was analyzed by the statistic program SPSS 29.02.0. Results showed a moderately high overall level of readiness for transdisciplinary approach (M = 3.82), with higher scores among students who had completed internships (M = 3.92) and taken interdisciplinary courses (M = 3.94). Although graduate students exhibited higher competence than first-year students, the difference was not statistically significant. These findings show the need for integrating hands-on experience and interdisciplinary courses into teacher education programs to foster transdisciplinary skills. The study recommends early integration of such practices, faculty development, and alignment with international models to improve educational outcomes in Kazakhstan.

Keywords: transdisciplinary education, teacher preparation, STEM, STEAM, Kazakhstan, interdisciplinary learning

Introduction

The increasing complexity of global challenges such as climate change, technological disruption, and evolving workforce demands, necessitates an education system that goes beyond traditional disciplinary boundaries. To deal with real-world challenges, future teachers need to combine knowledge from different subjects and develop skills such as critical thinking, creativity, and systems thinking (Morze & Strutynska, 2021). These competencies are closely aligned with the principles of STEM and STEAM education, which aim to enhance both intellectual and practical abilities while fostering innovation and problem-solving skills essential for the 21st century (Widodo W., 2019). Ultimately, this interconnected skill set supports the development of a transdisciplinary learning approach (Holbrook et al., 2020). Transdisciplinary education helps students connect ideas from different subjects and use them together in practice. For example: science, technology, engineering, arts, and mathematics through collaborative projects that utilize these technologies. For example, students can use STEM and STEAM tools to solve real-life problems, which helps them think more critically and creatively. The integration of scientific and artistic perspectives show how they stimulate innovative thinking and develop a nuanced understanding of content and real-world applications (Burnard & Colucci-Gray, 2021). Despite the global emphasis on interdisciplinary and transdisciplinary methods, many teacher preparation programs still focus primarily on

subject-specific content without offering sufficient opportunities for integrated, hands-on learning. In Kazakhstan, there is a pressing need to modernize teacher education by embedding interdisciplinary pedagogies and real-world problem-solving experiences. Introducing future teachers to project-based and inquiry-driven models can significantly enhance their ability to design engaging, cross-disciplinary lessons. Furthermore, fostering collaboration among students from various fields during training can simulate the type of teamwork required in contemporary education environments. This shift is vital for preparing educators who can lead transformative learning experiences in increasingly complex classrooms. However, despite its growing importance, its implementation within teacher training programs remains underexplored in Kazakhstan (Abdrakhmanova et al., 2025).

Jean Piaget introduced the term "transdisciplinarity" in 1970 and provided its first definition. He envisioned it as a stage beyond interdisciplinarity, where knowledge transcends disciplinary boundaries and forms a global, integrated system (Cohen & Waite-Stupiansky, 2023). As Basarab Nicolescu stated, “Transdisciplinarity is a way of being, thinking, and acting that goes beyond disciplines and seeks unity of knowledge”. In his exploration of transdisciplinarity, Basarab Nicolescu delineates this approach in contrast to other methodologies such as multidisciplinarity and interdisciplinarity. He notes that multidisciplinarity involves examining a research topic through multiple disciplines simultaneously, contributing an additional perspective to the primary discipline while operating within its established framework. Interdisciplinarity, on the other hand, focuses on the transfer of methods from one discipline to another, which can lead to the creation of new fields, yet it remains contained within the overarching structure of disciplinary research (Nicolescu, 2014). Today, the transdisciplinary approach goes beyond theoretical part and is actively implemented in the educational process, particularly in the training of future teachers. Researchers argue that future teachers need to learn how to work with complex, real-world problems that cannot be addressed within a single discipline, especially in the field of sustainable development (McGregor, 2022). This shift reflects the growing demand for educational models that connect knowledge with practice and encourage students to integrate perspectives from different domains.

Research shows that STEM and STEAM approaches help students think critically, collaborate, and apply what they learn in real-life situations. However, these approaches often remain difficult to implement in practice, as many teachers lack the necessary training and methodological support (Herro & Quigley, 2017). As a result, there is still a noticeable gap between theoretical models of transdisciplinary education and their application in real educational settings. Recent empirical studies also highlight the importance of innovative pedagogical approaches, including inquiry-based and technology-enhanced learning. These methods support deeper student engagement and make it easier to connect abstract concepts with real-life contexts. In particular, the use of digital and AI-supported tools creates new opportunities for interactive and collaborative learning, which are essential for the development of transdisciplinary competence (Holmes et al., 2019).

