education sciences

MDPI

Article

Capacity Building for Engineering Training and Technology via STEAM Education

Damira Jantassova [1,*], Daniel Churchill [2], Olga Shebalina [3] and Dinara Akhmetova [1]

1 Foreign Languages Department, Abylkas Saginov Karaganda Technical University, Karaganda 100027, Kazakhstan
2 Faculty of Education, University of Hong Kong, Hong Kong, China
3 Department of Social Sciences, Gumilyov Eurasian National University, Karaganda 010008, Kazakhstan
* Correspondence: d.dzhantasova@kstu.kz; Tel.: +7-7089112516

Abstract: This paper reports the "Capacity building for innovative engineers through STEAM education" project conducted at Kazakhstan's Saginov Technical University ('STU') and funded by the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan (Grant No. AR09260338). The problem of intercultural communication and the ability to collaborate, the issues of critical thinking development, and using the creative approach to solving professional tasks remain weak in the system of engineering higher education in Kazakhstan. STEAM Education appears to serve a role in overcoming the problem. Conducting a comprehensive study of the world experience and developing strategies for introducing STEAM into the educational process at Kazakhstani universities based on multifactor SWOT analysis made it possible to form several STEAM approaches for innovative engineering education. In the paper, we present the STEAM (Science-Technology-Engineering-Arts-Mathematics) Education framework for innovative training of engineers developed based on the best practices from around the world. This framework focuses on sustainable engineering education for intercultural communication, creative industry, and creative cooperation. In developing the STEAM Education framework, the researchers applied a methodology that included classification and comparison of international STEAM Education practices, analysis of regulatory documents, and statistical data in the sphere of education and multifactor SWOT analysis.

Keywords: capacity building; engineering education; international benchmarking; multifactor SWOT analysis; STEAM Education

Citation: Jantassova, D.; Churchill, D.; Shebalina, O.; Akhmetova, D. Capacity Building for Engineering Training and Technology via STEAM Education. *Educ. Sci.* **2022**, *12*, 737. https://doi.org/10.3390/educsci12110737

Academic Editor: Kelum A.A. Gamage

Received: 22 September 2022
Accepted: 13 October 2022
Published: 24 October 2022

1. Introduction

Contemporary industries in Kazakhstan demand local engineering education reforms and integration of scientific approaches, modern technologies, and creative components. Engineering education institutions from around the world have recently turned to the adoption of interdisciplinarity and integration of five disciplines (Science, Technology, Engineering, Art, and Mathematics), known as STEAM, as a solution for addressing engineering education reforms. Integrating Art with STEM is a method for developing engineers' creative thinking, communication, collaboration, and other essential skills. The international partners' experiences show that bringing Art to engineering education leads to advancing the creative industries and economy [1,2].

For Dougherty M.K. [3], Art allows students to work with Technology and Design to imagine and innovate. Claymier B. [4] believes that adding Art to the engineering curriculum and using design challenges in STEAM Education fosters a unique set of skills among students. In the 1990s, the concept of creative economy evolved in Australia and the United Kingdom. This involves a system of creative cooperation, including innovative, scientific, and economic relations, formed through developing and launching new products and services. Developing the creative economy requires engineering professionals with STEAM skills, known as creativity, critical thinking, communication, and cooperation.

Institutions worldwide have started implementing STEAM Education, achieving positive results in increasing the quality of engineering education and training in technical disciplines. STEAM Education is emerging as a bridge connecting learning activities, employment, and professional career development [4]. Furthermore, based on our teaching experience, we consider that STEAM Education makes it possible to prepare future engineers for a technically advanced professional world.

One of the main problems for STEAM Education adoption is the lack of an appropriate curriculum design and teacher preparation standards. In addition, most STEAM Education initiatives are implemented at the secondary level and not in higher education. The most exciting adoption of STEAM Education has been reported in the USA, Singapore, China, South Korea, and other developed countries [3–7]. For example, the Strategic Plan for the Development of STEAM Education emphasizes the importance of STEAM Education in the USA [8]. That plan proposed extensive training of 100,000 new STEAM teachers by 2020 and support for currently practicing teachers. Another goal of the plan has been to increase the percentage of secondary school students involved in STEAM every year by 50%. It is also planned to increase the number of college and university graduates in STEAM specializations by 1 million. Today, more than 400 STEAM-related professions are reported in the USA, and this list is being expanded with new professions added continuously [7].

The Massachusetts Institute of Technology (MIT) is frequently mentioned as an example of effective STEAM adoption. The motto of this university is "Menset Manus" ("Mind and Hand"). The MIT has developed STEAM courses and even created STEAM training centers at other educational institutions [7].

Educational institutions in France, Great Britain, Australia, Israel, China, and Singapore have undergone projects to train STEAM Education specialists and offer their students certified state educational programs in the scientific and technical fields [9]. Vietnam, Hong Kong, Turkey, Qatar, Canada, and Ukraine are also involved in the development of STEAM, but to a somewhat lesser extent. In general, according to the European Schoolnet report [10], which studied 30 countries, in 2016, 80% of countries underlined STEAM Education as their priority. Almost all of them are now implementing reforms in STEAM Education with a focus on socio-economic factors.

Despite the successful spreading of STEAM methods in secondary and extracurricular education, there is a general lack of practice, research, and clear standards about the implementation of STEAM in higher/tertiary education in Kazakhstan [9]. In recent years, secondary schools in Kazakhstan have been actively pursuing STEM Education. As a result, the Kazakhstani academic communities have presented numerous and diverse tutorials on developing and implementing STEM Education. Respectively, new robotics and computer design centers are being opened and developed across the Republic. However, despite great attention to STEM Education, unresolved issues reduce the effectiveness of ongoing activities and slow the integration of Art in STEM. The most acute problems are:

- Poor intercultural communication among teachers and students;
- Lack of collaboration skills, for both teachers and students;
- Poor critical and creative thinking and approaches to solving professional tasks.

This adversely affects education at all levels. While efforts are being made within the school education sector to overcome existing barriers, engineering higher education lags far behind. Despite the focus on educational programs that meet the demands of the labour market, higher education institutions face several problems when training specialists to meet the needs of the contemporary socio-economic developments in the country [11]. In Kazakhstan's engineering education institutions, STEAM Education is not implemented. Although there is a rising emphasis on STEAM, only individual higher education teachers explore the adoption of STEAM Education. There are no comprehensive state programs for developing and supporting STEAM Education in Kazakhstani universities. That is true even though STEAM Education was mentioned in the State Program for the Development of Education and Science for 2020–2025. Although various pilot programs and projects are being implemented (e.g., teachers are being retrained), STEAM Education has not yet received full attention from the authorities in Kazakhstan.

