Implementing Team-Based Learning in Geomatics Education: enhancing hard and soft Skills in multicultural academic Contexts

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Keywords: Team-Based Learning, Geomatics Education, Active Learning, GIS, Soft Skills, Intercultural Competence

Abstract

This practice paper presents the design, implementation, and first evaluation of Team-Based Learning (TBL) activities in university-level Geomatics courses taught in English to multicultural and international student groups. The study documents a structured pathway for adapting TBL to technically demanding subjects, including GIS suitability analysis, network analysis, remote sensing classification, and heat-risk assessment. Its main contribution lies in showing how a pedagogical model widely discussed in general higher education can be translated into software-based Geomatics teaching while supporting both disciplinary learning and intercultural collaboration. The paper also identifies the main organizational conditions for successful adoption, including team formation, workload calibration, and suitable classroom settings. Results from 12 TBL implementations involving 187 students and 470 total participations show clear benefits of teamwork: average team test performance was markedly higher than individual performance, repeated participation was associated with improved results, and student satisfaction increased after the introduction of TBL. Qualitative evidence further indicates gains in communication, teamwork, and intercultural interaction. Although the first implementation required substantial preparation effort, the approach proved replicable and scalable in subsequent editions, making TBL an effective instructional model for Geomatics education.

1. Introduction

Active learning and “learning by doing” approaches are increasingly recognized as essential to promoting deeper understanding, helping students move from applying knowledge to analyzing and evaluating it within Bloom’s taxonomy (Bloom et al., 1956) framework.

Lecturing has been criticized for fostering a passive learning environment, emphasizing a one-way flow of information, and not adequately engaging students. In contrast, active-learning approaches, such as Team-Based Learning (TBL), prioritize student interaction and engagement and create multidirectional flows of information (Huggins et al., 2015). TBL, as a structured active learning strategy, fosters collaboration, accountability, and higher-order thinking through the application of concepts to real-world problems (Simonson et al., 2014; Stein et al., 2015). In the context of international and intercultural classes, this study builds on the Politecnico di Torino’s Teaching and Language Lab (TLlab)[1] initiatives for faculty development in innovative teaching, presenting a TBL experience in Geomatics courses aimed at enhancing both hard and soft skills. Franco-Ángel et al. (2022) analyzed the relevance of both hard and soft skills in the performance of internship students. While hard skills represent knowledge and professional skills, soft skills allow the transfer of this knowledge effectively and help people to manage conflicts, create inclusive relationships, persuade and influence customers, negotiate with business partners, and communicate with peers and superiors. Soft skills also determine how executives perceive and understand their work environment. Soft skills are important beyond a student’s academic career, e.g. Lamberti et al. (2023) found that perceived quality of soft skills was important for the higher-salary students.

In this framework, the authors decided to introduce TBL in different Geomatics-related courses, focused on GIS and Remote Sensing and belonging to different teaching areas and degree programs (including an interuniversity course) with a majority of international students representing dozens of nationalities, thus posing didactic challenges that go well beyond the disciplinary content.

2. The implementation process

The idea to test the integration of TBL in a Geomatics-related course was inspired by the Learning to Teach (L2T) initiative of the Politecnico di Torino’s TLlab[2]. L2T is a course, mainly dedicated to young researchers but open to all University faculty members who wish to acquire skills and knowledge to enrich their teaching in a stimulating environment of discussion and reflection. It is a transformative experience for all Politecnico di Torino teachers who want to update and enhance their teaching approach. The course guides teachers through a structured program consisting of six modules that combine theory, practice, and pedagogical reflection to give new energy to the teaching. Covered topics include blended teaching techniques (e.g., flipped classroom and TBL), teaching technologies, teacher-student relationships in the classroom, learning methods, assessment, and much more. L2T promotes a community of educators dedicated to evidence-based experimentation and continuous improvement in teaching and learning.

The following sections describe how this educational intervention was conceived, how the different TBL steps have been adapted to the context of the academic courses, the type of support received by means of a mentoring opportunity, and finally how the authors decided to introduce a specific evaluation

[1] https://www.polito.it/en/education/teaching-lab

[2] https://www.polito.it/en/education/teaching-lab/teacher-training

https://doi.org/10.5194/isprs-archives-XLIX-B5-2026-3-2026

framework to estimate the impact on students in terms of intercultural competences.

