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A transdisciplinary approach in teacher education: the case of a STEAM workshop on sustainable development

This study presents an experience of developing transdisciplinary education through a three-week workshop based on the STEAM framework. A total of 67 students from nine different pedagogical majors at Korkyt Ata Kyzylorda University participated in the workshop. The majors were selected to align with the STEAM fields. Students worked on group projects addressing relevant issues such as reducing food waste, saving water, and developing green spaces or gardens by integrating knowledge from various disciplines. During group collaboration, students encountered challenges related to teamwork and cooperation. However, guided and supported by practices grounded in research, the future teachers managed to overcome these difficulties. The study employed both qualitative and quantitative methods: inductive thematic analysis of workshop observations and reflections, and pre- and post-testing to measure understanding of transdisciplinarity. The results demonstrated significant improvement in students' integrative thinking, collaborative skills, and ability to connect academic knowledge to real-life contexts. This study confirms the effectiveness of the transdisciplinary approach in teacher preparation and can serve as a basis for future research on the long-term impact of systematically integrating transdisciplinary elements into educational programs.

Keywords: transdisciplinarity, STEAM, pre-service teachers, workshop, sustainability, real-world problems, interdisciplinary, collaborative skills.

Introduction

In today's fast-changing world, pre-service teachers need to build new skills such as critical thinking, collaboration, creativity and systems thinking in order to teach students how to solve real-world problems. A transdisciplinary approach and STEM/STEAM education play a crucial role in helping teachers connect knowledge across subjects and prepare learners for the complex global challenges they face. Implementing cross-disciplinary experiences in higher education gives the initial stage of development along this path [1].

STEM/STEAM education is widely received in developed countries where governments support educational policies and implement cross-disciplinary experiences among subjects into curricula and programs to develop 21st century skills. Most European countries, fast-growing China, and South Korea are actively implementing STEAM in their primary and secondary education systems, integrating its principles into teaching methods, and educational environments at all levels. At the same time, the concept of transdisciplinarity is positively embedded in these regions. The initial goal of transdisciplinarity aligns with STEAM approaches, which give knowledge beyond disciplines and destroy subject barriers. It is directly related to Sustainability issues, where the decision of a single discipline is insufficient.

In Kazakhstan, updating the education system to align with international standards is crucial, as both current and future teachers often possess insufficient knowledge of STEM education [2]. Research on STEAM awareness among Kazakhstan pre-service teachers demonstrates a significant lack of understanding of integrative pedagogies. This gap reflects a broader systematic issue: teacher education programs still do not prepare students for transdisciplinary thinking, despite growing demands for such modern approaches [3]. It shows the issue is relevant locally in our country. One of the effective ways to develop integration and creation of new knowledge is implementing transdisciplinarity.

The concept of transdisciplinarity has been extensively researched since the 1970s and still does not have one comprehensive definition, as it is considered highly context-dependent. Transdisciplinarity is a research approach that addresses society's knowledge demands for solving wicked problems, requiring integration beyond traditional disciplinary paradigms. It incorporates knowledge at multiple levels (empirical,

pragmatic, regulatory, and values) while considering the perspectives and goals of non-academic stakeholders, and is explicitly dedicated to changing processes and practices to achieve established objectives [4]. This integrative approach not only fulfils academic needs but also aligns with global educational priorities. UNESCO promotes transdisciplinarity in its report, “Reimagining Our Futures Together”, urging educational systems to adopt ecological, intercultural, and interdisciplinary learning to tackle existential risks. The report notes that pedagogical methods based on the principles of cooperation, mutual assistance and an analytical approach are needed to address pressing social and environmental issues. Since these issues go beyond traditional academic disciplines, educational systems must use interdisciplinary and transdisciplinary approaches that promote the collaborative acquisition of knowledge by students, teachers, and society. This highlights the importance of transdisciplinarity as a key strategy to prepare students for future uncertainties and complex challenges [5]. Moreover, it aligns with UNESCO’s four pillars of education (learning to know, do, live together, and be), which transdisciplinary approaches inherently support. The International Standard of Transdisciplinary Education aims to unify disciplinary knowledge across higher education levels (bachelor’s to postgraduate). It emphasizes transdisciplinary competence, enabling students to generalize knowledge beyond traditional disciplinary silos [6]. Thus, transdisciplinary education is increasingly recognized as essential for fostering holistic, goal-oriented learning across all levels of higher education.