As experiences from other countries show, STEAM Education might set new directions for developing the labor market at the national and regional levels. STEAM Education can have a significant impact on the development of the labor market in Kazakhstan. Effective implementation of STEAM Education in Kazakhstan will change the labor supply, increasing the number of competitive, professionally qualified groups with higher wages and better working conditions. At the same time, specialists with developed STEAM skills will be characterized by higher professional skills, social entrepreneurship, and territorial mobility. In this regard, high-quality STEAM Education will create prerequisites for reducing structural and long-term unemployment in Kazakhstan. Due to its features, STEAM Education contributes to forming active, enterprising, creative, and qualified professionals. As a rule, a specialist with STEAM skills has higher competitiveness in the labor market, can quickly find a job, and is always in demand due to more advanced research, project, communication, leadership, and other socially and professionally significant qualities and skills.

Therefore, increasing the competitiveness of engineering graduates through STEAM Education might provide a more active transition to an innovative knowledge-based economy and the development of creative industries in Kazakhstan. It is important to note that one of the main issues hindering Kazakhstan's economic growth is an insufficient level of specialist training in technical fields. Sustainable development of all sectors of the country's economy requires higher professional-level technical specialists who can create new technologies and innovation and produce competitive goods and services.

2. The Project

The project "Capacity Building for Innovative Training of Engineers through STEAM Education" has been interdisciplinary. Its aim has been to develop and implement a framework for capacity building in engineering education via STEAM Education. We believe that achieving our project's goal via STEAM Education would improve the quality of engineering education for the Republic's economy. Within the project, the research component focused on factors leading to enhancing higher education through integrating Science, Technology, Engineering, Arts, and Mathematics.

This project was conducted at Kazakhstan's Abylkas Saginov Technical University (STU). The choice of the University is determined by the territorial significance of the STU in the industries sector of Kazakhstan's economy. STU is a large regional technical university that provides training in 83 educational programs, including 46 Bachelor's, 29 Master's, and 8 PhD programs. The industrial base of the Karaganda region is formed by more than 200 enterprises and industries focusing on mining, manufacturing, electricity, and water supply. These industries occupy a predominant share of the gross regional product. The GRP of the region includes the mining and manufacturing industry (31.4%), electricity supply, gas supply, steam, and air conditioning (13.1%), water supply (3.2%), and sewerage system, control over the collection and distribution of waste (0.7%). Therefore, STU educational programs are in high demand in the region and the Republic, so there is a significant need to enhance the preparation of engineers via STEAM Education.

The project analyzed the process of preparing students for engineering specializations through STEAM Education: adoption of STEAM learning models, learning strategies, and outcomes focused on critical thinking, communication, and cooperation; and creative decision-making skills. There was a content analysis of the normative documents correlated with the internal analytical reports on the surveys of students and stakeholders aimed at academic needs assessment. Then, the correlation findings were applied in multifactor SWOT analysis and in terms of international STEAM best practices.

3. A Review of International STEAM Education Approaches

To develop effective ways to integrate STEAM into university education, the project team conducted a comparative analysis of international STEAM Education practices in the USA, Europe, and Asia as STEAM hubs. The analysis demonstrated that STEAM Education practices appear to include methods for developing critical and creative thinking, professional communication and collaboration skills, and integrating various fields of knowledge. This analysis enabled the project team to classify STEAM Education approaches and adapt them for adoption in Kazakhstan.

The educational data analysis in the project shows the great potential of the first STEAM Education approach which has roots in Asia: *The Studio Learning Model* [5]. When learning STEAM, student-centered methods, such as oral presentations, debates, exhibitions, written products, model building, design, project work, and problem-solving, provide students with opportunities to demonstrate their learning. *The Studio Learning Model* supports adopting learning technology, learning in context, simulation, case studies, problem-solving, and focus-based learning. At the same time, an important point is an assessment of outcomes of students' learning activities, including the formation of 'hard skills,' the development of 'soft skills,' creativity, critical thinking, communication and cooperation, flexibility, the plasticity of thought, an interdisciplinary approach at different levels, self-esteem, and reflection [3]. Assessment tasks typically involve students in authentic, real-life, hands-on learning activities and place high cognitive demands, leading to meaningful learning. The information provided by these assessment tasks reveals the strengths and weaknesses of students and assists teachers in further learning during the project. In completing assignments, teachers should consider the following factors: the focus of the assignment, the context of the assignment, the directions provided for learners, and the rubric used for grading. The focus of the assessment task should be closely related to the learning outcomes. The context should give background and questions related to the learning outcomes. In addition, students should be provided with instructions that clearly describe the performance or product being assessed, as well as criteria for assessing the quality of the assignment. These assessment methods can improve STEAM Education and create an enabling environment for focused learning, increased self-esteem and effectiveness, creative collaboration, and openness [12]. Furthermore, through the opportunities offered by STEAM Education, students have an increased chance of fulfilling their potential and pursuing careers previously unknown to them or written off by them as unattainable or undesirable. Experiences from other Asian countries' STEAM Education adoption show that the *Studio Learning Model* is valuable from the point of developing skills for the future.

Another model we looked at is the *Philippine STEAM Education Model* [13]. Adopting this framework demonstrated high student engagement and teacher adoption of modern learning technologies and interactive methods. In recent years, a lot has been conducted to promote STEAM Education and learning technologies [14]. The *Philippine STEAM Education Model* has been adopted in STEAM Education in high schools to transform students from critical thinkers to "Experienced 21st Century STEAM Student(s)". This includes classroom adoption of:

- Simulation of real-world applications (virtual and computer modeling);
- Illustration of real-life examples (production site visit);
- Facilitating life experience (problem-based and project-based learning);
- Integration of values (development of values and life skills);
- The application of the above concepts in solving unforeseen problems in the workplace.

STEAM Education has become a central topic for educational research and education policies in China. Currently, China's sustainable development process is facing three key challenges: the lack of high-level specialists, the pressure of economic transformation, and the complexity of education reform. Although China urgently needs high-level graduates to address these challenges, a further step is required to develop suitable and innovative education [6]. Chinese researchers explored combining technology and engineering education with arts and humanities education to develop students' talents [15,16]. However, effective

STEAM Education is impossible to achieve without well-prepared teachers. STEAM Education focuses on developing students' practical skills while integrating knowledge across and beyond disciplinary courses. It is a comprehensive, student-centered, problem-solving approach, emphasizing research, engineering design, and open problem-based learning.

