

PAPER

Enhancing University Education Quality through MOOCs: Effective Learning Strategy Combinations and Pedagogical Innovations

Tamás Köpeczi-Bócz()University of Tokaj,
Sárospatak, Hungarykopeczi.bocz
tamas@unithe.hu**ABSTRACT**

This study examines the impact of combining innovative teaching strategies, including massive open online courses (MOOCs), to enhance the quality of university education. It focuses on the interplay between active learning methods and student-centered pedagogy, exploring how the integration of MOOCs with interactive, student-driven instruction fosters increased engagement and improves learning efficacy. A mixed-methods approach was employed, combining quantitative measures of academic outcomes with qualitative assessments of student motivation, participation, and satisfaction. Results indicate that the strategic combination of MOOCs and active methodologies creates a more engaging and practical learning environment, promoting deeper learning and greater involvement. The study also highlights key challenges and opportunities in applying these approaches, offering valuable recommendations for educators. Findings suggest that such innovative practices can significantly improve educational quality, supporting higher levels of student performance and better preparing graduates for professional success. These insights hold important implications for higher education policies aimed at transforming teaching methods and enhancing institutional effectiveness.

KEYWORDS

university education quality, student engagement, pedagogical innovation, massive open online courses (MOOCs), active learning, learning efficacy, educational policy

1 INTRODUCTION

The quality of education, or “Quality Education” is perceived in many different educational research discourses. The evolution of the concept from ancient philosophical insights to contemporary educational theories illustrates how its definition changes in different historical and cultural contexts. Some have argued that quality education is an elusive concept that can take on different meanings and values and that it appears at many levels of any educational system, from early childhood

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education to postgraduate levels [1]. In my view, quality education is a very tangible concept. *The quality of education is an added value measured in terms of an individual's personal and career success.* The only catch is that it is necessary to predict the success of a future performance in the present, which in reality is almost impossible, but is nevertheless a goal to strive for. What is certain, however, is that if at the end of the training students do not have the skills, they need to build a personal and professional career, the quality of education is questionable, to say the least. There is a research consensus that students trained using traditional teaching methods often lack the skills needed to succeed in their careers [2], and therefore, continuous and multi-directional research on this topic is both warranted and timely.

However, if we are to get to the root of the problem, we need to focus not on the development of individual skills but on enabling the development of the most important skill, the ability to learn, to the highest possible level. For example, [3] emphasize the multifaceted nature of inspirational teaching in higher education. In their work, they reveal that inspirational teaching is not just about the content delivered but also significantly involves teacher-student relationships, curriculum design, and the learning environment. The key lesson is that effective teaching goes beyond mechanical skills and requires a blend of knowledge, personal qualities, and a conducive learning environment.

It is therefore worthwhile to conduct educational experiments that provide a diverse learning environment and to explore the notion of quality education in this environment. *One important measure of quality, measured in terms of learning responses, is students' engagement, or motivation, in the subject matter.* It will therefore be appropriate to investigate the extent to which the learning process itself is perceived as effective by the students themselves and to what extent this effectiveness can be measured.

The rich data provided by blended learning environments will allow formal assessment frameworks to flourish, which will help to improve the effectiveness of the learning process. New methods of blended learning, such as flipped classrooms (FC), gamification, personalized learning, and their counterparts, offer significant opportunities to enrich the learning experience [4]. When exploring the concept of quality education in diverse learning environments, measuring student motivation and the effectiveness of the learning process is of paramount importance. Different teaching methods, such as FC and project-based learning (PBL), can provide a more relevant learning experience, increasing learning motivation [5]. One meta-analysis [6] found that the FC approach has a positive impact on students' self-efficacy in different educational environments, increasing learning engagement. In our research, we complement our experience with the FC method by exploring additional methods to enhance learning experience and motivation. In their study, [2] investigate the effectiveness of face-to-face, online, and blended learning modes, showing that the quality of content remains consistent, while significant differences are observed in facilitation and learning effectiveness. Facilitation, which includes program structure, active participation of participants, and feedback received during the course, is significantly higher in blended learning, especially compared to face-to-face learning [2].

The FC paradigm can significantly improve student motivation, especially for extroverted and reflective learners who can benefit the most from this method [7]. For all of these, universities have now developed institutionalized support and monitoring systems. Higher education institutions ensure the quality of teaching through independent evaluations implemented as part of an internal quality assurance system, which are key to the objective measurement of learning outcomes and the continuous development of a quality culture.

Quality assurance is a priority in higher education, as supported by research conducted by [8]. This study investigated the effectiveness of combining massive open

online courses (MOOCs) with traditional teaching methods. The results show that the integration of MOOCs into traditional courses can help improve learning outcomes and increase student motivation, which is in line with the goals of institutionalized quality assurance systems. This research shows that the integration of MOOCs in higher education offers the potential to enrich learning experiences and enhance motivation.