Both inter- and transdisciplinarity aim to cross traditional disciplinary boundaries. However, while interdisciplinary research seeks to coordinate and combine insights from various academic fields into a unified perspective, transdisciplinary research extends beyond academia by integrating scholarly knowledge with non-academic or practical forms of understanding (Popa et al., 2015).

Current research in Kazakhstan’s education system focuses primarily on disciplinary and interdisciplinary approaches, with limited studies assessing the readiness of future teachers for transdisciplinary education. Moreover, while transdisciplinary education has been successfully integrated into teacher training programs in countries such as Finland, Canada, and Singapore, Kazakhstan lacks empirical studies evaluating its teacher education system

through a transdisciplinary lens (Zhumabay et al., 2024). Despite significant scientific and practical interest in STEM education in the international community, this model is underused in educational institutions in Kazakhstan (Ibraeva & Shaushekova, 2023). Given the underuse of STEM education in Kazakhstan, it is crucial to explore how transdisciplinary approaches can enhance teacher preparedness.

Research aim of this study to assess future teachers' readiness for transdisciplinary education.

Research tasks: to design a scientific survey instrument using proven theoretical frameworks; to conduct survey among students of pedagogical field in the universities of Kazakhstan; to analyze and give results.

Research Questions:

1) How well are future teachers in Kazakhstan prepared for transdisciplinary education in terms of interdisciplinary integration, systems thinking, creativity, collaboration, and critical thinking?

2) What challenges do future teachers face in developing transdisciplinary competencies, and how do these challenges relate to their current educational training?

3) How can teacher education programs in Kazakhstan be adapted to better integrate transdisciplinary approaches, based on Piaget's constructivist learning theory and Nicolescu's concept of knowledge unity?

This study is grounded in the premise that the integration of transdisciplinary education within teacher training in Kazakhstan remains underexplored and under-implemented. The research advances the idea that future educators must be equipped with a blend of interdisciplinary thinking, systems analysis, creativity, and collaboration skills to meet the complex challenges of modern education. Unlike prior research which primarily emphasized subject knowledge or STEM content delivery, this study takes a holistic approach assessing the readiness of teacher candidates to operate across disciplines using validated frameworks by Piaget and Nicolescu. The findings aim to contribute evidence for reforming teacher education policies in Kazakhstan and aligning them with international standards for 21st-century teaching competencies.

Materials and Methods

To examine students' skills and their readiness to solve complex tasks that require knowledge from different areas, we conducted a quantitative study with 166 participants. It covered 5 universities across Kazakhstan, selected based on their relevance to teacher education programs especially: Korkyt Ata Kyzylorda State University, Kyzylorda Bolashak university, Alikhan Bokeikhan University in Semey, Karaganda Buketov university and L.N.Gumilyov Eurasian National university in Astana. Participants were 1-4 academic year students. The demographic part includes the age of students, academic year, their major and information about attending internship.

In this study we used a survey made based on J.Piaget`s and B.Nicolesku`s theories. The survey consists of 5 parts: educational integration and interdisciplinary connections; system thinking; innovation and creativity in pedagogy; collaboration and teamwork and critical thinking and reflection. The first part educational integration and interdisciplinary connections consists of 10 questions which assess interdisciplinary and transdisciplinary competencies, particularly in an educational context. They measure a student's ability to integrate knowledge across disciplines and apply it to real-world situations: Interdisciplinary Thinking; Problem-Solving Approach; Holistic Understanding; Application to Teaching Practices; Confidence in Interdisciplinary Instruction.

The second part of survey assess systems thinking, analytical skills, and interdisciplinary awareness, particularly in the context of education and problem-solving. They help determine an individual's ability to see connections between different factors and predict broader

implications of decisions: Systems Thinking and Holistic Analysis; Multifaceted Problem-Solving; Critical and Predictive Thinking; Interdisciplinary Connections; Use of Visual and Conceptual Tools.