2.1 Educational context and TBL design

After deciding to test the introduction of the TBL format in one of the Geographic Information System (GIS) courses the authors were involved, the first step was to check if any of the course topics could be adapted to this specific teaching format. The authors identified that suitability analysis, a spatial decision-making process that uses GIS tools to identify the most appropriate locations for a specific purpose by evaluating multiple spatial criteria, was an appropriate topic for a TBL application. The choice was made considering that suitability mapping and analysis is one of the most useful applications of GIS for planning and management (Yang et al., 2007) and that its level of complexity is appropriate within the curricula path in which the authors are involved.

The authors sought support from the Mentoring Project[3] of the TLlab to plan the implementation in detail. Mentors are a group of faculty members who have been trained by pedagogical experts in previous years, are available to work with colleagues (mentees) who wish to exchange experiences, share ideas, or be guided in the implementation of innovative teaching practices. Specifically, expert colleagues helped in defining:

- rules and procedures for creating and managing teams. Team formation is a key component of TBL and must be managed by the instructor rather than via self-selection by students (Michaelsen et al., 2004). It was therefore decided to ask the students about their willingness to provide data on their academic curriculum, a self-assessment of relevant technical capabilities, their experience working in teams, the role they usually take in a group, and the preferred group size. AI-based tools can effectively support the formation of TBL teams by assisting instructors in composing groups that satisfy the aforementioned criteria, thus promoting balanced team structures and enhancing the pedagogical robustness of the instructional design. In this process, all data uploaded to the LLM is anonymized and associated with a unique identifier, thus enabling AI-assisted team allocation while preserving participant privacy and ensuring secure data handling;
- final evaluation and grading criteria. In a context where class attendance is not mandatory, it was important to find a solution to adequately reward the performance of students participating in TBL without preventing non-attenders from obtaining the highest grades. It was therefore decided to assign bonus points to the participants, to be added to the standard evaluation process. To compute the bonus points, this process assigned a weight to each student's results in each phase of the TBL.

Mentors agreed to be present in class during the first implementation of the TBL, collecting their observations and the opinion of the students, summarising them and providing a report to the authors.

As mentioned, an application in the domain of the GIS suitability analysis was developed, following the TBL 4S problem-solving framework[4] (Significant problem, Same problem, Specific choice, Simultaneous report): the main objective is to “give(s) individuals, and teams, many opportunities to make decisions and get timely feedback on the quality of their thinking and their process for arriving at their answer”. Furthermore, learning documents and resources to be provided to the students for the individual study were assessed and selected.

Only after this first TBL deployment and the related positive evaluation collected through the Mentoring Project support, the authors decided to develop three additional applications in the fields of network analysis, supervised classification of remotely sensed images, and heat risk analysis.

2.2 TBL implementation

The first edition of the TBL experience was implemented in the academic year 2023/24 within a Master’s degree course of the Master of science-level of the Bologna process in Urban and Regional Planning at Politecnico di Torino. As the activity was offered on a voluntary basis, it was scheduled as an optional activity during the final week of lectures.

A preliminary one-hour session was organized to introduce students to the TBL structure and workflow (Figure 1). In particular, the session explained the sequence of activities, including the preliminary independent study, an individual readiness assurance test based on ten multiple-choice questions, the same test completed collaboratively in teams, the team Application phase, and a final peer evaluation.

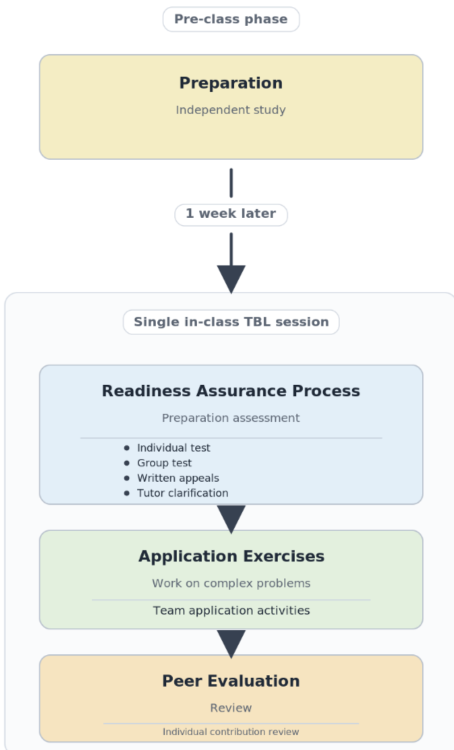


Figure 1 – Schematic representation of the Team-Based Learning (TBL) workflow (adapted from Sparkes, 2018)