All grades of school require a transdisciplinary approach because it promotes deeper, more meaningful learning that connects knowledge across subjects and prepares students for complex challenges. It is considered that transdisciplinary education breaks down traditional subject boundaries, allowing students to explore real-life problems that span multiple disciplines [7]. This helps students develop a comprehensive understanding rather than fragmented knowledge. For instance, a question like “How do we benefit from sunlight?” integrates geography, biology, physics, and mathematics, encouraging students to think broadly and critically. From Gürkan’s findings, transdisciplinarity supports cognitive, social, emotional, and physical development by providing a holistic learning experience that reflects the interconnectedness of knowledge and life. It is defined by engaging with real-world problems that cannot be solved by one discipline alone; students learn to analyze issues from multiple perspectives, enhancing their critical thinking and inquiry skills [8]. It is implied that transdisciplinary learning requires students to work collaboratively in teams, developing social skills such as communication, responsibility, role-sharing, and respect for different viewpoints [9].

O’Sullivan assumes that society and policymakers increasingly expect universities to produce knowledge that directly addresses pressing global challenges [10]. Transdisciplinarity helps universities meet these expectations by integrating academic and extra-academic actors in knowledge production and solution development. The complexity of contemporary higher education requires innovative teaching and research approaches. Moreover, this approach encourages universities to rethink curricula, research agendas, and institutional incentives to foster collaboration and integration across disciplines. Budwig & Alexander claimed that a transdisciplinary approach in universities fosters deeper learning and inquiry by connecting theoretical knowledge with real-life experiences, promoting active student engagement and collaboration. Given that implementing transdisciplinary education requires overcoming institutional barriers such as disciplinary silos, rigid curricula, and assessment methods that are not designed for integrated learning [11] [12]. There is a need for institutional support structures that encourage collaboration among faculties and provide resources for interdisciplinary initiatives.

One of the effective ways to explain the transdisciplinary approach in universities is through a workshop. A workshop is an interactive, participatory educational or training session designed to actively engage participants in learning, problem-solving, or skill development through collaborative activities, discussions, and practical exercises. This methodology emphasizes hands-on activities, group work, and real-time problem-solving rather than passive listening. Participants often engage in case studies, role-playing, design thinking, or collaborative projects. Particularly in transdisciplinary contexts, workshops focus on real-world global issues of humanity that require integrating knowledge from multiple disciplines and stakeholder perspectives. It has been noted that workshops have gained popularity in educational contexts, including early childhood education and care (ECEC), as they encourage meaningful and active engagement from participants [13]. Workshops are increasingly being employed as a qualitative research method across various fields, allowing researchers to gather data directly from participants [14].

While workshops provide active learning opportunities, they also have drawbacks. They demand considerable time, resources, and skilled facilitators, and their quality can vary. Short sessions may limit in-depth learning. Additionally, active personalities might overshadow others, causing some participants to feel excluded or hesitant to engage, which affects the overall learning experience. Measuring the long-term im-

part of workshops can be challenging, and knowledge or skills gained may not always transfer to practice if not reinforced [15].

This article explores the characteristics of transdisciplinary learning, drawing on the insights from scientists' research, practical applications, and educational activities. It elucidates the functional and instructional dimensions of transdisciplinarity within contemporary educational systems. The piece also investigates the relationship between transdisciplinarity and education for sustainable development, as well as its role in fostering universal skills. Furthermore, it emphasizes the significance of transdisciplinarity in addressing complex and multifaceted social and environmental challenges. This approach encourages reciprocal and transformative learning, transcendence, problem-solving, and transcending boundaries. It manifests itself in the values of active participation of students and their orientation towards solving real-life problems. Additionally, it integrates disciplinary knowledge and creates new knowledge, skills, competencies, and values in collaboration with classmates, teachers, and society. An important aspect remains the familiarization of future teachers with STEM/STEAM technologies, their application in practice and their demonstration of its connection with current problems. In this regard, it should be emphasized that students need to develop interdisciplinary skills.

The aim of this research is to examine the effectiveness of a transdisciplinary educational workshop in developing students' understanding of transdisciplinarity in teaching through a mixed-methods approach that involves both qualitative thematic analysis and quantitative pre- and post-testing.

Research objectives:

- to organize and conduct a three-week workshop introducing transdisciplinarity in education to students of various pedagogical majors;
- to familiarize students with the principles and applications of transdisciplinary teaching through real-world examples related to STEM/STEAM fields;
- to collect and analyses qualitative data from workshop activities using inductive thematic analysis;
- to administer and analyze pre-test and post-test data to evaluate changes in students' understanding of transdisciplinarity.

