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СТЕПГРАД

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INVESTIGATING THE ROLE OF LABORATORY RESEARCH WORK IN CIVIL ENGINEERING EDUCATION WITHIN THE EDUCATION 5.0 FRAMEWORK

Abstract:

Laboratory-based research plays a crucial role in civil engineering education by connecting theory with practice. Within the Education 5.0 framework, laboratory work supports human-centered, digital, and sustainable learning. This paper presents the conceptual development of a questionnaire for undergraduate civil engineering students. The questionnaire explores students' perceptions of laboratory research and its educational significance. Its design is grounded in learning theory, educational psychology, and engineering education literature. Data collection was planned as anonymous using a QR-code-based survey approach. The proposed questionnaire represents a flexible tool for future research and conference discussion.

Keywords: laboratory research, civil engineering education, Education 5.0, questionnaire design, experiential learning

ИСТРАЖИВАЊЕ УЛОГЕ РАДА У ЛАБОРАТОРИЈИ У ОБРАЗОВАЊУ СТУДЕНАТА ГРАЂЕВИНАРСТВА У ОКВИРУ ЕДУКАЦИЈЕ 5.0

Сажетак:

Лабораторијска истраживања играју кључну улогу у образовању студената грађевинарства повезивањем теорије са праксом. У оквиру Едукације 5.0, лабораторијски рад подржава образовање окренуто ка човјеку, дигитално, и одрживо учење. Овај рад представља концептуални развој упитника за студенте основних студија грађевинарства. Упитником се истражује став студената о лабораторијским истраживањима и његовом образовном значају. Његов дизајн је заснован на теорији учења, психологији образовања и литератури о инжењерском образовању. Прикупљање података је планирано као анонимно, коришћењем приступа истраживању заснованог на QR-коду. Предложени упитник представља флексибилан алат за будућа истраживања и дискусију на конференцији.

Кључне ријечи: лабораторијско истраживање, студије грађевинарства, едукација 5.0, креирање упитника, искуствено учење

1. INTRODUCTION

Laboratory research and experimental work have long been recognized as fundamental components of engineering education, particularly in disciplines such as civil engineering, where physical phenomena, material behavior, and structural response are core elements of professional practice. Traditional lecture-based teaching methods are effective for introducing theoretical concepts; however, they often remain abstract and detached from real-world engineering problems. From both pedagogical and psychological perspectives, this separation can limit students' ability to construct meaningful knowledge and sustain learning motivation.

Educational psychology emphasizes that learning is most effective when students are actively engaged, cognitively involved, and able to relate new information to prior experience. Experiential Learning Theory (experience as the source of learning and development) conceptualizes learning as a cyclical process in which concrete experience and active experimentation play central roles [1]. Laboratory environments directly support this process by allowing students to manipulate variables, observe outcomes, and reflect on inconsistency between expected and observed results. Such experiences are particularly important in civil engineering, where understanding uncertainty, variability, and the real behavior of materials is essential for professional competence.

In addition to cognitive aspects, motivational psychology provides strong arguments for laboratory-based instruction. According to Self-Determination Theory (SDT), students' motivation is enhanced when learning environments support autonomy, competence, and relatedness [2]. Laboratory work often fulfills these conditions by giving students a sense of control over experimental procedures, opportunities to demonstrate competence through problem-solving, and collaborative interaction with colleagues. These psychological factors contribute to deeper engagement and more durable learning outcomes than passive instructional formats.

In recent years, higher education has undergone a significant transformation driven by digitalization, societal challenges, and evolving labor market demands. Within this context, the concept of Education 5.0 is closely linked to Society 5.0 and Industry 5.0. This education focuses on preparing students for a future where technology and human values are seamlessly integrated [3].

Education 5.0 has emerged as an extension of previous educational paradigms, emphasizing human-centered learning, interdisciplinarity, sustainability, ethical responsibility, and the integration of advanced digital technologies [3,4]. Engineering graduates are now expected not only to possess strong technical knowledge but also to demonstrate critical thinking, teamwork, communication skills, and social awareness.