Our study took place in an educational setting where FC is commonplace and thus already considered a traditional teaching method. Experiences in this area were based on continuous measurement. We have had a long experience of careful course design as a means of optimizing effectiveness. However, we are looking for related methods that can enhance the learning experience and thus motivation. Sharma and Shree [2] investigated the comparative effectiveness of face-to-face, online, and blended learning modes in higher education. They also confirm our observation that the quality of content remains consistent across these modes, but significant differences are observed in terms of facilitation, perceived value, and learning effectiveness. This suggests that although the way in which content is delivered may vary, the key to successful learning outcomes lies in the facilitation of courses and the perception of students. *For this reason, the importance of self-evaluation is also increasing.* For example, in South-Eastern European countries, student satisfaction surveys are preferred as an alternative approach to assess the quality of higher education [9].

Recognizing the problem of disconnection from reality in university education, an alternative 'learning through practice' approach can help to achieve meaningful interaction between pure and applied ideas [10].

Therefore, we include in our experiments the possibility of collaborating in real-life situations using project-based learning (PBL), which can lead to an increase in learning motivation. The aim of our research is to investigate the effect of combining FC and PBL on learning motivation. Our first research question **(Q1)** investigates whether combining FC and PBL increases motivation and performance.

Among the factors that influence motivation to learn, interest, engagement, optimism, and a suitable learning environment are prominent. Intrinsic motivation is significant because students' intrinsic drive, goals, and ambitions are fundamental to their learning success [11].

According to one study [5], the PBL makes a significant contribution to student learning outcomes. "The incorporation of project-based tasks allows for the creation of real-life experiences, which further encourages the development and growth of real-life competencies."

The use of PBL in university courses has a significant impact on students' academic success and contributes to the development of their professional judgment. Technology-enhanced PBL allows students to experience real-life situations that promote interdisciplinary collaboration and teamwork [12].

(Q2) With our second research question, we investigate whether this combined learning approach makes a measurable difference in performance at different levels of university education? [13] investigates students' motivation, resilience, and perceived competence in different classroom environments, highlighting the effects of class size and instructor profiles. Differences in training, even by level of training, will not be interpretable without knowledge of the work invested by the instructor.

Great teachers are not born but made through constant efforts to improve their knowledge and skills. An important characteristic of a great teacher is a deep understanding of the teaching-learning process, which helps them to appreciate both their profession and the process of teaching. These colleagues consistently advocate that learning is a transformation that occurs through the acquisition of new knowledge, understanding of empirical laws, or a change of mind [14].

Teachers' enthusiasm leads to a higher level of learning experience, positive attitudes towards staff, increased student achievement, and a more stable learning environment. FC and PBL do not diminish but rather enhance these teacher roles as they require continuous interaction during the learning process. However, it must also be acknowledged that the combined method we are investigating requires a significant amount of extra work from teachers. This work should be recognized and supported by universities, for example, in the context of the overall objective of "Teaching Excellence."

Supporting teachers' teaching methods in practice, continuous innovation, and the joint development and testing of new knowledge with students. In this context, knowledge research is a dialogue-based, organic process in which all participants focus on finding the most effective solutions [15].

In the 4th Industrial Age (4th IA), educational institutions need to adapt to new technological developments such as artificial intelligence and the use of big data. These developments require a continuous review of pedagogical approaches to ensure that university students can achieve sustainable learning in an uncertain future [16].

Therefore, the question of effectiveness, i.e., the return on the work invested, arises. **(Q3)** In our third research question, we seek to answer the question of how effectively training can be implemented using the combined FC and PBL method.

2 MATERIALS AND METHODS

2.1 Methodology for participant selection, data collection and analysis

The experiment was carried out in the framework of the University of Tokaj courses in Entrepreneurship Development Master of Science (MSc), Wine Viticulturist Engineer Bachelor of Science (BSc), and Wine Viticulturist "Assistant Engineer" higher vocational education and training¹ (HVET), taught in two academic years in the field of innovation. We conducted experiments in six groups during two academic years (2021/22; 2022/23).

Data were collected by assessing participants' subject performance (on a scale of 1–5) and by self-reflection and analysis of their motivation to learn (on a scale of 1–5). Data were collected separately by level of education and by academic year. The data were not evaluated by project group, as there were no project groups in the control group, but by training level. Subject progress was obtained from the electronic record system used at the university.

The learning motivation of the students in the experimental groups was measured using a four-pillar method to produce discrete data that could be evaluated, also on a scale of 1–5 (1 = worst, 5 = best).

Based on the data of the students taught with traditional FC methods as a control group and the experimental group supplemented with PBL, the effectiveness of the learning process and the change in learning motivation were examined using statistical methods.

T-tests were used to compare the differences in learning outcomes and motivation to learn between the two groups at each of the three levels of education.

However, due to the low number of elements, we considered it important to carry out an effect size test so that we could determine the extent of the difference between the two methods.

¹ HVET: This stands for "Higher Vocational Education and Training." It refers to post-secondary education that is more focused on practical skills and vocational training, often leading to professional qualifications that are less academic and more job-specific than a bachelor's or master's degree.

It was a logical methodological step to carry out a meta-analysis alongside the statistical analysis.

We then carried out a textual analysis and answered the research questions.