The third part questions assess creativity, interdisciplinary innovation, and flexible thinking in educational and problem-solving contexts. They measure an individual's ability to integrate diverse knowledge sources and explore unconventional solutions: Interdisciplinary Innovation & Integration; Creativity & Open-Mindedness; Application of Interdisciplinary Thinking in Teaching; Problem-Solving Flexibility; Exploration of Diverse Knowledge Sources.

The fourth part questions assess collaboration, interdisciplinary communication, and teamwork skills, particularly in educational and academic settings. They help determine how well an individual engages with experts from different disciplines and integrates diverse knowledge sources into collective work: Interdisciplinary Communication Skills; Collaboration & Teamwork; Cross-Disciplinary Knowledge Exchange; Integration of Multiple Perspectives; Application of Interdisciplinary Knowledge in Problem-Solving.

The fifth part questions assess interdisciplinary reflection, critical thinking, and self-assessment skills, particularly in education and problem-solving. They help determine how well an individual integrates knowledge from multiple disciplines and evaluates their own learning and decision-making processes:Interdisciplinary Reflection & Self-Assessment; Integration of Cross-Disciplinary Knowledge; Critical Thinking & Problem Analysis; Recognition of Knowledge Limitations; Pedagogical Innovation & Complexity Awareness.

Statistics of validity

Cronbach's Alpha	Number of items
,978	50

The reliability of the survey instrument was assessed using Cronbach's Alpha. The result showed an alpha value of 0.978 across 50 items, indicating excellent internal consistency. According to widely accepted benchmarks, a Cronbach's Alpha above 0.9 demonstrates that the items are highly correlated and consistently measure the same underlying construct—in this case, transdisciplinary competence. These results confirm that the instrument is statistically reliable and suitable for further analysis.

The collected data was analyzed using the SPSS 29.02.0 program. We used statistical t-tests to define impact of Practical Experience on Transdisciplinary Competence and ANOVA + Tukey HSD to define Competence Differences among students of 1-4 academic years.

Results and Discussion

Internships play a significant role in future career of students because at the time of practice they develop essential skills in order to force and manage with real problems. It helps to integrate theoretical knowledge with practical application (Shethiya et al., 2025). Skills that enhance employability, commonly known as "soft skills," encompass a wide array of abilities, including effective communication, collaboration, problem-solving, managing time efficiently, and critical thinking (Bridgstock, 2009). Many of these competencies also align with the foundational elements of transdisciplinary competence.

Based on this, the following hypothesis is proposed:

Hypothesis 1. *Students who have completed an internship have higher transdisciplinary competence than students who have not completed an internship.*

According to the results, individuals who completed an internship reported a higher average level of transdisciplinary competence ($M \approx 3.91$) compared to those who did not complete an internship ($M \approx 3.67$). This suggests that internship participation may be positively associated with greater development of skills that span across disciplinary boundaries.

Transdisciplinary competence, often understood as the ability to integrate and apply knowledge across various domains in collaborative and innovative ways, is evidently more developed among participants who have undergone practical, hands-on experiences such as internships.

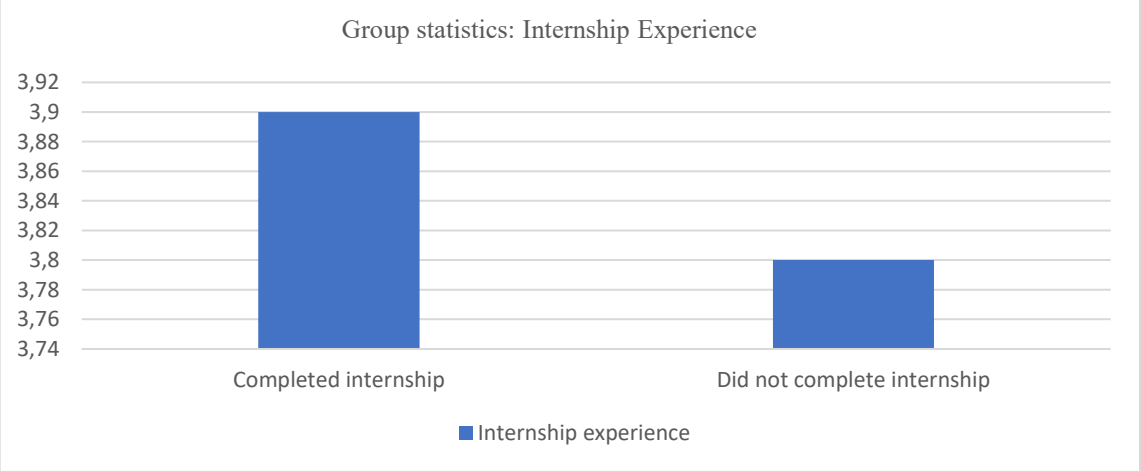
The bar graph titled "Group Statistics: Internship Experience" presents the mean scores of transdisciplinary competence among two groups of participants: those who completed an internship and those who did not. This visual representation is based on descriptive statistical analysis conducted using the SPSS 29.02.0. The mean scores are used to compare perceived levels of transdisciplinary competence between the two categories of internship experience (Figure 1).