Research Questions:

What is the impact of a transdisciplinary STEAM-based workshop on the development of transdisciplinary education among pre-service teachers?

How do pre-service teachers from different academic disciplines collaborate to solve real-world problems in a transdisciplinary context?

How can the integration of STEAM disciplines support the development of transdisciplinary competence in future teachers?

Methods and Materials

We employed a mixed-methods approach to familiarize students with the transdisciplinary approach in education. More specifically, we conducted a workshop as a qualitative method and administered pre- and post-tests as a quantitative method. Initially, 67 students from various pedagogical majors participated in a three-week workshop on how transdisciplinarity functions in education and teaching. The chosen majors allowed us to elucidate transdisciplinarity through STEM/STEAM.

The primary aim of the workshop was to assist students in developing a robust understanding of transdisciplinary education by engaging them in practical activities centered on real-world challenges. By collaborating on issues such as food waste, water conservation, and gardening, students were encouraged to draw on knowledge from various fields. These topics were chosen to match Sustainability wicked problems in order to overcome the gap between theory and practice. This experience sought to enhance crucial transdisciplinary skills, including systems thinking, problem-solving, collaboration, and linking academic learning to real-life teaching scenarios.

After three weeks of lessons, we invited all participants to a final workshop to assess the effectiveness of our work using pre- and post-tests. Because the last lesson coincided with exam times, some students were unable to attend due to their schedules. In the quantitative study, 47 students took part, all of whom completed the pre-test and post-test.

This study was conducted at Korkyt Ata Kyzylorda University in collaboration with students from biology, physics, mathematics, chemistry, IT, art, engineering, foreign language teaching, and pedagogy and psychology majors. The qualitative study involved students from nine majors (Table 1).

Table 1

Research participants

№	Major	Academic year	Number of students
1	6B01101-Pedagogy and psychology	3	10
2	6B01515- Chemistry	2	7
3	6B01517- Biology	2	7
4	6B01510- Mathematics	3	8
5	6B01582- Physics	2	7
6	6B01501- IT	2	7
7	6B02132- Art	3	7
8	6B07367- Engineer	2	7
9	6B01725- Foreign language: two foreign languages	2	7

Qualitative data collected during a three-week transdisciplinary workshop were analyzed using the six-step inductive thematic analysis process. The workshop involved 67 students from various disciplines aligned with the STEAM framework, including majors such as physics, biology, chemistry, psychology, engineering, and foreign languages. A quantitative data set collected using pre-tests and post-tests was analyzed using the SPSS 29.02.0 program. We used the Paired Samples T-Test to determine the effectiveness of the workshop on Transdisciplinarity.

Results and Discussion

Workshops create opportunities for participants to build relationships and interdisciplinary networks. Consequently, we conducted a transdisciplinary workshop for future teachers from different majors. It consists of six interconnected phases designed to foster transdisciplinarity in education among pre-service teachers through real-world problem-solving aligned with the STEAM framework (Table 2).

Table 2

Workshop report template sections

Component	Description
Preparation Phase	Students from 9 majors (e.g., Pedagogy, Psychology, Math, Physics, Art, etc.) were selected based on their alignment with STEAM. Topics such as food waste, saving water, and gardening were chosen for real-world relevance. Workshop materials were prepared accordingly.
Introduction to Transdisciplinarity	In the first session, students were introduced to the concept of transdisciplinarity, with definitions from Piaget and Nicolescu. The goal was to distinguish it from interdisciplinarity and multidisciplinary then highlight its application in education.
Weekly Interactive Sessions	Over three weeks, sessions included short lectures, video examples (e.g., Greenpeace), team tasks, and discussions. Students applied their disciplinary knowledge to sustainability topics using STEAM tools.
Group Collaboration	Students were divided into interdisciplinary groups and assigned one of the three core themes. They worked collaboratively to analyze the problem, design a response, and prepare presentations. Roles were distributed based on expertise.
Reflection and Synthesis	After group presentations, students reflected on their learning process. Facilitators guided them to identify how their own and others' disciplines contributed to solutions. Emphasis was placed on collective knowledge-building and integration.
Evaluation	To evaluate the understanding of the concept of TD we conducted pre- and post-test based on the survey of awareness about transdisciplinarity. The results gave comparative analysis of conceptual growth.