2.2 Specific aspects of the research design and study methods

In the experiment, measuring student motivation was the most difficult operation to perform. We developed a four-pillar method that integrates the features of the intrinsic motivation inventory (IMI), the Ryff psychological well-being scale (RPWS) [17], and the short flow state scale (SFSS).

The four pillars are understood as an evaluation process, so sequencing was also important.

1. Self-reflection: Self-reflection allowed students to assess their intrinsic motivation and well-being. This method was combined with features of the IMI and RPWS measurement tools to help students reflect on their own motivation and feelings, thus encouraging them to learn. In our experience, self-analysis has proved useful. It helps students to learn. Students complete a self-analysis task to analyze their own soft and communication skills. Through this analysis, students understand their strengths and weaknesses [18].

2. 360-degree peer assessment: Student interactions and group dynamics were assessed using the RPWS and SFSS analysis methods. This feedback helped us to get an overall picture of the interaction between students and their motivation.

Methods used:

- Team analysis: to observe and evaluate students' ability to cooperate in group tasks, including their level of engagement, contribution and cooperation in achieving common goals;
- Peer assessment: provides students with the opportunity to evaluate their peers' contribution to group work through objective and constructive assessments;
- Self-assessment and peer assessment: provides opportunities for students to reflect on and assess their own progress and development, as well as the progress and development of their peers in the affective domain [19].

3. Teaching experience: In line with the IMI and RPWS methods, students' performance and behavior was monitored over time. This allowed the identification of students' motivational patterns. An attempt was made to monitor students' performance and behavior through a two-phase structured process in line with the IMI and RPWS methods [20]. In the first phase, students were categorized according to pre-defined criteria (level of education, age, previous learning performance) that took into account learning motivation and behavioral patterns. We then used a pilot assessment tool to further refine and rank the students' data based on their performance and behavioral patterns.

In the second phase, students participated in a supplementary assessment process, during which the most recent performance data were collected and analyzed. Based on the results of these analyses, students were assigned a final ranking (i.e., a rating of 1–5) reflecting their motivation to learn and their behavioral patterns.

We also tracked students' progress over time in real time, comparing their initial rankings with their subsequent performance. This allowed us to evaluate the effectiveness of our method and changes in each student's learning motivation patterns.

4. Workflow observations and participation tracking: Elements of the SFSS methodology were used to identify ‘flow’ states and active participation. This helped to track changes in students’ motivation levels and engagement over time. Taking into account the nine components of Csikszentmihalyi et al.’s (1988) ‘flow’ states, we assessed ‘flow’ states in our research based on five components: attentional focus, loss of self-awareness, sense of control or competence, intrinsic enjoyment, and perception of clear goals. We also took into account the experiences of other experiments in the professions [21]. These components helped us to observe and assess the ‘flow’ state in the students’ submitted work and in the comments and cover letters that accompanied it. The quality of the students’ comments and the quality of their work can be used to determine which of them experienced these ‘flow’ components during the learning process.

Due to the limitations of using a simple self-assessment questionnaire, we decided to use this more complex, multidimensional approach. Although the self-assessment questionnaire provides a quick and simple solution, it is prone to respondent bias and does not provide as detailed information as the above methods combined. The results were obtained by numerically correcting the student ratings received on a scale of 1–5. 1, 3, and 4 instruments were used for the control group.

As you can see, we have done qualitative analysis that goes beyond the numbers. This helped us to understand the impact of the two methods on the teaching process, motivation, or learning experience.

We have also carried out further in-depth analysis of the scores, for example, analyzing changes in the results over time, and we have taken other external factors into account when drawing conclusions and limitations.

These types of analyses are often used by the Campbell collaboration’s education coordination group (ECG), which conducts systematic reviews and meta-analyses that allow researchers to get a more accurate picture of the effects of interventions. It was by studying these papers that we conducted our meta-analysis design. We did this because the methodological quality of Campbell’s reviews of systematic reviews in the social sciences, including education, was good compared to other reviews [22]. Specifically, 59 percent of Campbell reviews were of high or medium quality based on AMSTAR 2 [22].

In the social sciences, meta-analysis is widely used to analyze the effectiveness of educational interventions, psychotherapeutic methods, and social programs. It allows researchers to synthesize and analyze a wide range of data from different studies, contributing to informed policy decisions and practical recommendations.

Our qualitative meta-analysis seeks to examine the extent to which the most recently published qualitative research and the findings we find actually contribute an additional paradigmatic perspective to offer a deeper understanding of complex phenomena” [23].

Overall, meta-analysis allows the scientific community to go beyond the limited scope of individual studies and provide a more comprehensive assessment based on larger datasets, which contributes to increasing the accuracy and reliability of scientific findings.

2.3 Ensuring the authenticity and validity of our data

A complex data-cleaning protocol was used in the motivational data analysis process to ensure validity and reliability. This protocol consisted of several steps based on best practices in scientific research methodology. The main steps were **data screening**, identification of **outlier** values, **outlier analysis** [24], data deletion

or separate analytics, and finally **data validation**. All this included checking the consistency and completeness of the data and assessing their consistency with the research objectives.