The visual comparison also includes vertical error bars, which likely represent standard deviations or standard errors, highlighting the variability within each group. The figure does not show exact statistical indicators such as p-values or effect sizes, but the difference in mean scores is clearly visible. Students who completed internships demonstrate higher levels of transdisciplinary competence, which points to the importance of practical experience in their training.

Internships help students face real situations, work with complex tasks, and apply knowledge from different areas. This makes their learning more meaningful and closer to professional practice. The results show that including internships in teacher education programs can strengthen students' readiness for multidisciplinary work. At the same time, additional statistical analysis is needed to confirm these differences and better understand what factors influence the development of transdisciplinary competence.

Figure 1

Internship experience



Higher education institutions are adopting new educational strategies to prepare graduates with the skills needed to address complex, real-world challenges. These strategies include interdisciplinary courses and problem-based learning experiences that promote collaboration across disciplines (Amelink et al., 2024). These evolving educational strategies reflect a growing emphasis on interdisciplinary and transdisciplinary learning, particularly through courses designed to foster problem-solving, collaboration, and innovation across fields. Such courses give students the opportunity to look at problems from different perspectives and work with more complex ways of thinking. This experience plays an important role in the development of transdisciplinary competence.

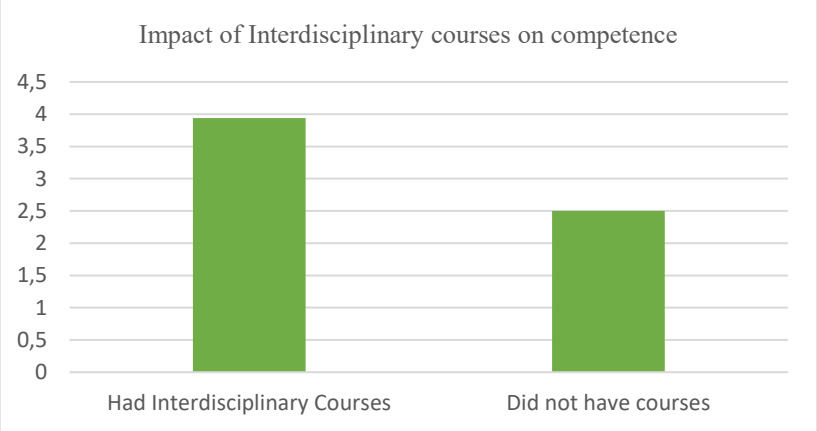
Based on this, the following hypothesis was formulated:

Hypothesis 2. Students who take interdisciplinary courses show higher levels of transdisciplinary competence than those who do not.

The results support this assumption. Students who participated in interdisciplinary courses demonstrated a higher average score (M = 3.94) compared to those who did not (M = 3.72) (Figure 2). Although the difference is not large, it still shows a clear tendency. Learning in interdisciplinary settings helps students combine knowledge from different fields, think more broadly, and find solutions to complex problems. These results align with previous studies that highlight the importance of cross-disciplinary learning for developing flexible thinking and problem-solving skills. Therefore, this result supports the hypothesis that interdisciplinary course participation enhances transdisciplinary competence, underlining the importance of curricular reform to incorporate more interdisciplinary content in teacher education programs.

Figure 2

Impact of Interdisciplinary courses on competence



The findings from longitudinal research emphasize that structured transdisciplinary training at the graduate level can significantly enhance students' ability to engage in collaborative research and apply complex conceptual frameworks. As students progress through their academic journey, their exposure to diverse learning experiences and higher-level problem solving may contribute to stronger transdisciplinary competencies (Liechty et al., 2022).