The third model we explored in our project was the *Chinese Maker Education Model* [17]. This model offers a transformational approach to teaching and learning, focusing on the 'maker', who develops through an interactive, open, interdisciplinary experience that allows one to use the time and space for acquiring skills, knowledge, and ways of thinking. In educational environments focused on the "maker", students design, create, and present projects that align the content of the training with practical application. The methods used in the context include project-based learning, a combination of technology and engineering education with arts and humanities education aimed at promoting innovations in technology-based learning, an integrated approach, creativity and exchange promotion, engineering design method, and open learning.

The fourth approach we explored was the *iSteam Teaching Model*. The primary strategy of this approach is the design research method with four main features [18]:

- Theoretical developments to test the feasibility of theories or to propose prototype theories;
- A detailed report on the research process and interactions in the system;
- Valuable repetition of modifications, thus revealing the modification process;
- Systematic analysis to help investigate multilayered interactions.
- The *iSteam Teaching Model* integrated the following in learning tasks:
    - Research—Study the existing environment and cultural background and accumulate knowledge on the topic;
    - Brainstorming—Set the starting point and goal of imagination according to the available experience and explore the knowledge;
    - Association—Expand your imagination, analyze the structure, and determine relations;
    - Transformation—Set a new starting point, or think backwards, starting with the goal; assemble and experiment with components;
    - Connection—Combine and connect all the ideas and add a new dimension to them to define the theme and contextual content; start designing;
    - Clarity—Apply imagination to action and create; test devices and make changes.

The fifth approach explored in the project was the *Active Learning Model* [19], which "maximizes the learner's skills in active learning". Flexibility and adaptability are attractive advantages for learning and access to information in a globalized world. This approach is used to implement research scenarios and joint exercises of students supported by an assessment system that gives preference to discovery skills. The STEAM led to the development of an educational model aimed at overcoming fragmented bridges in academic subjects. Practical and functional attributes of visual communication methods through diagrams, symbolic logic, scientific illustrations, and photographs, among others, are added to allow the perception of Art as a means of transmitting scientific content. The use of supporting initiatives and the influence exerted by the visualization of scientific content to solve problems when teaching and learning at the university, given its creative body of knowledge, offer participation and consistency in STEAM Education. Within this framework, STEAM Education includes consultations, design and interdisciplinary cooperation of students, and an interactive teacher–student method. Transdisciplinary pedagogy of STEAM and the corresponding subcategories and the category of complementarity of STEAM in the curriculum content is actively used. Creativity and innovation must be considered part of STEAM, and Arts make this possible. Arts in STEAM Education place students at the center of the learning process and support disciplinary knowledge integration. This approach holds that larger engineering projects must be interdisciplinary and involve engineers and other professionals, nonprofessionals, and teams in collaboration and partnership.

The further approach examined in the project was *The Removing Boundary Model* [20]. Fundamentally, this approach attempts to blur the boundaries between traditional academic subjects so that Science, Technology, Engineering, Arts, and Mathematics can be integrated into a single curriculum. It is proposed to apply learning design approaches such as project-based and problem-based learning. Emphasis is placed on the following:

- Embracing different disciplines (covering close interdisciplinary links, including both related fields and additional fields of knowledge);
- Designing projects for students (setting tasks for students to develop their projects);
- Teasing out creativity (identifying and stimulating the development of creative abilities);
- Allowing and encouraging failure (the use of mistakes for self-assessment and lifelong learning);
- Realizing students are different (individual approach to students);
- Considering vertical orientation (using previous learning outcomes to achieve new learning goals);
- Exploring horizontal blurring (application of interdisciplinary practices: usage of other fields of knowledge in the discipline and for project design);
- Having higher expectations encourages students to solve high-level complexity problems and achieve advanced findings.

The Interdisciplinary Thinking initiative showed that learning through the Arts can transcend disciplines and enrich learning by utilizing the Art component [13,20,21]. This approach argues that first-year university students should participate in STEAM Education, combining at least one Arts course with at least one STEM course. This approach has been practiced for the past several years. Learning outcomes of the initiative included a focus on critical thinking, civic engagement, information literacy, interpersonal communication skills, effective communication, and relationship building. Students would develop these essential life skills with the help of Art–Science and Art–Technology programs. The primary learning approaches promoted include experiential learning, learning based on socio-cultural theory, and interdisciplinary thinking. In addition, these would lead to the development of creative thinking skills through approaches such as: engaging in reflection; looking for many possible answers, not just one; allowing students to make 'wild' suggestions; not rejecting ideas early in the process but applying to all ideas containing something potentially useful; allowing students to draw, daydream, or play with theory or conjecture; developing awareness that these approaches necessarily involve many propositions that are unrealizable and may seem 'stupid,' and make mistakes and study what did not work, and what worked.

Another approach explored in the project was the *Critical and Creative Thinking Model* [22]. Critical thinking, considered one of the standard STEAM Education features by practitioners and educators, allows recognizing a wide range of subjective analyses of objective data and evaluating how well each analysis can meet specific needs. Facts can be facts, but how we interpret them can vary, and critical thinking is intelligent and reflective thinking, focusing on deciding what to believe or do. Critical thinking strategies incorporated in this approach include [22]:

- Reflections;
- Rationality—rely on reason rather than emotion, demanding evidence, ignoring and following any known evidence, caring more about finding a better explanation than being correct, and analyzing apparent confusion and asking questions;
- Self-awareness—weigh the influence of motives and biases and acknowledge your assumptions, prejudices, prejudices, or point of view;
- Honesty—think critically, recognize emotional impulses, selfish motives, vicious goals, or other ways of self-deception;
- Openness—evaluate all reasonable conclusions; consider many possible points of view; stay open to alternative interpretations; accept a new explanation, model, or paradigm because they explain the evidence better, are simpler, or have fewer inconsistencies or cover more data; adopt new priorities in response to the reassessment of evidence or a reassessment of one's fundamental interests; and do not reject unpopular views right away;

- Discipline—be precise, meticulous, comprehensive, and exhaustive; engage in active listening and reading practices; resist manipulation and irrational appeals; and avoid hasty judgments;
- Judgment—recognize the relevance or merits of alternative assumptions and points of view and the scope and weight of evidence.

Analyzing international practices and approaches allowed us to explore the possibility of implementing STEAM Education in Kazakhstani universities. Emerging as common to these approaches are:

- Project method and design thinking;
- Development of communication and collaboration skills;
- Problem-based learning in close connection with science and production;
- Interdisciplinary and critical thinking;
- Blurring boundaries between subject areas.