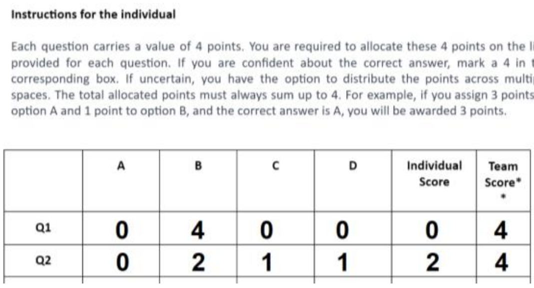
[3] https://www.polito.it/en/education/teaching-lab/mentoring-project

[4] https://cdn.ymaws.com/teambasedlearning.site-ym.com/resource/resmgr/Docs/TBL-handout_February_2014_le.pdf

The timing and duration of each phase were also presented.
The overall TBL session structure was also presented in detail:

- roll call;
- individual Readiness Assurance Test (iRAT, 15 minutes);
- team Readiness Assurance Test (tRAT, 25 minutes);
- appeals and related discussion (20 minutes);
- short presentation and comments on the iRAT and tRAT (15 minutes);
- team Application (tAPP, 2 hours);
- peer evaluation (15 minutes);
- closing remarks (30 minutes).

It was also necessary to describe the response mechanisms adopted for the iRAT and tRAT, which are uncommon and require a dedicated explanation.
For the iRAT, students were required to distribute a total of four points among the available answer options for each question (Figure 2), thus making their answer choice and level of confidence explicit.



Instructions for the individual

Each question carries a value of 4 points. You are required to allocate these 4 points on the line provided for each question. If you are confident about the correct answer, mark a 4 in the corresponding box. If uncertain, you have the option to distribute the points across multiple spaces. The total allocated points must always sum up to 4. For example, if you assign 3 points to option A and 1 point to option B, and the correct answer is A, you will be awarded 3 points.

	A	B	C	D	Individual Score	Team Score**
Q1	0	4	0	0	0	4
Q2	0	2	1	1	2	4

Figure 2 – Answer sheet used during the individual Readiness Assurance Test (iRAT) and example of point distribution and evaluation (last two columns, obviously to be calculated only after the tRAT step)

In the tRAT phase, teams used a scratch sheet (Figure 3) to assess their answers autonomously. This tool made the activity more interactive and engaging, while also encouraging discussion, immediate feedback, and collaborative decision-making among students.

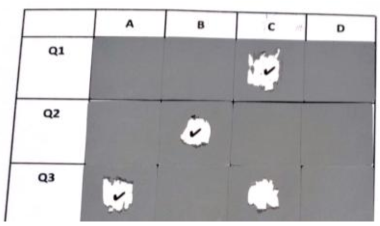


Figure 3 - Scratch sheet used during the team Readiness Assurance Test (tRAT) to enable teams to assess their answers autonomously (in the example, 4 points for questions 1 and 2, 2 points for question 3)

During the preliminary session, the main topic of the TBL application was also introduced, and students were provided with pre-class independent study material together with a step-by-step tutorial for completing a software-based exercise, requiring approximately 2 to 3 hours of preparation.

The following week, a 4.5-hour session was devoted to the full implementation of the TBL activity, according to the previously defined agenda. A coffee break was organised after the appeals phase, enabling teams to prepare for the longest and most intensive part of the session, namely the team Application phase (tAPP).

The same approach was also positively tested in an academic training initiative conducted at the University of Belgrade within a Horizon Europe project. This additional experiences confirmed the versatility of the method, in line with the existing literature, and prompted the authors to integrate TBL as a standard component of four different GIS and remote sensing related courses at both Master's and PhD level.

In operational terms, the TBL approach has been expanded in other two courses and from one session per course to three sessions per course. All these courses are taught in English and attended by international classes, including a significant number of ERASMUS+[5] students. An additional distinctive feature is that one TBL experience is jointly delivered for two different courses, which take place during the same teaching period. This creates mixed classes composed of students enrolled in different universities and degree programmes, and therefore characterized by heterogeneous backgrounds and levels of prior knowledge. Such diversity makes this context particularly well suited to a TBL approach.