Accordingly, the third hypothesis is proposed:

Hypothesis 3**.** *Graduate students have more developed transdisciplinary competence than the students of the beginning courses.*

As shown in table 1, an analysis using Tukey's HSD post-hoc test was conducted to compare transdisciplinary competence across different academic years. The results indicated a gradual increase in competence scores as students progressed through their academic programs. First-year students reported the lowest mean score (M = 3.71), while fourth-year students exhibited the highest (M = 4.09). Intermediate scores were observed for third-year (M = 3.92) and second-year students (M = 4.05).

Although the observed trend suggests that transdisciplinary competence tends to develop over time and with academic experience, the differences among the groups were not statistically significant at the 0.05 level (p = 0.142). This implies that while graduate students (particularly those in their fourth year) demonstrate higher levels of transdisciplinary competence than their junior counterparts, the variation is not sufficient to conclusively confirm the hypothesis based on this sample.

Nonetheless, the increasing trend provides empirical support for the pedagogical assumption that transdisciplinary skills are strengthened through continued exposure to higher education, practical experience, and interdisciplinary learning.

Table 1.
Differences of results among 1-4 academic year students

Transdisciplinary_competence
Tukey HSD[a,b]

Academic years	N	Subset for alpha = 0.05
1 year	103	3,7085
3 year	31	3,9174
2 year	19	4,0465
4 year	13	4,0877
significance		,142

a. Uses the harmonic mean sample size = 23.321.
b. Group sizes are unequal. The harmonic mean of group sizes is used.
Type I error levels are not guaranteed under these conditions.

Despite global advancements in STEM education, Kazakhstan continues to face structural and systemic challenges in its implementation. As highlighted in recent comparative analyses, the absence of a unified national approach to STEM and STEAM integration in teacher education, along with a gap between university-level pedagogical training and the realities of school instruction, limits the development of essential competencies among future educators. These limitations directly impact the cultivation of transdisciplinary skills, which rely heavily on interdisciplinary exposure and real-world application (Zholymbayev et al., 2021).

Based on this, the fourth hypothesis is proposed:

Hypothesis 4. *Students of the pedagogical direction of Kazakhstan have a low level of trandisciplinary education. Due to the fact that the system of transdisciplinary Education STEM STEAM is not implemented at the state level, teachers have a low level of transdisciplinary education.*

Table 2 offers descriptive statistics from the study (N = 166) reveal that the overall transdisciplinary competence among pedagogical students in Kazakhstan is moderate, with a mean score of 3.82 (SD = 0.61) on a 5-point scale. The range of scores, spanning from 1.00 to 5.00, indicates a substantial variation in competence levels among participants.

These results show that some students reach a high level of knowledge, while many others still do not have basic understandings about transdisciplinarity. The standard deviation further supports the presence of variability in preparedness among respondents.

The findings partially support the hypothesis, indicating that while future teachers in Kazakhstan demonstrate a moderate level of transdisciplinary competence (M = 3.82), the absence of a nationally implemented STEM/STEAM framework likely contributes to the inconsistency and overall underdevelopment of these competencies.

Table 2.
The level of readiness of students for transdisciplinary education

Descriptive statistics

	N	Minimum	Maximum	Mean (Average)	Standard Deviation
Transdisciplinary_competence	166	1,00	5,00	3,8159	,61444
N valid	166				

These findings align with global literature that emphasizes the impact of experiential learning and interdisciplinary exposure on transdisciplinary competence. For instance, studies in Finland and Canada have demonstrated that practical experiences, combined with reflective, project-based learning, significantly enhance teachers' ability to integrate knowledge across domains and foster innovation in the classroom. Similarly, the observed increase in competence scores among students who participated in interdisciplinary courses supports claims that such exposure improves not only theoretical understanding but also flexible thinking and problem-solving capacity.

Although the differences across academic years were not statistically significant, the upward trend suggests that sustained exposure to complex educational tasks over time contributes to the gradual development of transdisciplinary competence. This trend shows that early support and targeted learning activities can help students develop these skills faster and reduce differences in competence levels.