International STEAM Education practices reviewed in the project are summarized in Figure 1.

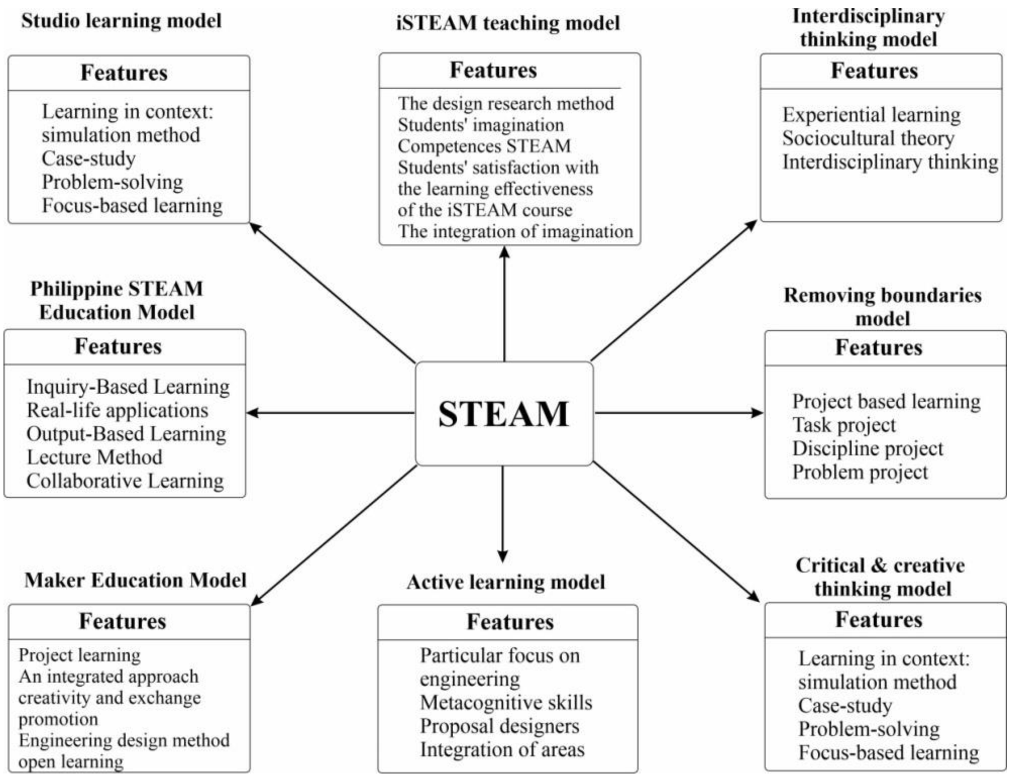

Figure 1. The international STEAM Education practices analyzed in the project.

The identified features of the reviewed approaches made it possible for our project team to develop measures for integrating STEAM Education into engineering degree programs. For implementation of the best practices of STEAM Education into the university educational processes, we applied a multifactor SWOT analysis aimed at analysing STU's current academic situation. In the SWOT analysis, the determined STEAM learning models are used as the main categories.

4. A SWOT Analysis of Strengthening Engineering Education through STEAM

A multifactor SWOT analysis was conducted to identify critical factors for implementing STEAM within the local engineering education environments. This type of analysis was developed based on the works of Henry Mintzberg and the *Design School Model*, aimed at assessing external and internal factors, threats and opportunities in the environment, and the strengths and weaknesses of an institution [23]. Additionally, we considered the work of Philip Selznick [24], who proposed focusing on protecting an institution's distinctive values and identity from internal and external threats, which, by focusing on the structure and functions of that institution, allows it to determine specific competencies [24]. Furthermore, we gave attention to the work of Wheelen and Hunger [25] proposing the development of strategic decisions through a combination of the *Strategic Factors Analysis Summary* (SFAS), the *External Factor Analysis Summary* (EFAS), and the *Internal Factor Analysis Summary*. The SFAS matrix summarizes strategic factors by combining external factors from the EFAS table with internal factors from the IFAS table. When creating the SWOT matrix, possible alternative strategies can be generated by referring to the EFAS and IFAS tables [25,26]. We applied aspects of these approaches in SWOT analysis for the assessment of engineering education needs and STEAM.

For the complete consideration of all processes, a combined SWOT analysis scheme was developed and applied based on content analysis of the Policy and Objectives of the University in the Field of Quality [27], Strategic Plan of STU for 2018–2022 and 2014–2023, the Comprehensive Program for the Development of STU for 2021, the Academic Policy of the University [28], technical degree programs, curricula of major disciplines, catalogues of elective disciplines in the areas of engineering training, and opinions of the expert group. The analysis aims at determining the ratio of internal and external factors and their influence on each other and formulating the most significant strategic decisions for implementing STEAM Education at a technical university in Kazakhstan. The scheme for conducting the SWOT analysis is shown in Figure 2.

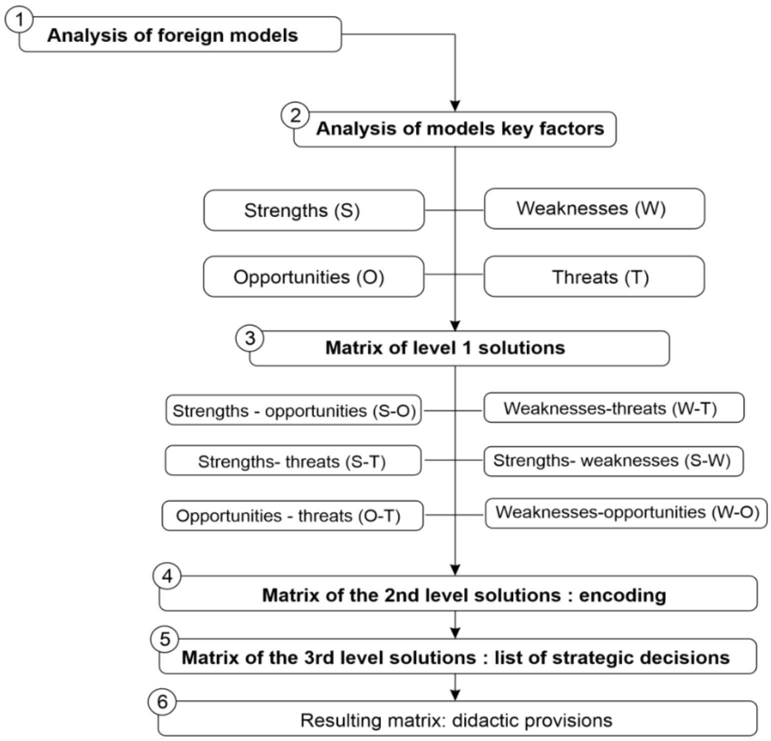

Figure 2. A schema for conducting the SWOT analysis.