3. Ongoing developments

In the academic year 2025/26 the authors requested a new support from the Mentoring Project, specifically focused on if and how the TBL activities are helping in establishing intercultural relationships in the classroom. By means of in-class visits and interviews, the mentors produced a report where the students explicitly appreciate group work because it allows them to learn from their peers and understand the subject matter more deeply than individual study. Furthermore, the team activities fostered intercultural dialogue by bringing together people from different backgrounds. Some areas of improvement were identified, notably:

- the group size must be set considering that most tasks require working on a single computer. Too large groups may lead to situations where some students cannot actively participate;
- the provision of estimated time duration for each sub-task of the team application may help the team in managing time more effectively and in reducing stress;
- assigning a well-defined role to each member, and changing those during the different TBLs, may help in avoiding that only one or two students, those directly working on the computer, are doing the majority of the work or taking the lead just thanks to a better fluency in the working language.

3.1 Intercultural competences assessment (soft skill)

Since the very first implementation, it was evident that students significantly improved their capacity to interact with their teammates and with the teaching staff. Furthermore, the teams were able to benefit from diversity without being negatively

[5] https://erasmus-plus.ec.europa.eu/

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affected by the lack of prior personal interactions: this was particularly evident in the case of a TBL organised by mixing students from two different courses, that therefore firstly met in the occasion of the TBL. This is in line with the evidence reported by Michaelsen and Sweet (2008). But the evidence was mainly qualitative, derived from in-class observations, informal comments gathered in classes and formal free-text comments in teaching evaluation surveys.

In order to better formalize and measure the TBL's impact on intercultural competences, supported by the TLlab's specific expertise in teaching methods applied to multi-cultural classes, the authors identified specific expected learning outcomes for the TBL activities. These learning outcomes have been defined based on a rubric developed by the American Association of Colleges and Universities[6] and with the purpose to generate evidence that can be shared and compared. Based on the rubric, the identified learning objectives are:

- Cultural self-awareness: identify own cultural rules and biases;
- Knowledge of cultural worldview frameworks: partial understanding of the complexity of elements important to members of another culture in relation to its history, values, politics, communication styles, economy, or beliefs and practices;
- Verbal and nonverbal communication: minimal level of understanding of cultural differences in verbal and nonverbal communication;
- Curiosity: minimal interest in learning more about other cultures;
- Openness: receptive to interacting with culturally different others.

Based on the research by Van Dyne et al., 2008, the authors developed a self-assessment form to be submitted to individual students in order to assess the initial level of cultural intelligence (CI), defined as the ability to adapt and adjust to the environment and the capability to function effectively in culturally diverse settings. The cultural intelligence of everyone can be differentiated into four main components, each evaluated on a scale from 0 to 7:

- Metacognitive (MC): is an individual's cultural consciousness and awareness during interactions with those from different cultural backgrounds;
- Cognitive (COG): is an individual's cultural knowledge of norms, practices, and conventions in different cultural settings;
- Motivational (MOT): is an individual's capability to direct attention and energy toward cultural differences;
- Behavioral (BEH): is an individual's capability to exhibit appropriate verbal and nonverbal actions when interacting with people from different cultural backgrounds.

The cultural intelligence components have been linked to the learning outcomes according to the schema included in Table 1. The results of the self-assessment of the CI is communicated to all teams before the first TBL, to reiterate the importance that the authors assign to this aspect and to make them aware of cultural strengths and weaknesses in every team (Figure 4).

Learning outcome	CI component
Cultural self-awareness	MC
Knowledge of cultural worldview frameworks	COG
Verbal and nonverbal communication	BEH
Curiosity	MOT
Openness	MOT

Table 1 – The link between the identified learning outcomes and the cultural intelligence components

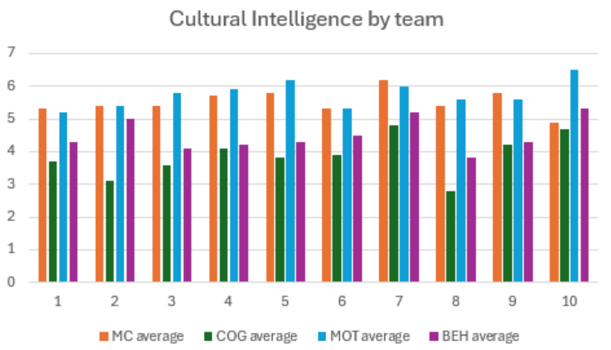

Figure 4 – Example of chart used to communicate the average starting level of cultural intelligence (range 0-7) within each of the 10 TBL student teams

Finally, the authors are currently developing a peer review mechanism, based on the same source used for the self-assessment level of intercultural knowledge and competence, asking all TBL participants to evaluate their teammates and themselves at the end of the final course TBL. The results of the peer evaluation compared against the initial self-assessment, will allow for revising the self-evaluation and to quantitatively estimate the impact of the TBL in terms of intercultural knowledge and competences. At the time of the preparation of this contribution, this last step is still not operationally implemented.