Laboratory research work aligns closely with both psychological learning theories and the principles of Education 5.0. Through inquiry-based and collaborative laboratory activities, students actively construct knowledge, develop self-efficacy, and engage in reflective thinking while simultaneously acquiring digital, ethical, and sustainability-related competencies [5,6].

Despite the recognized educational and psychological benefits of laboratory work, there remains a need for systematic research instruments that can capture students' perceptions of their value in contemporary engineering education. Research instruments are tools used to gather, measure, and analyze data in research studies. These instruments are crucial for obtaining accurate and reliable information, which forms the basis for drawing valid conclusions and making informed decisions.

For this research, the chosen research instrument is a questionnaire. The aim of this paper is therefore to present the conceptual development of a questionnaire designed to assess undergraduate civil engineering students' perceptions of laboratory research work, its role in learning processes, and its contribution to competency development within the Education 5.0 framework. The paper focuses on the methodological aspects of questionnaire design, which is the first step of this research.

Laboratory-based learning is widely discussed in the broader research on active and experiential learning in engineering education. Experiential Learning Theory (ELT) explains how learners transform experience into knowledge through iterative cycles of experiencing, reflecting, conceptualizing, and experimenting—an especially appropriate model for laboratory instruction [1]. In engineering programs, active learning approaches have repeatedly been associated with improved conceptual understanding and student engagement when compared with purely lecture-based formats [6].

In civil engineering education, laboratories provide a setting in which students can observe material behavior, structural response, measurement uncertainty, and the constraints imposed by real testing procedures. Such experiences help students connect idealized theoretical models to physical reality and develop engineering judgment. In addition to supporting outcomes, laboratory work also provides opportunities for collaborative, inquiry-based tasks that resemble authentic engineering workflows.

Problem-based and project-based learning (PBL) research offers additional insights relevant to laboratory pedagogy. PBL emphasizes learning triggered by complex problems and sustained investigation, often in teams. A widely cited synthesis highlights core PBL characteristics that align with laboratory environments, including student-centered work, facilitation rather than direct instruction, and integration of knowledge across subject areas [5]. In the civil engineering context, laboratory tasks can be designed as mini projects (e.g., material characterization, structural testing) that require planning, data collection, analysis, and reporting.

From a curriculum and accreditation standpoint, modern engineering programs are increasingly expected to demonstrate outcomes related not only to technical competence but also to communication, teamwork, and professional responsibility. Guidance on aligning course design and assessment with engineering accreditation outcomes further underscores the need for learning experiences that go beyond passive knowledge reception [7]. Laboratories are one of the most direct means of operationalizing such outcomes through observable performance and deliverables.

Finally, contemporary discourse on Education 4.0 and Education 5.0 positions higher education within wider socio-technical change, emphasizing digitalization, human-centered learning, and societal relevance [3,4]. For civil engineering students, laboratory environments can serve as a practical space for developing data literacy, proficiency with digital tools, and awareness of sustainability and ethical issues related to measurement accuracy and responsible decision-making—competencies frequently highlighted in Education 5.0 discussions [3].

2. METHODOLOGY

2.1. RESEARCH DESIGN

The research adopts a qualitative–quantitative methodological framework focused on the development of a structured questionnaire as a research instrument. Questionnaire-based research is widely used in studies of engineering education to capture students' perceptions, attitudes, and self-reported learning outcomes [8]. The primary objective of this study is not to test hypotheses but to design a theoretically grounded instrument suitable for future empirical investigations.

The questionnaire was developed following a multi-step process that included: (i) analysis of existing scientific literature on laboratory-based learning and engineering education, (ii) identification of key learning dimensions relevant to Education 5.0, and (iii) formulation of obvious questionnaire items aligned with these dimensions.

2.2. THEORETICAL FRAMEWORK

The theoretical foundation of the questionnaire is based on experiential learning theory, which emphasizes that learning occurs through concrete experience, reflective observation, abstract conceptualization, and active experimentation [7]. Laboratory work naturally supports this learning cycle by allowing students to engage directly with engineering phenomena.

In addition, the Education 5.0 framework was used to define competency domains addressed by the questionnaire. These domains include critical thinking, problem-solving, teamwork, communication skills, digital literacy, sustainability awareness, and ethical responsibility [3,6]. By integrating these dimensions, the questionnaire reflects contemporary expectations of civil engineering education.