5. The Results of the Multifactor SWOT Analysis

The technology of the matrix was created based on the personal experience of experts who are research team members. Each team member is a practitioner and researcher in the fields of engineering, IT, art, communication, pedagogy, and management in education area. In addition to this, for creating matrices, country's reports and internal university documents were used [9,27,28]. The factors in each group in the SWOT analysis are categorized in eight international STEAM learning models identified in the project. The possibility of applying these models in the educational process at a technical university was evaluated during the analysis. At the next stage, the *Basic SWOT Analysis Matrix* was compiled. It included four quadrants where the internal and external factors influencing the achievement of the goals were located. A fragment of this matrix is shown in Table 1 (for the complete matrix, see Supplementary Table S1).

Table 1. Fragment of basic matrix.

	Strengths (S)	**Weaknesses (W)**
Internal factors	*1.Studio Learning Model:* • Availability of lecture rooms equipped with interactive tools. • Availability of trained teaching staff. • Availability of presentation material, including virtual works. • Collective work of the student group about the lesson. • The possibility of dialogue learning. • Availability of job centers.	*1. Studio Learning Model:* • Not every lecture is suitable for an active or interactive model—there are passive ones. • Several teaching staff lack the skills to conduct interactive classes. • Different levels of interactive information perception among students. • The complexity and laboriousness of preparing relevant content for classes. • An insufficient number of prepared classrooms for small groups. • The need to periodically update both the technical equipment of the audience and the presentation material.

To formulate the most relevant strategic solutions for the implementation of STEAM Education based on the analysis of the results obtained, Matrix of Solutions 1 should be completed in the following areas:

- S-O—line of strength—the development of STEAM's capacity through strengths and opportunities;
- W-O—improvement line—the neutralization of existing shortcomings;
- S-T—line of defense—using strengths to protect against uncontrolled external factors;
- W-T—warning line—measures to prevent future risks.

With additional consideration of the mutual influences of external and internal factors, it became possible to respond to potential changes in the external environment along the line of O-T forecasting and reduce the influence of weaknesses on advantages along the S-W line. A matrix fragment along the W-O line is shown in Table 2 (for a complete matrix, see Supplementary Tables S2–S7.

The probable solutions for the proposed lines are, to a certain extent, universal to STEAM Education and can be applied to several learning models. As a result, when forming a matrix for managing the processes of implementing the STEAM models, it is not necessary to exclude solutions common to one or more models. To identify such strategies, at the stage of forming Decision Matrix 2, the coding of factors is introduced in such a way as to visually display the relationship with the critical factors of the external and internal environment. Encoding of factors is carried out as follows:

- Strengths—SN; N-sequence number of factors;
- Weaknesses—WN; N-sequence number of factors;
- Opportunities—ON; N-sequence number of factors;
- Threats—TN, N-sequence number of factors.

A fragment of the solution matrix of the second level is shown in Table 3 (for a complete matrix, see Supplementary Table S8.

Table 2. Fragment of the first level solution matrix for the W-O line.

W-O: Weaknesses + Opportunities		
Weaknesses	**Opportunities**	**Decisions**
Studio learning model		
1. Lack of studios with a variety of logistics. 2. Low degree of teaching staff preparation (pedagogical design of studio training), creative and dialogical communication development, and interactive methods. 3. The format of the traditional lecture is used (the format of the lecture is a teacher-centered approach). 4. Lack in the educational process of teaching methods practice contributes to the perception of interactive information (different perceptions of students). 5. . . .	1. The possibility of attracting lecturers from leading universities. 2. The possibility of using open access to educational material on the lecture topic, including the author's courses. 3. Availability of online access for highly qualified teaching staff upgrading their qualifications. 4. A large selection of multilevel, including international, language courses for preparing teaching staff.	1. The organization of the educational process via distance learning technologies. 2. Ensuring access to partners' educational resources by expanding cooperation in the field of education and science. 3. The organization of upgrading training courses for teaching staff on the management of the pedagogical process. 4. Creation of a digital resource center for developing MOOC and providing the educational process with digital content. 5. . . .

Solution matrix of the third level provides a list of necessary strategic decisions for each factor group per the international model. In addition, coding factors allow you to track their comprehensive coverage of the proposed solutions. A fragment of the specified matrix is shown in Table 4 (for a complete matrix, see Supplementary Table S9).

Table 3. Fragment of the solution matrix of the second level.

Studio Learning Model		
	Strengths (S)	**Weaknesses (W)**
Internal factors External factors	1. Availability of presentation material, including virtual practical and laboratory work 2. Collective work of the student group on the topic of the lesson 3. Availability of centers for working professions 4. Application of interactive learning methods for the development of course projects.	1. The absence of studios with a variety of material and technical support (SMART-POINT). 2. Low degree of preparedness of teaching staff (pedagogical design of studio education SO), development of creative and dialogical communication, interactive methods. 3. The format of the traditional lecture is used (the format of the teacher-centered approach lecture). 4. . . .

Table 3. *Cont.*

Studio Learning Model		
Opportunities	**Possible strategies:**	**Possible strategies:**
1. Opportunity to attract lecturers from leading universities. 2. The possibility of using open access educational material about the lecture, including the author's courses. 3. Availability of online access for highly qualified improvement of the teaching staff of their qualifications (Coursera). 4. . . .	1. Expanding the list of presentation materials through cooperation with foreign scientists (S1, O2). 2. Creation of a digital resource center for the development of MOOCs, and virtual laboratories to provide the educational process with digital content (O4,O2,S2). 3. Advanced training of teaching staff aimed at the formation and development of highly specialized, pedagogical, language, and IT competencies (S4, O3, O4). 4. Formation of students' professional competencies through the centers of working professions, design, and design bureaus (S2, S3, S4, O1, O2). 5. . . .	1. Organization of the educational process through DLT (W1, W6, O1, O2, O3). 2. Ensuring access to educational resources of partners by expanding ways of cooperation in the field of education and science (W3, W4, W5, O1, O3, O4). 3. Organization of advanced training courses for teaching staff on the management of the pedagogical process (W2, W3, W4, W5, O3). 4. Creation of a digital resource center for the development of MOOCs and provision of the educational process with digital content (W1, W2, W4, O3). 5. . . .

Table 4. Fragment of the matrix of solutions of the third level.