The findings also reveal systemic gaps: despite a moderate overall level of competence, the lack of a national STEM/STEAM implementation strategy likely contributes to uneven training quality and preparedness. This suggests that transdisciplinary education in Kazakhstan still relies heavily on institutional initiative rather than policy alignment.

In response, teacher education programs should incorporate structured opportunities for interdisciplinary collaboration, critical reflection, and real-world problem-solving from the first year of study. Faculty development is also essential, as instructors must be trained not only to deliver integrated content but also to model the cognitive flexibility and cross-disciplinary thinking required for transdisciplinary teaching.

Future research should explore longitudinal impacts of such interventions and include qualitative measures (e.g., interviews or reflection journals) to deepen understanding of how transdisciplinary competence develops across time and context.

Conclusion

This study examined the readiness of future teachers in Kazakhstan for transdisciplinary education across five universities using a quantitative approach with 166 students from different academic years. Overall, students demonstrated a moderately high level of readiness to transdisciplinary approach (M = 3.82). The findings revealed that practical experience through internships (M = 3.92) and participation in interdisciplinary courses (M = 3.94) were associated with higher levels compared to those without such experiences. Although an upward trend was observed in competence from the 1st to the 4th year of study, the differences were not statistically significant. These results highlight the importance of integrating hands-on experiences and interdisciplinary coursework into teacher education programs to enhance transdisciplinary skills from early stages of academic training.

The findings of this study point to several actionable strategies for enhancing transdisciplinary competence among future teachers in Kazakhstan. First, increasing opportunities for practical experience, such as internships, appears essential, as students with such experience demonstrated higher competence levels. Second, the expansion of

interdisciplinary courses within teacher education curricula could foster broader and deeper integration of knowledge, given their positive association with competence development.

Moreover, the study highlights the importance of early integration of transdisciplinary concepts, suggesting that introducing interdisciplinary and hands-on learning experiences from the first year may accelerate skill acquisition. Targeted development of specific competencies such as systems thinking, creativity, collaboration, critical reflection, and integrative thinking is also recommended to build a strong foundation for transdisciplinary practice (Wall & Shankar, 2008).

In addition, embedding real-world problem-solving tasks that require the application of knowledge from multiple domains can help simulate the complex challenges educators face. It is important to regularly assess how students develop transdisciplinary competence during their studies in order to track their progress and improve teaching approaches over time (Steiner, 2011).

Teachers also play a key role in this process. They need support and training to use transdisciplinary methods in their teaching. When instructors feel confident in these approaches, they can better guide students and model the skills needed for real professional situations. These steps can help bring teacher education closer to the current demands of the education system and prepare future teachers for complex and interdisciplinary work.

Today, many countries focus on flexibility, innovation, and collaboration in education. Transdisciplinary learning supports these directions. If teacher education programs in Kazakhstan start developing these skills from the early stages, graduates will be better prepared to respond to changing conditions in schools and society. Over time, this can strengthen the education system and help it meet both local needs and global development goals. Encouraging institutional support, policy alignment, and continued research into effective transdisciplinary strategies will be essential to sustaining this transformation and ensuring its long-term impact.

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Conflict of Interest Statement

The authors declare no potential conflicts of interest regarding the research, authorship, or publication of this article.

Author Contributions

Arystankyzy G.: Conceptualization, Methodology, Investigation, Data curation, Writing - Original draft preparation. Nagymzhanova K.: Supervision, Writing - Reviewing and Editing.

References

Abdrakhmanova, K., Kadirbayeva, R., Kudaibergenova, K., Zharmukhanbetov, S., & Nurmukhanbetova, G. (2025). Formation of STEM Competencies of Future Teachers: Kazakhstani Experience. Open Education Studies, 7(1), 20240058. https://doi.org/10.1515/edu-2024-0058

Amelink, C. T., Grote, D. M., Norris, M. B., & Grohs, J. R. (2024). Transdisciplinary Learning Opportunities: Exploring Differences in Complex Thinking Skill Development Between STEM and Non-STEM Majors. Innovative Higher Education, 49(1), 153–176. https://doi.org/10.1007/s10755-023-09682-5

Bridgstock, R. (2009). The graduate attributes we've overlooked: Enhancing graduate employability through career management skills. Higher Education Research & Development, 28(1), 31–44. https://doi.org/10.1080/07294360802444347