2.3. PARTICIPANTS AND EDUCATIONAL CONTEXT

The target population for the questionnaire will be undergraduate students enrolled in bachelor 's-level civil engineering programs. The instrument is designed to be applicable across years of study, recognizing that students' experiences with laboratory work may vary with their academic progression. This approach allows future studies to compare perceptions between early- and late-stage students.

2.4. DATA COLLECTION PROCEDURE

The questionnaire is an anonymous web-based survey. Access is provided through a QR code distributed during lectures and laboratory sessions at the selected courses. The use of QR codes facilitates easy access, increases response rates, and aligns with digital practices commonly adopted in modern higher education environments [9]. Participation is voluntary, and no personal identifiable information is collected, ensuring ethical compliance with research standards.

2.5. FORMAT OF THE QUESTIONNAIRE

The questionnaire items are formulated as statements that elicited attitudes and perceptions regarding laboratory work. For each statement, students have the option to select the response option or options that best reflect their personal standpoint. Respondents are not restricted to a single choice and are allowed to mark multiple answers when they feel that more than one option accurately reflects their views. In this way, participants indicated the responses that best described their attitudes and perceptions without imposed limitations.

This flexible response format is appropriate for exploratory, perception-oriented educational research, as it captures the complexity of students' viewpoints and enables analysis of response frequencies and co-occurrence patterns.

3. QUESTIONNAIRE STRUCTURE

The questionnaire is organized into six sections: basic information; perception of laboratory work; comparison of laboratory work and lectures; impact on competency development within Education 5.0; organization and quality of laboratory work; and open-ended questions. The full English version of the questionnaire is provided below.

Questionnaire (English Version)
The Role of Laboratory Research Work in Civil Engineering Education
Instructions:
The questionnaire is anonymous. The responses will be used exclusively for scientific research purposes.
For each statement, please select the response option or options that best reflect your views. You may choose more than one answer if applicable.
A. Basic Information
A1. Year of study:
( ) 1st ( ) 2nd ( ) 3rd ( ) 4th
A2. Have you participated in laboratory exercises or research projects during your studies?
( ) Yes, only mandatory laboratory exercises
( ) Yes, both mandatory exercises and additional research projects
( ) No, very little or not at all
A3. How often do you attend traditional lectures (in-person or online)?
( ) Almost always
( ) Often
( ) Occasionally
( ) Rarely
B. Perception of Laboratory Work
B1. Laboratory work helps me better understand the theoretical content covered in lectures.
B2. I remember course material more easily when I observe it directly through experiments or measurements.
B3. Through laboratory work, I have gained a better understanding of how real civil engineering structures and systems function.
B4. I feel more actively engaged in the laboratory than in traditional lectures.
B5. Laboratory exercises stimulate my curiosity and desire for further exploration.
B6. Laboratory work helps me connect different courses (e.g., mechanics, materials, structures).
B7. I consider time spent in the laboratory to be as important as time spent in lectures.
B8. After laboratory exercises, I have a clearer understanding of why what we learn is relevant for professional practice.
C. Comparison of Laboratory Work and Traditional Lectures
C1. In traditional lectures, I am mostly passive, while in the laboratory, I am an active participant.
C2. In the laboratory, I have more opportunities to ask questions and engage in discussion than in lectures.
C3. Laboratory work gives me greater confidence than traditional lectures.
C4. Compared to lectures, laboratory work better helps me understand how theory is applied in practice.
C5. For me, laboratory work is a more effective learning method than traditional lectures.
C6. If I had to choose, I would prefer courses with a strong laboratory component rather than those consisting solely of traditional lectures.
C7. After laboratory exercises, I find it easier to follow and understand lecture content.