Possible Solution	Factors of Influence
Changing attitudes toward the university in society—moving away from the provider of educational services toward partnership, a member of the consortium "University-Enterprise"	S3, S4, O2, W1, W6, Th3
Ensuring access to educational resources of partners by expanding ways of cooperation in the field of education and science	W3, W4, W5, O1, O3, O4
Updating the material and technical base at the expense of partner enterprises	W1, W6
Organization of advanced training courses for teaching staff on the development of creative thinking and the use of innovative pedagogical technologies	S1, S4, S5, O3, O4, W2, W3, W4, W5 Th1, Th2
Organization of advanced training courses for teaching staff on the management of the pedagogical process	W2, W3, W4, W5, O3
Organization of scientific seminars for students to discuss and discussion on issues of education	S4, O1
Organization of training in addition to industrial practice at the branches of the departments together with leading specialists of partner enterprises	S2, S3, W3, W6, O2
Organization of training in a virtual environment, including through DLT	S4, S1, O1, O2, O3, O4, W1, W6, O1, O2, O3
Advanced training of teaching staff aimed at the formation and development of highly specialized, pedagogical, language, and IT competencies	S4, O3, O4
Obtaining and improving practical skills in parallel with theoretical training	W3, W4, O3
Involving employers in training and internships of teaching staff to work with innovative equipment and creating collaborations University-Enterprise	S3, Th2, Th3
Application of interactive teaching methods	W2, W3, W4, W5, O1, O2, O3
Development of incentive mechanisms for teaching staff to participate in foreign courses on the development of professional, language, and IT competencies	S1, S3, S4, TH1, Th2, Th3, W2, W3, W4, W5, O3
Expanding the list of presentation materials through cooperation with foreign scientists	S1, O2
Reflection of teaching staff for operational correction of pedagogical activity	W2, W4, W5,O3
Creation of a digital resource center for the development of MOOCs and provision of the educational process with digital content	S1, S2, S3, Th1, W1, W2, W4, O4, O2, O3

The exclusion of dual strategies and their consolidation is carried out at the formation stage of the resulting matrix "STEAM Approaches in the University Process" containing the formulated STEAM approaches for innovative engineering education. During the formation of this matrix, the proposed solutions were grouped within the main processes of the university. The final matrix based on the results of the SWOT analysis contains the main STEAM approaches for the implementation in the STU's leading processes, which include (for a complete matrix, see Supplementary Table S10:

- *Academic process*, which includes all types of students' education activities;
- *Methodological process* considers main recommendations for providing all aspects of the academic process;
- *Research work (students)* determines the important directions and ways of integration in students' research work;
- *Extracurricular process* forms students' social and emotional skills for stimulating civic engagement, leadership, and social responsibility;
- *Management of the learning environment and social partnership* provides the interaction of academic programs with the research results and industry needs;
- *Advanced training process* provides teachers' self-development and lifelong learning;
- *Upgrading the infrastructure process* aimed to improvement universities' academic environment.

6. Discussion: Integration of STEAM Approaches into the University Processes

The analysis of the formulated STEAM approaches made it possible to identify ways to integrate STEAM methodology into the university's processes, as presented in Figure 3.

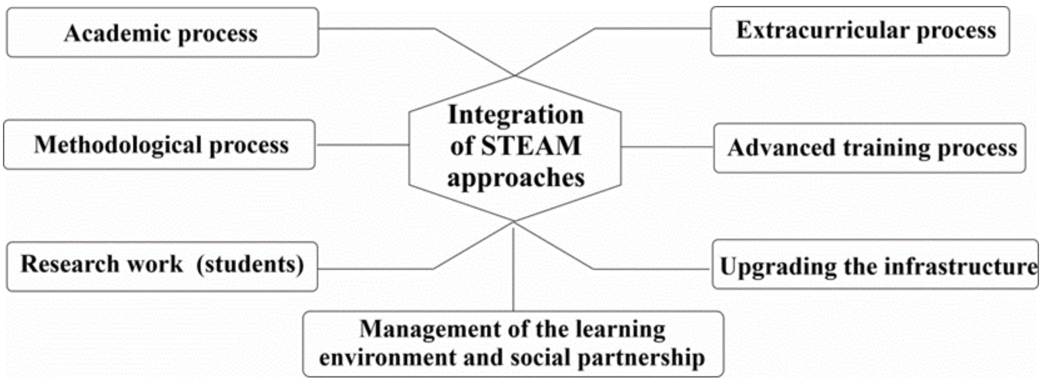

Figure 3. Ways of integration of STEAM approaches into the main university processes.

Within the *academic process*, five approaches have been identified. The first one is the development of a new discipline aimed at implementing the STEAM methodology: considering the specifics of the training area; ensuring the formation of professional competencies among students; considering the needs of modern production, based on the flexibility of thinking; and creative approach, with stable links with actual production processes. It is also necessary to make changes to the content of the disciplines taught within the educational program based on the STEAM approach: developing professionally essential qualities of future specialists will be ensured by strengthening interdisciplinary connections and developing transactive memory and metacognitive skills.

One of the main parts of the academic process is the development and implementation of a new trajectory in training and minor programs. The new trajectory should be focused on interdisciplinary collaboration: provide training for specialists of a new formation with a comprehensive profile of engineering competencies in related fields through horizontal blurring technology to achieve institutional diversity. The minor programs should be based on integrating the engineering field of knowledge and Art (Art component): enhance practical skills in developing innovations according to the principles of creativity.

For the introduction of STEAM approaches in the academic process of training technical specialists, it is demanded to design the teaching recommendations to ensure the quality of engineering and technical specialists' training using project-based and studio-based learning as well as training in the context of production and the introduction of mentoring programs.

The next complex of STEAM approaches has been identified as the main approaches for integration into the *methodological process*. One of them is the training recommendations for changing the instructional tools, including developing recommendations to improve teaching staff skills using innovative STEAM techniques.

To provide students with access to advanced skills, it is necessary to work out and recognize the results of microqualification and nanodegree programs. Therefore, the concept of STEAM training includes a unified, coordinated policy for implementing STEAM approaches in training specialists with higher technical education.

Recommendations for changing the structure and the content of general disciplines: adjusting the content as a university component, considering the development of students' "soft skills", and the vertical orientation of disciplines.

To involve employers in the process of educational programs' design aimed at updating the existing and developing new and innovative curricula focused on the creative industry's needs and the labor market.

The design of minor programs should be oriented toward implementing the Art component, auxiliary subcategories, and interdisciplinary cooperation.