4. Results and preliminary evaluation

Since academic year 2023/24, when the TBL-based teaching approach was initially tested, a total of 470 participations were recorded by 187 unique students to 12 different TBLs: out of the 187 students, 65 experimented a TBL only once, 3 twice and 119 three or more times. The suitability analysis TBL is the topic that registered the highest total participation (226 participants in 6 editions), followed by Network analysis (122 participants in 3 editions), Heat risk index (72 participants in 2 editions) and Supervised classification (50 participants in 1 edition).

Table 2 reports basic statistics on individual and average performances in the different TBL steps: iRAT and tRAT are evaluated in a range from 0 to 40 points, while tAPP is in the range from 0 to 30 points.

As far as the RAT phase is concerned, the benefit of answering the quiz as a team instead of individuals is confirming evidence found in literature (Conroy et al., 2012), with an average score more than 10 points higher and a relatively small variability: both differences in average and standard deviation can be interpreted as a sign that not only the overall result is better but that teams

[6] https://www.aacu.org/initiatives/value-initiative/value-rubrics/value-rubrics-intercultural-knowledge-and-competence

are capable of compensating the variability in the preparation and understanding of the individuals.
The fact that tAPP performances are generally lower than RAT ones is intrinsically linked to the greater complexity of this step. The statistics on the different applications help identify the relative level of complexity from the students’ perspective and, therefore, the need for specific adaptation measures (e.g., more material for off-class preparation, more time to complete the application in class, etc.).

TBL steps	Average score	Standard deviation	Minimum score
iRAT	28.5	7.8	4
tRAT	38.9	2.3	19
tAPP (overall)	22.8	6.3	10
tAPP (Suitability analysis)	24.3	6.3	10
tAPP (Network analysis)	17.4	3.9	12
tAPP (Heat risk index)	23.8	4.9	12.9
tAPP (Supervised classification)	29	2.2	24

Table 2 – Comparison between individual and team average performances (range 0-40 points for iRAT and tRAT, range 0-30 for tAPP) in the different TBL steps

Table 3 shows how TBL results seem to improve within participants who had the occasion to participate in more than one TBL. The improvement in average performance is more evident for the iRAT, because this phase is more closely linked to the individual preparation variability, but it is also observed in the tRAT. In the case of the tAPP, the decrease in performances on the second TBL can be mainly explained by the fact that in most of the considered cases the second TBL topic was network analysis, the one that in general is perceived as the most difficult one. The significant increase in the tAPP on the third TBL seems therefore confirming the positive impact for the students in being involved in more than one TBL in a same course.

TBL	N. of participants	iRAT (avg)	tRAT (avg)	tAPP (avg)
First	210	26.8	38.2	23.3
Second	104	30.3	39.7	18.7
Third	84	30.9	39.7	26.1

Table 3 – Comparison of participants' average iRAT, tRAT and tAPP results according to their experience with TBLs

For the following impact analysis, we considered only the 2 master's degree courses offered by Politecnico di Torino, to obtain homogeneous and comparable data.

The impact of TBL activities can be indirectly observed in the students’ survey results (Figure 5). In one case (Course 1), the introduction of TBL during the 2023/24 academic year was associated with a significant increase in course satisfaction. The slight decrease in 2024/25 was associated with the increase in the TBL events (from 1 to 3) that occurred that year for the first time: a possible interpretation for this decrease is related to an overload feeling from some students, corroborated by some comments received in the free-text section of the survey. But the new satisfaction increase in 2025/26, when again 3 TBLs were proposed, calls into question this association that therefore needs to be further analysed in the next years.

Similar trends are observed also in the second case (Course 2): in absolute terms, the increase in satisfaction registered in the 2023/24 year (first implementation of the TBL in this case too) is lower, but this is due to a significantly higher previous satisfaction rate.