3 RESULTS

3.1 Detailed presentation and statistical analysis of the research results

During the experiments, project groups were formed, led by MSc students, who worked together with BSc and HVET students to develop their own innovative project plans based on their own data collection and research to improve the innovation capacity of winegrowing and winemaking enterprises. The project group consisted of 5–6 people, 1 main MSc student leader, 1–2 technical coordinators who were BSc or HVET students, and 3–4 HVET students collecting data. The training was therefore project-based, based on the “traditional” FC method. Before the contact hours and during the semester, online training was continuously provided through Teams and Moodle. In the two academic years, there were also 3–3 control groups where only the FC method was used, but no project-based task-solving took place.

$$n_{\text{total}} = 66; n_{\text{experimental}} = 31; n_{\text{control}} = 35$$

The steps of the statistical analysis are shown in Figure 1. After cleaning and organizing the data, the calculations were carried out in three phases, followed by a meta-analysis to present the results.

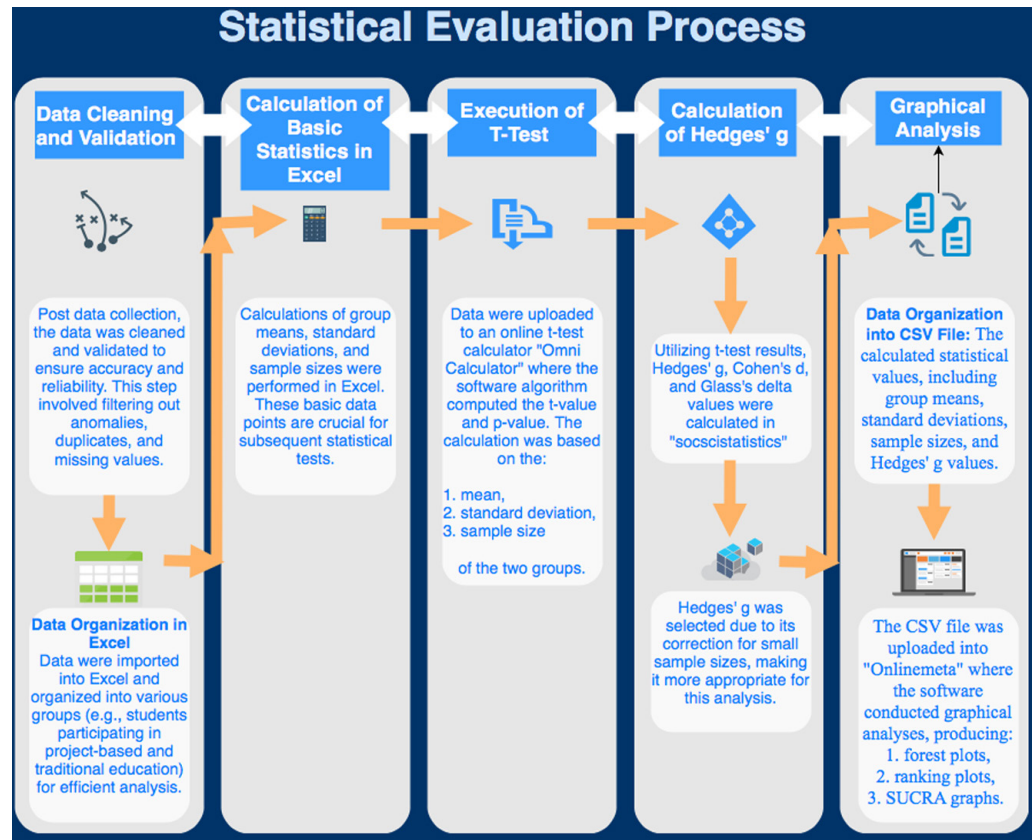


Fig. 1. Steps of statistical analysis

1. **Data cleaning and validation:** Post-data collection, the data was cleaned and validated to ensure accuracy and reliability. This step involved filtering out anomalies, duplicates, and missing values.
2. **Data organization in Excel:** Data were imported into Excel and organized into various groups (e.g., students participating in project-based and traditional education) for efficient analysis.

These two phases (1, 2) can be followed in the left column of Figure 1.

3. **Calculation of basic statistics in Excel:** Calculations of group means, standard deviations, and sample sizes were performed in Excel. These basic data points are crucial for subsequent statistical tests.
4. **Execution of T-Test using online software:** Data were uploaded to an online t-test calculator (<https://www.omnicalculator.com/statistics/t-test>) where the software algorithm computed the t-value and p-value. The calculation was based on the mean, standard deviation, and sample size of the two groups. The formula used was as follows:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \quad (1)$$

where, \bar{X}_1 and \bar{X}_2 are the means of the two samples, s_1^2 and s_2^2 are the variances of the two samples, and n_1 and n_2 are the sample sizes.

Statistical evaluation of the t-test results

I. Between MSc and MSc Control:

- T-statistic: -1.746
- P-value: 0.1000
- The p-value is higher than the usual threshold for significance (typically 0.05), indicating that the difference between the two groups is not statistically significant.

II. Between BSc and BSc Control:

- T-statistic: -5.555
- P-value: 0.0001248
- The extremely low p-value indicates that the difference between the two groups is statistically significant. The negative t-statistic suggests that the BSc group achieved better average results than the BSc control group.