One of the crucial solutions is the creation of the STEAM Networking Center targeted to develop mechanisms for cooperation in the field of education, including international partners. Within the framework of the *"Research work (students)" process*, the set of unique approaches based on the Creative Industry School (CrIS) concept is defined. This concept aims to create a center of attraction for creative youth and generate productive ideas, developing sustainable mechanisms for implementing start-ups focused on multilevel interaction. In addition, consulting through CrIS provides services to support student and faculty business initiatives, including in related fields.

Orientation to future social challenges, research results presentation, and reflexive thinking development should be centered on the methods for organizing practice-oriented conferences according to international experience.

Creation of stable links with production and socio-economic institutions through online dialogue platforms intended to ensure the monetarization of the research results and the implementation of interdisciplinary studies (including initiative) in popular areas of economics and production in the context of social change.

The orientation to the students' microresearch on industries' needs through STEAM approaches should be regulated by guidelines for implementing problem-based learning methods during the final diploma project and course design.

As an example of the *methodological process,* the STEAM Networking Center will ensure the demand for scientific developments by changing teaching methods, increasing the publication activity of students, and involving enterprises in interdisciplinary collaboration.

Three main approaches have been identified for the *extracurricular process* of the university, also the introduction of changes to the Concept of the educational policy of the University for the development of critical thinking and willingness to cooperate among students, civic engagement, and the ability to comprehend the socio-cultural processes of society. The second one is recommendations for changing the structure and content of general disciplines: forming personal qualities and soft skills in professional development, including collaborative ability. The last approach is changing the teaching methodology of several primary and professional disciplines to develop stable value attitudes for forming responsibility, dedication to professional work, purposefulness, and self-organization.

The *management of the learning environment and social partnership process* includes the next approaches, including making changes to the Strategic Plan of the University: ensuring the integration of STEAM approaches at all levels of the main processes of the university, such as: changing the indicators of development in the annual University's Comprehensive Program for building a system of clear and measurable goals to analyze progress. The next point is the development of recommendations for preparing digital content with an emphasis on the specifics of online communications and learning methodology. As a result, the quality of online content and compliance will be improved according to international standards within the formation of a list of uniform requirements for online learning, including teaching technical disciplines, considering the Art component. Furthermore, to conduct trainings and workshops on the methodology of online learning and the development of cross-cultural collaboration, it is necessary to develop the teaching staff competencies focused on improving the quality of interdisciplinary and intercultural interaction. Finally, it is important to implement changes to the mechanisms of stimulating the motivation and self-development of teaching staff based on international experience.

Furthermore, changes in the learning process for improving the effectiveness and quality of educational services per the specifics of the disciplines taught should require a differentiated approach considering the Art component. Finally, the development of communication will promote the main university processes' rebranding for sustainable development.

Methodology for assessing the system's parameters for individual professional development should be aimed at increasing student satisfaction, focusing on increased expectations and reflection on professional development.

Proposals for changing regulations governing the activities of the alumni association will focus on solving social problems through a high level of thinking and advanced skills.

In this process, as in the previous one, CrIS is significant for innovative engineering and humanitarian literacy, professional competence based on multilevel interactions, and creative and critical thinking. Therefore, it is necessary to design minor programs as additional education in the humanities and technical profiles for developing creative skills among future technical specialists.

The recommendations for implementing the bottom-up approach in university management will determine the critical attributes of a future specialist's personal and professional activity. Along with recommendations for designing, a creative thinking team should generate the implementation of innovative ideas in education and science via the Art component.

As a result, a favorable environment to support students' educational and scientific initiatives will be formed.

The *advanced training process* as the primary approach involves the development of lifelong learning programs *"Teacher excellency"*.

The process of *infrastructure modernization* includes several approaches. The first one is the development of recommendations for making changes to the classroom fund (studio training, smart points, coworking zones) and the organization of a comfortable educational environment to increase creativity. The second one is the development of a university digital ecosystem within the framework of forming a creative academic environment to ensure the horizontal blurring method and improvement of critical thinking and metacognitive skills.

The last recommendation is for adapting students with special educational needs through the Art component in a professional environment.

7. Conclusions and Recommendations

The problem of intercultural communication and the ability to collaborate, the issues of critical thinking development, and using the creative approach to solving professional tasks remain weak in the system of engineering higher education in Kazakhstan. STEAM Education appears to serve to overcome the problem. Conducting a comprehensive study of the world experience and developing strategies for introducing STEAM into the educational process at Kazakhstani universities based on multifactor SWOT analysis made it possible to form several STEAM approaches for innovative engineering education. The processes within the identified approaches focusing on external and internal factors in the eight STEAM models served as the analysis. They ensured the exclusion of the influence of weaknesses, neutralization of threats, and the realization of the potential of the university engineering education for the Republic. It has become more apparent that applying the STEAM Education methodology in the engineering education system contributes to developing the critical competencies for the creative industry, including creativity, collaboration, communication, and critical thinking.

An analysis of the developed STEAM approaches made it possible to determine how to integrate STEAM into the main processes of the university. The analysis of the primary activities of the university was carried out based on a study of the current regulatory documents that ensure the implementation of internal academic policy, the state compulsory standard of higher and postgraduate education, as well as analytical reports, statistical data, and expert opinions. The project has resulted in proposals for updating engineering educational programs per the developed STEAM integration approaches, including the design of new disciplines with changes in the content of taught disciplines within the two pilot degree programs, "Computer Sciences" and "Mechanical Engineering". We also designed a teaching guide for introducing STEAM in engineering education, focusing on interdisciplinary collaboration. The most functional integrator combining the approaches within different university processes is establishing the Creative Industry School (CrIS) for hot spot analyses of industry issues, searching for new ideas and forming creative STEAM space. The other practical project result is the development of the STEAM Networking Center targeted to realize collaborative mechanisms in education and research.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/educsci12110737/s1.

Author Contributions: Cnceptualization, D.J.; data curation, O.S. and D.A.; formal analysis, O.S.; funding acquisition, D.J.; investigation, D.A.; methodology, O.S.; project administration, D.J.; resources, D.A.; supervision, D.J. and D.C.; validation, D.A.; writing—original draft, O.S. and D.A.; writing—review & editing, D.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Science Committee of the Ministry of Education and Science of the Republic Kazakhstan, grant number AP09260338.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Ethics Committee of Abylkas Saginov Karaganda Technical University.

Informed Consent Statement: Informed consent was obtained from all participants involved in the study.