Levensen defines a workshop as “an arrangement whereby a group of people can learn, acquire knowledge, perform creative problem-solving, or innovate in relation to a domain-specific issue”, emphasizing active and genuine participation, pre-defined goals, and the involvement of domain experts and practitioners. In our workshop about transdisciplinarity, we gathered students from different fields of knowledge to assess the effectiveness of their integration in tackling complex global problems [16]. The integration of STEAM disciplines fosters the development of transdisciplinary competence by encouraging students to connect theoretical knowledge from multiple subjects with practical, real-world challenges. During the workshop, students applied insights from physics, biology, art, mathematics, chemistry, psychology, engineering, IT, and language teaching to collaboratively address topics: “food waste”, “saving water”, and “building gardens”. This process nurtured core transdisciplinary skills such as systems thinking, creativity, teamwork, and critical reflection. The structure of the workshop demonstrated that engaging future teachers in interdisciplinary tasks within a collaborative environment helps them learn how to combine knowledge from different fields and apply it practically, both of which are important indicators of developing transdisciplinary competence.

In the first session, students explored key definitions of transdisciplinarity, which helped them distinguish it from related concepts. More precisely, definitions were provided with examples to explain the differences between multi-, inter-, and transdisciplinarity. There is one of the dominant parts of the transdisciplinary approach, which can make a clear goal for the workshop. Furthermore, it enhanced their understanding of transdisciplinary thinking, aligning with Nicolescu’s emphasis on conceptual clarity.

Mitchell and Klein emphasize that active, problem-based learning plays a crucial role in fostering integrative thinking and creativity among students [17, 18]. Our three-week workshop consisted of short videos, lectures, and tasks about complex issues of sustainability for which students were divided into three groups. Each group suggested several solutions for wicked problems using STEAM tools. Thus, students experienced working in collaboration with other majors and developed teamwork skills. Based on their practice, students from diverse disciplines, jointly discussed with students from other fields and demonstrated their solution. This process resembles Mezirow’s Transformative Learning Theory, which highlights the importance of critical reflection in changing students’ worldviews [19]. Due to the guided recommendations and discussions, pre-service teachers have changed their understanding of the transdisciplinary approach and demonstrated a strong positive example of the benefits of transdisciplinarity.

The first group, which included students from faculties of pedagogy, psychology, art, and environmental sciences worked on the topic “food waste”. The session began with an introduction to the concept of transdisciplinarity, illustrated through the example of paper waste, to demonstrate how addressing complex real-world problems requires integrating diverse forms of knowledge. Drawing from their respective disciplines, the group developed a multifaceted solution that combined educational strategies, psychological behavior-change approaches, and artistic awareness campaigns. Their final presentation reflected a well-rounded plan involving informational outreach and creative community engagement. This activity revealed a notable shift in students’ thinking. Initially inclined to approach problems from within their individual academic fields, the participants gradually came to appreciate the value of combining disciplinary insights. For example, psychology students examined the behavioral causes of food waste, while art students proposed innovative methods to capture public attention. This collaborative process emphasized the role of effective communication and mutual respect in co-creating meaningful solutions. Students not only gained a clearer understanding of transdisciplinary practices but also began to view them as essential tools for addressing sustainability and other global challenges. The decisions of the students of all three groups were very complex and were similar to the experiences in developed countries. For example, in order to reduce paper consumption, they presented an option where, in schools, teachers of each subject explain the topic and importance of reducing paper consumption based on the curriculum. This urgent environmental problem was solved both from a mathematical point of view, by calculating each student’s individual paper consumption, and from a psychological point of view, by compiling a diary of their paper consumption. Furthermore, solutions from other specialties were also integrated, where psychologists and programmers would create a digital application or platform that determines the amount of paper consumption and its various causes.

Despite all the efforts of the students, there were difficulties in the workshop. In the section “Group collaboration”, there were initially challenges in communication between peers and in building teamwork. Many students expressed a preference for working individually rather than collaboratively in their interdisci-

plinary groups. This resistance is a well-documented challenge in transdisciplinary and collaborative learning settings. As highlighted by McGregor, managing group processes is a key challenge in transdisciplinary collaboration, especially when participants come from diverse backgrounds and have established habits of individual academic work [20]. Furthermore, it is significant that group dynamics in such contexts often begin with a focus on individual needs and preferences, gradually shifting towards collective engagement as norms and trust are established. Additionally, one of the barriers in building teamwork was hierarchical issues, when exact sciences were prioritized over social sciences.