III. Between HVET and HVET Control:

- T-statistic: -2.051
- P-value: 0.0485
- The p-value is close to the conventional threshold for significance, suggesting that the difference between the two groups is statistically significant. The negative t-statistic suggests that the HVET group achieved better average results than the HVET Control group.

In summary, there are significant differences between the BSc-BSc control and HVET-HVET control pairs, with the 'non-Control' groups performing better in both cases. However, no statistically significant difference was found between the MSc-MSc control pairs.

5. **Calculation of Hedges' g, Cohen's d, and Glass's delta:** Utilizing t-test results, Hedges' g, Cohen's d, and Glass's delta values were calculated in another online tool (<https://www.socscistatistics.com/>). Hedges' g was selected due to its correction for small sample sizes, making it more appropriate for this analysis.

We will apply Hedges' g analysis after the t-test results because this method provides an accurate and corrected estimate of effect size when comparing experimental and control groups, especially concerning potential biases arising from small sample sizes. While the t-test determines statistical significance, it does not provide any insight into the size of the difference or its practical relevance. Hedges' g , however, quantifies the size of the difference and compensates for the bias caused by small sample sizes, thus offering a more reliable tool for assessing the real-world significance of research effects.

The Hedges' g formula is:

$$g = \frac{\bar{X}_1 - \bar{X}_2}{s_p} \times \left(1 - \frac{3}{4(n_1 + n_2) - 9} \right) \quad (2)$$

where, \bar{X}_1 and \bar{X}_2 are group means, s_p is the pooled standard deviation, and n_1 and n_2 are the sample sizes.

MSC. Group I (learning outcomes and motivation change):

- Results: There is no significant difference in the results of the MSc group between project-based (mean: 4.875) and non-project-based (mean: 4.700) education.
- Change in motivation: There is a small but not significant difference in the change in motivation between project-based (mean: 4.600) and non-project-based (mean: 4.4286) education.

BSc Group II (learning outcomes and motivation change):

- Results: There is a significant difference in the results of the BSc group between project-based (mean: 4.700) and non-project-based (mean: 3.8571) education.
- Change in motivation: there is a medium difference in the change in motivation between project-based (mean: 4.2500) and non-project-based (mean: 2.8333) education.

HVET Group III (learning outcome and motivation change):

- Results: There is a medium difference in the results of the HVET group between project-based (mean: 4.6471) and non-project-based (mean: 4.1176) education.
- Change in motivation: There is a small difference in change in motivation between project-based (mean: 4.1765) and non-project-based (mean: 3.4706) education.

These results suggest that project-based training was particularly effective for the BSc group, both in terms of results and motivational change. The differences were less significant for the MSc and HVET groups. The effect size test also confirmed our post-test T-test findings, and Hedges' g analysis confirmed and overcame the validity deficit due to the small number of items.

For the analysis based on Hedges' g data, we could not fully take into account the large amount of written material recorded for the control group, so we would be evaluating the effect sizes for the groups under study without being able to take into account all of their observations (compared to our other analyses). For a more complete analysis of our results (which we also consider as a basis for scientific discourse), a meta-analysis was carried out. This phase allows us to put the results in a broader context, to evaluate the effects on a larger analytical base, and to increase the reliability and generalizability of the conclusions.

These three phases (3, 4, 5) can be traced in the three middle columns of Figure 1.

6. Data organization into CSV file: The calculated statistical values (CSV), including group means, standard deviations, sample sizes, and Hedges' g values, were organized into the following CSV file format.

Table 1. Organized DATA in CSV file

Treatment	trt_class	Mean	Std.Dev	n
MSC	RESULT GROUP NON PORJECT	4.7000	0.4583	10
BSC	RESULT GROUP NON PORJECT	3.8571	0.6389	7
HVET	RESULT GROUP NON PORJECT	4.1176	0.9630	17
MSC	RESULT GROUP PORJECT	4.8750	0.3307	8
BSC	RESULT GROUP PORJECT	4.7000	0.4583	10
HVET	RESULT GROUP PORJECT	4.6471	0.5882	17
MSC	MOTIVATION CHANGE NON PROJECT	4.4286	0.7284	14
BSC	MOTIVATION CHANGE NON PROJECT	2.8333	0.6872	6
HVET	MOTIVATION CHANGE NON PROJECT	3.4706	1.1437	17
MSC	MOTIVATION CHANGE PROJECT	4.6000	0.4899	10
BSC	MOTIVATION CHANGE PROJECT	4.2500	0.4330	8
HVET	MOTIVATION CHANGE PROJECT	4.1765	0.6169	17

The CSV file in Table 1, was uploaded to another online tool (<https://smuonco.shinyapps.io/Onlinemeta/>), where the software conducted graphical analyses, producing forest plots, ranking plots, and SUCRA graphs. These visualizations provided an understandable representation of the effects and rankings among different groups.

This process ensures the validity and reliability of the research, enabling precise and comprehensive analysis of the data.

These two phases can be followed in the right-hand column in Figure 1.