Burnard, P., & Colucci-Gray, L. (2019). Reframing STEAM by posthumanizing transdisciplinary education: Towards an understanding of how sciences and arts meet and matter for sustainable futures. Research in Education. https://doi.org/10.1177/0034523719875637

Cohen, L. E., & Waite-Stupiansky, S. (Eds). (2023). Theories of early childhood education: Developmental, behaviorist, and critical (Second edition). Routledge. https://doi.org/10.4324/9781003288077

Ibraeva, E. S., & Shaushekova, B. K. (2023). Development of professional competencies in teacher education. Perspectives of Science and Education, 6, 276–290. https://doi.org/10.32744/pse.2023.6.17

Herro, D., & Quigley, C. (2017). Exploring teachers' perceptions of STEAM teaching through professional development: Implications for teacher educators. Professional Development in Education, 43(3), 416–438. https://doi.org/10.1080/19415257.2016.1205507

Holbrook, J., Rannikmäe, M., & Soobard, R. (2020). STEAM Education—A Transdisciplinary Teaching and Learning Approach. In B. Akpan & T. J. Kennedy (Eds), Science Education in Theory and Practice (pp. 465–477). Springer International Publishing. https://doi.org/10.1007/978-3-030-43620-9_31

Holmes, W., Bialik, M., & Fadel, C. (2019). Artificial intelligence in education: Promises and implications for teaching and learning. Center for Curriculum Redesign. https://curriculumredesign.org/wp-content/uploads/AIED-Book_Excerpt.pdf

Liechty, J. M., Keck, A.-S., Sloane, S., Donovan, S. M., & Fiese, B. H. (2022). Assessing Transdisciplinary Scholarly Development: A Longitudinal Mixed Method Graduate Program Evaluation. Innovative Higher Education, 47(4), 661–681. https://doi.org/10.1007/s10755-022-09593-x

McGregor, S. L. T. (2022). Transdisciplinary Teacher Education. Education Sciences, 12(7), 485. https://doi.org/10.3390/educsci12070485

Morze, N., & Strutynska, O. (2021). STEAM Competence for Teachers: Features of Model Development. In E. Smyrnova-Trybulska (Ed.), E-learning (1st edn, Vol. 13, pp. 187–198). STUDIO NOA. https://doi.org/10.34916/el.2021.13.16

Nicolescu, B. (2014). Methodology of Transdisciplinarity. World Futures, 70(3–4), 186–199. https://doi.org/10.1080/02604027.2014.934631

Popa, F., Guillermin, M., & Dedeurwaerdere, T. (2015). A pragmatist approach to transdisciplinarity in sustainability research: From complex systems theory to reflexive science. Futures, 65, 45–56. https://doi.org/10.1016/j.futures.2014.02.002

Shethiya, Y. C., Gaur, A. K., & Sharma, L. M. (2025). Philosophical foundations of education in the context of globalization. Journal of East-West Thought, 15(2), 506–515. https://www.jewt.org

Steiner, G. (2011). Competences for complex real-world problems: Toward an integrative framework. Sustainability Science, 6(2), 203–218. https://doi.org/10.1007/s11625-011-0127-0

Wall, S., & Shankar, I. (2008). Adventures in transdisciplinary learning. Studies in Higher Education, 33(5), 551–565. https://doi.org/10.1080/03075070802373008

Widodo W. (2019). The Movement of STEM Education in Indonesia: Science Teachers' Perspectives. Jurnal Pendidikan IPA Indonesia, 8(3). https://doi.org/10.15294/jpii.v8i3.19252

Zholymbayev, O. M., Abilmazhinov, Y. T., Shakerkhan, K. O., Ontagarova, D. R., & Sadykova, A. A. (2021). Priority aspects of STEM education implementation in

Kazakhstan and abroad and comparative aspects in development trends. Lomonosov Pedagogical Education Journal, (4), 87–98.

Zhumabay, N., Varis, S., Abylkassymova, A., Balta, N., Bakytkazy, T., & Bowen, G. M. (2024). Mapping the Kazakhstani STEM Education Landscape: A Review of National Research. European Journal of STEM Education, 9(1), 16. https://doi.org/10.20897/ejsteme/15576

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