Studies reveal that group work, while initially met with reluctance, ultimately fosters a sense of connection, shared knowledge, and improved communication skills. This tension between individual and group work is common: students may initially self-isolate due to uncertainty about their roles or discomfort with collaborative processes, a phenomenon observed in interprofessional training as well [21]. Overcoming this resistance typically requires intentional facilitation, opportunities for open communication, and structured activities that build trust and clarify the value of collaboration for complex problem-solving [22]. Finally, teamwork can be built by highlighting the value of collaboration and ensuring guidance and support for effective teamwork. The workshop facilitators helped to address communication barriers by sharing their own experience and using methods of developing communicative skills all three weeks.

Furthermore, after all sections, the final step involved determining the effectiveness of the workshop among pre-service teachers. To assess the effectiveness of the transdisciplinary workshop, a survey was conducted to compare students' scores on the pre-test and post-test. The survey was developed based on J. Piaget's and B. Nicolescu's theories. It consists of 5 parts: educational integration and interdisciplinary connections; systems thinking; innovation and creativity in pedagogy; collaboration, teamwork, and critical thinking and reflection. 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 (Table 3). These results confirm that the instrument is statistically reliable and suitable for further analysis. The results revealed a statistically significant increase in transdisciplinary competence following the workshop (Table 4).

Table 3

Statistics of validity

Cronbach's Alpha	Number of items
,978	50

Table 4

Mean of Paired Sample test

Paired Samples Statistics				
Pair	Mean	N	Standard Deviation the Mean	Standard Error of Mean
Pre-test	3,5700	47	,67955	,15195
Post-test	4,6580	47	,42302	,09459

The mean score on the pre-test was $M = 3.57$, $SD = 0.68$, while the post-test mean increased to $M = 4.66$, $SD = 0.42$. The mean difference was -1.09 with a standard error of 0.14 . This difference was statistically significant, $t(19) = -7.75$, $p < 0.001$.

These findings are particularly significant in the context of Kazakhstan, where the integration of transdisciplinary and STEAM-based approaches in teacher education remains in its early stages. The statistically significant increase in students' transdisciplinary competence following the workshop indicates a strong potential for employing such interactive, real-world learning formats in local pedagogical programs. Currently, many Kazakhstani teacher training institutions still rely heavily on traditional, discipline-specific methods, with limited focus on interdisciplinary or experiential learning. The workshop model introduced in

this study demonstrates that future teachers in Kazakhstan can adapt to and benefit from transdisciplinary learning when given the appropriate structure, guidance, and opportunities for collaboration. In addition, these results conform to Kazakhstan's broader educational modernization directions, which focus on innovation, global competitiveness, and 21st century skills development. The introduction of transdisciplinary methods in teacher training can help bridge the gap between national goals and teaching practices, as well as prepare future educators to address complex social and environmental issues both locally and globally. However, the conducted research identified a systemic gap in the education system. The strong improvement observed after the workshop indirectly shows that there was limited experience of interdisciplinary or real-world learning. Similar patterns have been examined in other countries where education systems were transitioning from discipline-based teacher training to competency-based training. Therefore, the effectiveness of the workshop may reflect the lack of alternative opportunities in Kazakhstan. Moreover, without continuous practice the workshop results may not be retained. At this point, it creates a contradiction, while national policies promote modernization, teacher education programs still rely on traditional curricula.

Conclusion

Increasingly growing of complexity of global issues such as sustainable development, digitalization, and social inequality requires new approaches in education that go beyond traditional academic disciplines. In this case, the improvement of transdisciplinarity among future teachers is becoming important, as it allows them to integrate knowledge from different disciplines and creatively approach wicked problems by collaborating with colleagues and using critical thinking. This study highlights the importance of transdisciplinary competence in teacher preparation, particularly when aligned with the STEAM framework, which reflects the interconnected nature of today's societal and educational challenges.

The workshop had a positive influence on students' knowledge of transdisciplinary education. Through three weeks of interactive sessions, interdisciplinary collaboration, and problem-solving activities aligned with STEAM, students demonstrated an improved understanding of transdisciplinary concepts. This is confirmed by a statistically significant increase in their scores on the final test results ($M = 4.66$) compared to preliminary test scores ($M = 3.57$), which indicates an increase in their ability to integrate disciplinary knowledge, think critically, and use integrative thinking in an educational context. Improvements in teamwork, integrative thinking, and creativity suggest that structured guidance and interdisciplinary tasks play a crucial role in fostering these skills.