3.2 Interpreting the results in terms of motivation to learn

An extended evaluation of the results of our research can be summarized as follows:

The effects of the combination of FC and PBL on students' motivation to learn are particularly significant at the BSc and HVET levels. The combination of project-based tasks and teaching with FC has a motivating effect on students, especially when MSC students take an active role in the learning process. Students showed higher interest and engagement in the course material, which resulted in increased motivation to learn. The opportunities for practical applications and project work had an inspiring effect on the students, which played a role in making the learning process more experiential and engaging.

In light of these results, further integration of FC and PBL in university teaching could have significant benefits for the development of students' motivation to learn. This integrated approach allows students to actively participate in the learning process, combining theoretical knowledge with practical application. The results of our

study confirm that this combined teaching method is an effective way to support student motivation and improve the quality of education.

4 DISCUSSION

4.1 Summarize the results and conclude the findings

Researchers [25] suggest several methods to increase motivation among higher education students. Three of these have been examined as follows:

1. Encouraging positive behavior and emphasizing the value of work
2. Supporting autonomy
3. Imagination and goals setting

These three principals were kept in mind when designing the tasks of each educational project and communicating them to groups of students, and we tested the magnitude of the impact. A key objective of improving teaching methods in higher education is to result in more active participation and higher motivation of students. Sometimes, however, new methods are counterproductive. FC are now a traditional method in higher education. Our experience shows that this teaching concept, despite its many advantages, still poses significant challenges in today's university environment. One of the main difficulties in the application of FC is the infrastructure requirements, such as complex software [26], which can be costly and technically challenging.

UNESCO's Global Education Monitoring Report 2023 highlights the rapid changes in educational technology and the associated challenges that directly affect higher education and education systems. The report highlights the key role that technology played in sustaining education during the COVID-19 epidemic, but also draws attention to inequalities in access, the lack of diversity in educational content and the negative impact that excessive use of technology can have on student performance.

The use of educational technology can improve certain types of learning, such as increasing access to teaching and learning resources, but it is important to focus on learning outcomes, not just digital inputs. Countries are beginning to prioritize digital skills development, but many students and teachers do not feel prepared to use digital technologies in education. Universities need to face and adapt to the rapid changes in these technologies, while also taking into account the ethical and regulatory aspects of digital technologies.

The general attitude of students towards self-preparation is associated with dropouts among students with low motivation to learn.

One way to reduce dropouts is to reinforce motivation to learn through student groups. An indirect experiment of this was carried out using PBL, building on traditional FC solutions within several student groups. PBL provides an opportunity for real collaboration between teachers and students, where students can contribute their own experience, knowledge, and creativity to the solution of the project [27]. The application of PBL in university education is also associated with the lack of motivation and passivity of students. While active learning with planned group performance helps to motivate learning, without a proper process of assessment and shared group organization, the phenomenon of "stowaways" can develop, meaning that some students may hide their individual underperformance behind the good performance of the group.

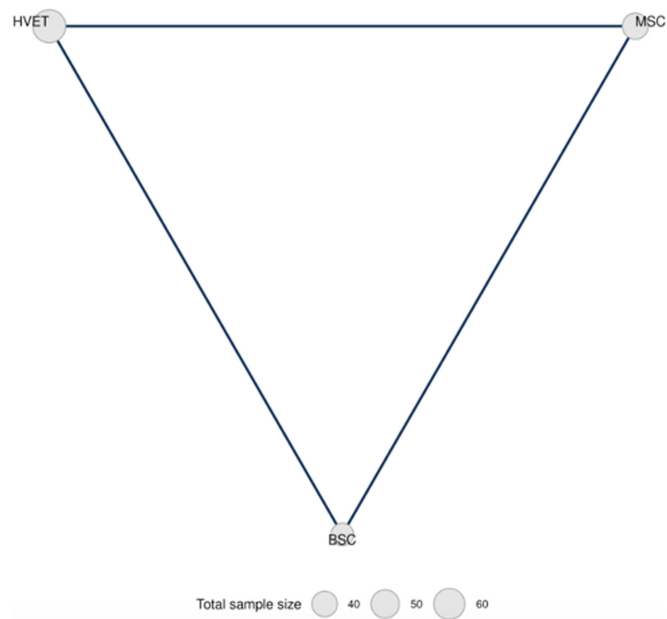


Fig. 2. Network meta-analysis

As shown in Figure 2, our results on the extent of comparisons between different groups are as follows:

- The MSC group scored higher average scores in both project-based and non-project-based instruction, indicating that they generally performed better than the BSC or HVET groups.
- For the BSC group, project-based learners had a higher average than traditional learners, which may indicate that PBL is more effective for them.
- For the HVET group, the average number of participants in project-based education is also higher than for the non-project-based group, which also confirms the effectiveness of project-based education.

Overall, the results suggest that project-based education has a positive impact on students’ attitudes and preparedness for innovation management.