Data Availability Statement: For further data, please contact the authors.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Creative Scotland Annual Review of Performance. 2018. Available online: https://www.gov.scot/policies/creative-industries/ (accessed on 17 September 2022).
2. IGI Global Online. What is Creative Industry. 2018. Available online: https://www.igi-global.com/dictionary/analysis-of-budapest-as-a-film-tourism-destination/72136 (accessed on 17 September 2022).
3. Daugherty, M.K. The Prospect of an "A" in STEM Education. *J. STEM Educ.* **2013**, *14*, 10–14.
4. Claymier, B. Teaching 21st Century Skills through an Integrated STEM Approach. *Child. Technol. Eng.* **2014**, *18*, 5. Available online: http://0search.proquest.com.library.uark.edu/docview/1533428628?accountid=8361 (accessed on 17 September 2022).
5. Reeve, E.M. STEM Thinking! *Technol. Eng. Teach.* **2015**, *74*, 8–16. Available online: http://0search.proquest.com.library.uark.edu/docview/1634176715?accountid=8361 (accessed on 17 September 2022).
6. McLaughlin, C.A.; McLaughlin, F.C.; Pringle, R.M. Simply Performance Assessment. *Sci. Child.* **2013**, *51*, 50–55. Available online: http://0-search.proquest.com.library.uark.edu/docview/1463730812?accountid=8361 (accessed on 17 September 2022). [CrossRef]
7. Yakman, G.; Lee, H. Exploring the Exemplary STEAM Education in the U.S. as a Practical Educational Framework for Korea. *Korea Assoc. Sci. Edu.* **2012**, *6*, 1072–1086. [CrossRef]
8. The Case for STEAM Education as a National Priority: Good Jobs and American Competitiveness. Updated June 2013. Available online: http://www.STEAMedcoalition.org/wpcontent/ (accessed on 17 September 2022).

9. Retrospective Analysis and Analysis of the Prospects for the Development of STEAM Education in the Republic of Kazakhstan. Nur-Sultan. 2021. Available online: https://caravanofknowledge.com/ (accessed on 17 September 2022).
10. Annual Report European Schoolnet. Available online: http://www.eun.org/documents/411753/817341/EUN+Annual+Report+2016_public_November2017_v3.pdf/a25dc1cc-2328-4416-a987-3138201abcf5 (accessed on 20 August 2022).
11. PISA 2018 Science Competencies for Tomorrow's World. Volume 1: Analysis. Available online: http://www.oecd.org/education/school/ (accessed on 20 August 2022).
12. Panaritis, P. Beyond brainstorming: Planning a successful interdisciplinary program. *Phi Delta Kappan* **1995**, *76*, 623–628.
13. Bass, J.E.; Contant, T.L.; Carin, A.A. *Teaching Science as Inquiry*, 11th ed.; Allyn & Bacon: Boston, MA, USA, 2009.
14. Taubaeva, S.; Maxutova, I.; Shagiyev, M. Increasing the effectiveness of educational technologies on the base of integrative potential of innovative didactics. *Pedagog. Phycol.* **2021**, *1*, 14–22. Available online: https://journal-pedpsy.kaznpu.kz/index.php/ped/article/view/165 (accessed on 12 August 2022).
15. Xing, B.; Marwala, T. Implications of the Fourth Industrial Age on Higher Education. The Thinker. 2017. Available online: https://arxiv.org/ftp/arxiv/papers/1703/1703.09643.pdf (accessed on 20 August 2022).
16. Kolesnikova, G.; Pustovalova, N. Development of students' research competences through educational project-based learning. *Pedagog. Phycol.* **2020**, *4*, 90–98. Available online: https://journal-pedpsy.kaznpu.kz/index.php/ped/article/view/125 (accessed on 24 August 2021).
17. Wang, X.; Xu, W.; Guo, L. The Status Quo and Ways of STEAM Education Promoting China's Future Social Sustainable Development. *Sustainability* **2018**, *10*, 4417. [CrossRef]
18. Chung, C.-C.; Huang, S.-L.; Cheng, Y.-M.; Lou, S.-J. Using an iSTEAM project-based learning model for technology senior high school students: Design, development, and evaluation. *Int. J. Technol. Des. Educ.* **2022**, *32*, 1–37. Available online: https://www.researchgate.net/publication/346582045 (accessed on 24 August 2021). [CrossRef]
19. Aguirre, P.S.; Vaca, V.C.; Poveda, R.S.; Moyano, E.J. STEAM Methodology, as a Resource for Learning in Higher Education. In Proceedings of the 14th International Technology, Education and Development Conference, Valencia, Spain, 17 August 2020; Available online: https://www.researchgate.net/publication/340122922_Steam_Methodology_as_a_Resource_for_Learning_in_Higher_Education (accessed on 20 August 2022).
20. Connor, A.M.; Karmokar, S.; Whittington, C. From STEM to STEAM: Strategies for enhancing engineering & technology education. *Int. J. Eng. Pedagog.* **2015**, *5*, 37–47.
21. Sosa, R.; Connor, A. !orthodoxies in multidisciplinary design-oriented degree programmes. In Proceedings of the Interplay 2 November, Brisbane, Australia, 2–5 November 2015; Available online: https://www.researchgate.net/publication/283504590_orthodoxies_in_multidisciplinary_design-_oriented_degree_programmes/link/563bb9a208ae34e98c47d092/download (accessed on 20 August 2022).
22. Coughlan, A. Learning to Learn Creative Thinking and Critical Thinking. DCU Student Learning Resources, Office of the Vice-President for Learning Innovation and Registrar. 2008. Available online: https://www.dcu.ie/sites/default/files/students/studentlearning/creativeandcritical.pdf (accessed on 20 August 2022).
23. Sarbah, A.; Otu-Nyarko, D. An Overview of the Design School of Strategic Management. Strategy Formulation as a Process of Conception. *Open J. Bus. Manag.* **2014**, *2*, 231–249. [CrossRef]
24. Selznick, P. *Leadership in Administration: A Sociological Interpretation*; Harper & Row Publishers: New York, NY, USA, 1957.
25. Wheelen, T.L.; Hunger, D.J. *Strategic Management and Business Policy, Pearson Education Limited*, 14th ed.; Pearson Education Limited: New York, NY, USA, 2015.
26. Prentice, H.; Emet, G.; Merba, T. SWOT Analysis: A Theoretical Review. *J. Int. Soc. Res.* **2017**, *10*, 51.
27. Quality Policy and Objectives of KTU [Electronic Resource]. Available online: https://www.kstu.kz/wp-content/uploads/2019/05/Politika-tseli.pdf (accessed on 1 July 2021).
28. Academic Policy of the STU. Available online: https://www.kstu.kz/akademicheskaya-politika-vuza/ (accessed on 1 July 2021).