D. Impact of Laboratory Research on Competency Development (Education 5.0)
D1. Laboratory work has contributed to the development of my critical thinking skills.
D2. Laboratory work has improved my problem-solving skills in an engineering context.
D3. In the laboratory, I have learned to work more effectively as part of a team with my peers.
D4. Laboratory projects have improved my communication skills (presentation of results, report writing).
D5. Through laboratory work, I have enhanced my digital skills (data processing, software use, sensors, measurements).
D6. Laboratory work has prompted me to consider sustainability and the societal implications of engineering decisions.
D7. Through laboratory activities, I have become more aware of ethical issues such as data accuracy and responsibility for results.
D8. Laboratory work has motivated me to pursue further research or academic work (e.g., Master's studies, PhD, projects).
D9. I believe that laboratory work prepares me better for future challenges in the Education 5.0 era (digitalization, automation, human-centric approach) than traditional lectures.
E. Organization and Quality of Laboratory Work
E1. In the laboratory, I receive sufficiently clear instructions about the tasks to be performed.
E2. Teachers and teaching assistants in the laboratory are open to questions and supportive of our ideas.
E3. I believe we have sufficient time to conduct experiments carefully and analyze the results.
E4. The laboratory equipment and software we use are modern and relevant for professional practice.
E5. I would like to have more laboratory exercises and research projects during my studies.
F. Open-Ended Questions
F1. What do you think laboratory work can provide that traditional lectures cannot (or only to a lesser extent)?
F2. What changes in laboratory organization would further improve your learning (more time, different tasks, more digital tools, work in smaller groups, etc.)?

4. DISCUSSION

The structure and content of the questionnaire were deliberately designed to reflect both pedagogical and psychological dimensions of laboratory-based learning in civil engineering education. The selection of questionnaire items was guided by the aim to capture students' perceptions of laboratory work as a learning environment that supports cognitive understanding, engagement, and competency development, rather than merely assessing satisfaction or preferences.

The items addressing the perceived contribution of laboratory work to understanding theoretical concepts were included to reflect core assumptions of experiential learning theory, which holds that knowledge construction is strengthened when abstract concepts are linked to concrete experience. In civil engineering education, where theoretical models often simplify complex physical behavior, it is particularly important to examine whether students perceive laboratory activities as helping them bridge this gap between theory and practice.

Questions focusing on student engagement and active participation were motivated by findings from educational psychology and active learning research, which emphasize that meaningful learning is closely related to students' sense of involvement and agency. By comparing laboratory work with traditional lectures, the questionnaire aims to explore whether students perceive laboratories as environments that support greater autonomy, interaction, and confidence—factors known to influence motivation and persistence in learning.

A distinct set of items was dedicated to developing transversal competencies associated with the Education 5.0 framework, including critical thinking, problem-solving, teamwork, communication, digital skills, sustainability awareness, and ethical responsibility. These questions were included to acknowledge that the educational value of laboratory research extends beyond technical knowledge. In laboratory settings, students are often required to collaborate, interpret data, use digital tools, and reflect on the broader implications of engineering decisions, making such competencies particularly visible and relevant.

Items related to the organization and quality of laboratory work were incorporated to contextualize students' perceptions and to recognize that the effectiveness of laboratory learning depends not only on content but also on instructional design, available resources, and teaching support. Understanding how students perceive clarity of instructions, time allocation, and the relevance of equipment can inform future improvements in laboratory teaching practices.

Finally, the inclusion of open-ended questions was intended to provide space for students to articulate perspectives that predefined response options may not fully capture. This qualitative component enables the identification of emerging themes, unanticipated issues, and concrete suggestions for improvement, thereby enhancing the instrument's exploratory value.

Overall, the choice of questionnaire items reflects an integrated view of laboratory research work as a multifaceted educational experience. The discussion highlights how the instrument aligns with established learning theories, educational psychology, and contemporary expectations for civil engineering education within the Education 5.0 framework, thereby supporting its suitability for future empirical studies.

5. CONCLUSION

Because of all the above, laboratory work can be considered a very important component of the formation of future civil engineers. Well-designed laboratory work can be a binder that connects what has been learned and can make an invaluable contribution to the professionalization of engineers. Therefore, this work, which presents the conceptual development of a questionnaire to assess the role of laboratory research in undergraduate civil engineering education contributes to raising awareness of the role of laboratory work in Education 5.0. By grounding the questionnaire in existing literature and the Education 5.0 framework, the study provides a solid methodological foundation for future conference and journal research. The questionnaire may be adapted to other engineering disciplines and educational contexts.

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