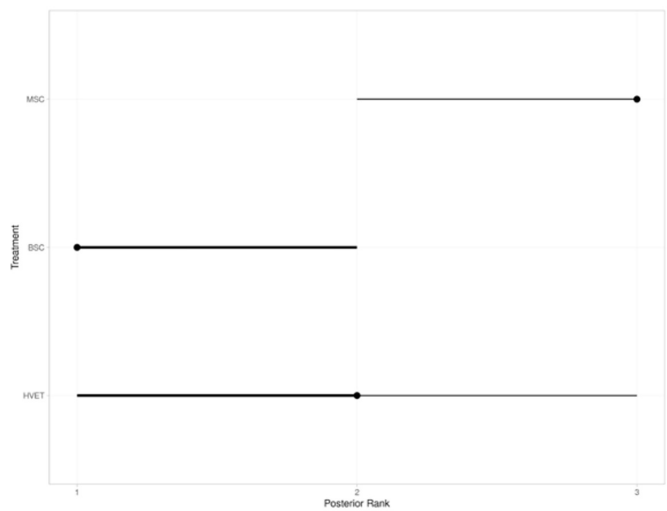


Fig. 3. Posterior ranks

Figure 3 is a ranking graph that evaluates the effectiveness of each training group in the context of our experiment.

- MSc group: The MSc Group score on the graph indicates the best posterior rank, which indicates that this group has performed the best. The position of the dot and the interval on the right edge of the graph may indicate that the MSc group is the most likely to have the most positive result.
- Group BSc: The BSc group is in the middle place in points and lines, with the second-best result. The width of the interval indicates uncertainty, but the central position of the point shows that the BSc group is performing solidly in the middle.
- HVET group: The point and line of the HVET group are located at the bottom of the graph, showing that this group was the least efficient. However, the end of the interval extends into the middle range, which may indicate that there is some uncertainty in the evaluation of the results.

Overall, the ranking graph shows the relative performance of the experimental groups in the context of the effectiveness of the educational program. There was no measurable effect of this experiment on the relative performance of the groups, nor was this the intention. We did not assume, for example, that the relative performance of the BSc group would exceed that of the MSc group. The graph confirms that the ‘division of labor’ within projects was in line with expected performance.

The meta-analysis also confirms that BSc students who participated in PBL achieved the best results and that this method was particularly beneficial for them. HVET students also showed a positive impact, indicating that practical fieldwork and report writing were also beneficial. The MSc students’ results were slightly different, indicating that the impact of the leadership role they experienced was less clear. In the control group, the scores of students who learned using traditional teaching methods were generally lower, suggesting that project-based teaching was more effective in preparing students for innovation management. Our meta-analysis concludes that project-based education had an overall positive effect on students’ perception of their preparedness and probably also on their actual abilities in innovation management.

4.2 The research questions formulated can be answered now

- Q1:** The combination of FC and PBL significantly increased students’ motivation to learn and improved learning outcomes, especially at BSc and HVET levels. This combined approach proved to be beneficial for students’ active participation and development of their independent learning skills.
- Q2:** At the BSc and HVET levels, we observed significant differences in the effectiveness of supplementing the traditional FC method with PBL, while at the MSc level, this difference was not significant. This suggests that different teaching approaches may be beneficial at different levels.
- Q3:** The three levels of training were effectively managed together using the hybrid method. The MSc, BSc, and HVET students effectively integrated the opportunities offered by the PBL methodology through the roles defined at the different levels, resulting in an overall improvement in learning motivation and outcomes.

The study has shown that the combination of FC and PBL has a significant positive impact on students' learning motivation and learning outcomes, especially at BSc and HVET levels. Different levels of tertiary education (HVET, BSc, MSc) showed different levels of effectiveness in complementing the traditional FC method with PBL, with higher effectiveness at BSc and HVET levels, while it was less significant at the MSc level. Overall, the hybrid method was effective in addressing the three training levels together, demonstrating that specific approaches at different levels are effective in supporting students' academic performance and motivation.

4.3 A presentation of the limitations of the research and further research opportunities

In our study, we did not show how the “stowaway” phenomenon was treated, which will be discussed in a later article. This in itself does not affect our present conclusion, but the tools used also affected the FC activities, so we do not claim that the study and control groups engaged in FC learning under the same conditions only. We do not believe that this effect is biased but rather demonstrates that the combination of methods also continuously develops and transforms educational concepts.

In educational research, accurately measuring students' motivation to learn is a complex yet vital task. While there are several methodologies available for this purpose, many of them are more objective but also entail higher costs. For instance, some researchers have developed sophisticated scales to measure both positive and negative aspects of motivation. An example of this is the reading motivation scales developed by [28], which assess both the valuing and devaluing of reading activities. These scales have proven effective in predicting reading outcomes, highlighting their utility in educational research [28], as cited in [29].

However, in our experiment, we opted for a different approach due to resource constraints. We chose to measure the change in students' motivation through a simpler instrument. Although this method may offer a more limited interpretation compared to more comprehensive scales, it still allowed us to detect a significant effect. This decision aligns with the understanding that motivation and its measurement are inherently subjective and situated within specific cognitive and social contexts. As noted by [28], task values can vary greatly among individuals, suggesting that the same educational task can be valued differently depending on the student.