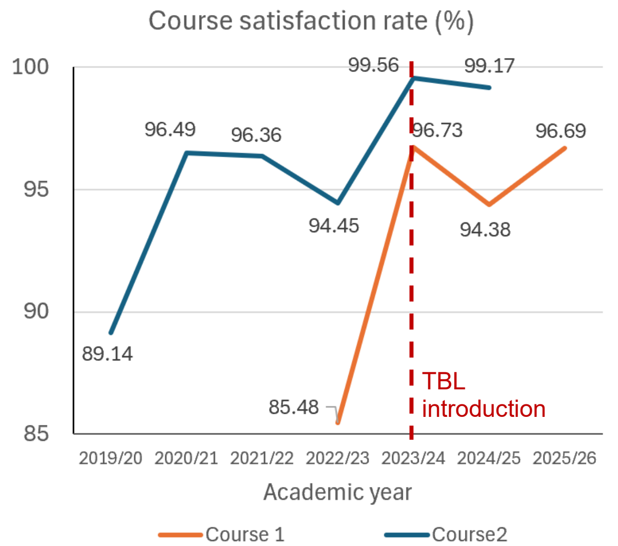

Figure 5 - Satisfaction rates for the 2 master’s degree courses analysed

In the same students’ surveys, students demonstrated appreciation for the TBL activities in the open comment section, either directly by mentioning the TBL activities or indirectly by appreciating the group work, attention to international students, and innovation and creativity. Some students complained not about the TBL itself but about the evaluation, suggesting that the number of credits that can be increased.
One of the features of the TBL that is particularly appreciated by students is the possibility to appeal the evaluation of the first phase of the TBL process (i.e., the individual and team RAT), enabling them to learn soft skills in properly addressing, motivating, and defending an appeal.

Among the students of the two master’s degree courses under consideration, the authors observed a slight decrease in the average number of days between the end of lessons and the exam successfully passed (Table 4). The standard deviation highlights the extreme variability of these figures, making not possible to measure a clear TBL impact based on this metric.
In terms of final vote, no TBL impact is registered within the currently analysed population.

	Days to exam (avg)	Days to exam (st. dev)
With TBL	57	114
Without TBL	68	131

Table 4 – Estimation of TBL impact in terms of days to pass the exam

5. Conclusions

The implementation of Team-Based Learning (TBL) in Geomatics-related courses at Politecnico di Torino has shown that this pedagogical approach can be effectively adapted to technically demanding, software-based teaching contexts and to multicultural academic environments. The experience presented in this paper demonstrates that TBL can support both disciplinary learning and the development of soft skills through a structured sequence of individual preparation, team-based assessment, and collaborative application activities. Its main contribution lies in showing how a model widely discussed in general higher education can be operationalized in Geomatics education, including applications in GIS suitability analysis, network analysis, supervised classification of remotely sensed images, and heat-risk assessment.

The intervention, progressively developed with the support of the Politecnico di Torino Teaching and Language Lab, proved feasible across different educational settings, including Master's-level, interuniversity, and doctoral courses. Although the initial implementation required substantial effort in the design of materials, tests, exercises, and evaluation criteria, the model became more readily replicable in subsequent editions, especially when the same application topic was retained and refined.

The experience also highlighted a number of operational conditions for the effective use of TBL in Geomatics education. These include careful calibration of student workload, balanced team composition and group size, clear timing and organization of the application phase, and the availability of suitable classroom facilities for software-based group work. Observations collected during the different implementations further suggest that assigning explicit roles within teams may improve participation and reduce the risk that only a limited number of students actively engage in computer-based tasks.

The quantitative evidence collected across 12 TBL implementations, involving 187 students and 470 total participations, confirms the pedagogical value of the approach. Team performance in the readiness assurance phase was consistently higher than individual performance, and repeated participation was generally associated with improved results over time. Student feedback also indicates an overall positive perception of the method, while at the same time pointing to the importance of avoiding excessive workload and carefully balancing the number of TBL activities within a course.

The findings further suggest that TBL may foster communication, teamwork, and intercultural interaction in international classes. However, this dimension currently relies mainly on qualitative evidence, while the assessment framework for intercultural competences is still being refined. Similarly, the impact of TBL on final examination performance remains limited and should be investigated further.

Overall, TBL emerges as a promising, scalable, and adaptable instructional model for Geomatics education, particularly in internationalized teaching contexts. Its main strength lies in combining technical learning with collaborative and intercultural dimensions in a structured and transferable format. Future work should therefore focus on consolidating the assessment of intercultural competences, refining peer-evaluation procedures, and further monitoring the medium-term impact of TBL on student learning and course performance.

Acknowledgements

The authors would like to thank Politecnico di Torino's Teaching and Language Lab, and in particular the mentors who directly supported the implementation of the TBL. Generative AI tools were used exclusively for editorial support, such as grammar correction, translations, paraphrasing suggestions, or improving readability.

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