This study contributes valuable insights for various fields in education. Schoolteachers and university faculty can apply these findings to design STEAM-based workshops that promote transdisciplinary skills in pre-service teachers, with a focus on collaboration, creativity, and real-world problem-solving. Researchers in the field of education are encouraged to continue this study, examining the long-term consequences of interdisciplinary learning and developing comprehensive tools for assessing its effectiveness.

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Болашақ мұғалімдерді даярлаудағы транспәнаралық тәсіл: тұрақты даму контексіндегі STEAM-семинар тәжірибесі

Бұл зерттеуде STEAM тұжырымдамасына негізделген үш апталық семинар арқылы транспәнаралық білім беруді дамыту тәжірибесі ұсынылған. Семинарға Қорқыт Ата атындағы Қызылорда университетінен 9 түрлі педагогикалық мамандық бойынша оқитын 67 студент қатысты. Мамандықтар STEAM бағытына сәйкестендіріліп таңдалды. Студенттер азық-түлік қалдықтарын азайту, суды үнемдеу, бақшаны жоспарлау немесе жасылдандыру сияқты өзекті мәселелерді шешу үшін түрлі пәндер бойынша білімдерін біріктіріп, топтық жобалар орындады. Топтық жұмыс барысында студенттер ынтымақтастық және командалық жұмыста бірнеше қиындықтарға тап болды. Алайда, бұрынғы дәлелденген зерттеулер тәжірибесіне сүйене отырып бағыт беру және қолдау көрсету арқылы болашақ мұғалімдер бұл қиындықтарға төтеп бере алды. Зерттеу барысында сапалық және сандық әдістер қатар қолданылды: семинар барысындағы бақылау мен пікірлерге индуктивті

тақырыптық талдау жасалса, ал транспәнаралық түсінік деңгейін анықтау үшін pre- және post-тесттер өткізілді. Нәтижелер бойынша семинар студенттердің интегративті ойлау, ынтымақтастық және білімді өмірмен байланыстыру қабілеттерін едәуір арттырғанын көрсетті. Бұл жұмыс транспәнаралық тәсілдің болашақ мұғалімдерді даярлауда тиімді әдіс екенін көрсетеді және келесі зерттеулерге білім беру бағдарламаларында транспәнаралық оқыту элементтерін жүйелі енгізудің ұзақ мерзімді әсерін талдауға негіз бола алады.

Кілт сөздер: транспәнаралық, STEAM, болашақ мұғалімдер, семинар, тұрақты даму, шынайы өмірлік мәселелер, пәнаралық, бірлескен жұмыс дағдылары.

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Трансдисциплинарный подход в подготовке будущих учителей: опыт STEAM-семинара в контексте устойчивого развития

В данном исследовании представлен опыт развития трансдисциплинарного образования посредством трехнедельного семинара, основанного на концепции STEAM. В семинаре приняли участие 67 студентов из 9 различных педагогических специальностей Кызылординского университета имени Коркыт Ата. Специальности были отобраны с учетом соответствия направлениям STEAM. Студенты выполняли групповые проекты, направленные на решение актуальных проблем, таких как сокращение пищевых отходов, экономия воды, озеленение и организация садов, интегрируя знания из различных предметных областей. В процессе групповой работы участники столкнулись с рядом трудностей, связанных с сотрудничеством и командной динамикой. Однако, благодаря руководству и поддержке, основанному на опыте подтвержденных исследований, будущие педагоги смогли преодолеть эти трудности. В исследовании применялись как качественные, так и количественные методы: проводился индуктивный тематический анализ наблюдений и отзывов, а также pre- и post-тестирование для оценки уровня понимания трансдисциплинарности. Результаты показали значительное улучшение у студентов интегративного мышления, способности к сотрудничеству и связи знаний с реальной жизнью. Работа демонстрирует эффективность трансдисциплинарного подхода в подготовке будущих учителей и может служить основой для дальнейших исследований по системному внедрению элементов трансдисциплинарного обучения в образовательные программы и оценке их долгосрочного воздействия.

Ключевые слова: трансдисциплинарность, STEAM, будущие учителя, семинар, устойчивое развитие, реальные жизненные задачи, междисциплинарность, навыки совместной работы.

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