Therefore, while more objective and costly methods of measuring learning motivation exist and can provide detailed insights, our experiment demonstrates that even simpler instruments can yield significant and valuable findings regarding student motivation. This approach, while perhaps more limited in scope, still contributes meaningfully to our understanding of how students engage with and value their learning experiences [29].

Given that we have studied almost identical groups of students in several grades and the statistical methods used have been carefully selected, we would get the same result with a larger sample. However, three years have passed since the first group, and a secondary phenomenon was observed, which we were not able to present in this paper. This is the phenomenon that the digital skills and online learning existence of students differ significantly (deteriorate) between those who are still in secondary or higher education during COVID and those who enter higher education afterwards.

The strength of the effect of the level of education and the discipline studied on the results of MSc and BSc students' needs further investigation. Therefore, we have indicated that the non-significant effect measured for MSc students is not considered a generalizable result.

4.4 Recommendations for university practice

Based on our findings, our recommendations for education policy and university practice are:

- By combining FC and PBL, students' motivation to learn can be increased and the quality of education improved.
- Universities and educational institutions should invest in developing and supporting hybrid teaching methods.
- The teaching methods used at different levels of training should take into account the different needs and prior knowledge of students.

Universities and higher education institutions can take steps to institutionalize PBL in the curriculum. One way to do this could be to integrate MOOCs [30], which provide broad access to interactive and PBL materials. In addition, universities can set up centers [31], such as the Teaching Excellence Centre, to support teachers in the application, development, and evaluation of project-based teaching methods.

Overall, the integration of PBL into university education can help students develop skills, deepen their understanding of knowledge, and better meet the needs of the labor market. The benefits of such education are supported by our study, which points to improved student performance and increased educational efficiency.

5 CONCLUSION

5.1 Our results lead us to the following conclusions

- The addition of PBL to the traditional FC method has had a significant positive impact on motivation and achievement, particularly at BSc and HVET levels.
- The use of PBL at the MSc level has not yielded significant improvements, suggesting that other types of interventions or methods may be more effective for MSc-level students.
- The positive effects of PBL were not only on academic performance but also on students' motivation.

Our results suggest that MOOCs and TECs should be designed for the following carefully planned tasks:

1. **Digital learning environment:** MOOCs help to develop a digital learning environment that promotes independent and flexible learning. This is in line with the benefits of FC and project-based learning.
2. **Interactivity and project-based approach:** The integration of MOOCs and TEC gives students the opportunity to apply what they have learned in an interactive and project-based way, which enhances motivation and the acquisition of practical knowledge.
3. **Teacher support and development:** TECs can help teachers to effectively use and develop modern teaching methods such as PBL and FC.
4. **Broad access and diversity:** MOOCs provide broad access for students from different backgrounds, thus promoting diversity and inclusiveness in education.
5. **Evaluation and feedback systems:** In both MOOCs and TECs, it is important to develop effective evaluation and feedback systems to continuously improve the quality and effectiveness of the teaching.

Overall, the introduction of MOOCs and TECs in university education can promote the development of students' skills and knowledge and support modern educational trends and challenges.

The main findings of our research are summarized as follows:

1. **Effectiveness of project-based education:** Research confirms that project-based education improves students' attitudes and preparedness for innovation management. In particular, students participating at the BSc and HVET levels showed significant improvements.
2. **Benefits of cooperation between levels of education:** Cooperation between students at different levels of education promotes multidisciplinary learning and cross-fertilization of skills, which enriches the learning experience and strengthens teamwork.
3. **The need to supplement traditional teaching methods:** Research suggests that supplementing traditional lecture-based teaching methods with project-based elements can make teaching more effective and provide better outcomes for students.
4. **Recommendation for the development of educational strategies:** The results encourage educational institutions to develop and integrate PBL into the curriculum, support teachers in the use of these methods, and increase the marketable skills of students.
5. **Need for Institutional Support:** The research stresses the need for educational institutions to support the introduction of new teaching methods, such as MOOCs and professional development centers, which promote the wider use of project-based education.
6. **Developing innovation skills:** The use of PBL can enhance students' innovation skills and preparedness, which is important in adapting to today's rapidly changing labor market needs. These findings can be of fundamental importance for education policy, curriculum development, and university teaching practices. The results can be used to further develop teaching methods, improve student skills and employability, and provide an evidence-based basis for educational decision-making.

5.2 Future research directions

In considering future research directions for this study, the following areas are planned for exploration:

1. **Comparative analysis:** Future studies should include a comparative analysis with other educational models or settings. This would offer a more comprehensive understanding of the relative effectiveness and applicability of the FC and PBL approaches.
2. **Long-term career impact:** Investigating the long-term impacts of these teaching methodologies on student career success would provide valuable insights into the enduring effects of innovative educational strategies on professional development and employment outcomes.
3. **Diverse student populations:** Expanding research to include diverse student populations across different academic disciplines, cultural backgrounds, and educational levels is crucial for assessing the broader applicability and efficacy of these teaching methodologies in varied educational contexts.

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7 AUTHOR

Dr. habil. Tamás Köpeczi-Bócz is with the University of Tokaj, Sárospatak, Hungary (E-mail: kopeczi.bocz.tamas@unithe.hu).