Enhancing Student Engagement: A Toolbox for Systematic PBL Implementation

Meng Yuan
Department of Sustainability and Planning, Aalborg University, Rendsburggade 14, 9000, Aalborg, Denmark, mengy@plan.aau.dk

Juebei Chen
Aalborg Centre for Problem-based Learning in Engineering Science and Sustainability, Aalborg University, Aalborg, Denmark, juebei@plan.aau.dk

Dennis Friedrichsen
Aalborg Centre for Problem-based Learning in Engineering Science and Sustainability, Aalborg University, Aalborg, Denmark, friedrichsen@plan.aau.dk

Izhar Mithal Jiskani
Department of Sustainability and Planning, Aalborg University, Rendsburggade 14, 9000, Aalborg, Denmark, imj@plan.aau.dk

Sara Bjørn Aaen
Department of Sustainability and Planning, Aalborg University, Rendsburggade 14, 9000, Aalborg, Denmark, sara@plan.aau.dk

Xiangyun Du
Aalborg Centre for Problem-based Learning in Engineering Science and Sustainability, Aalborg University, Aalborg, Denmark, xiangyun@plan.aau.dk

Abstract

To foster student engagement and improve learning outcomes, there is a growing shift from traditional teacher-centered, lecture-based teaching to student-centered, constructivist approaches. This paper proposes a student engagement toolbox designed to promote active student engagement in a systematic problem-based learning environment. The toolbox includes tools that support diverse teaching contexts, such as the 1-2-Team model, digital interaction tools, teamwork on cases, random interviews, and flipped classroom activities. To offer deeper insights, an example of applying the elements of the toolbox in a specific course at Aalborg University is presented. Furthermore, the practical implications of the toolbox are discussed, including application scenarios, advantages, potential risks, strategies for mitigating those risks, and authors' reflections on its implementation. The findings highlight the importance of selecting tools and designing courses according to the teaching contexts to promote psychological safety and foster student interactions. This approach ultimately contributes to an improved learning experience by creating an inclusive and supportive atmosphere, empowering students to take an active role in their education.

Keywords: Problem-based learning, Student engagement, Constructivist teaching, Toolbox

Type of contribution: Research paper

1 Introduction

The teacher-centered, lecture-based teaching approach has been adopted widely in universities globally, which positions the teachers as the primary sources of knowledge. While this method provides structured content delivery, it can also result in students becoming passive recipients, potentially leading to disengagement, disenchantment, and missed opportunities for deeper learning (Wedemeyer, 2010). To address these limitations, there has been a growing shift toward more student-centered, active learning approaches (Wright, 2011).

From the perspective of constructivist learning theory, knowledge is actively constructed by learners rather than passively received. This theory emphasizes the importance of hands-on experiences, collaboration, and

reflection in building understanding (Hendry et al., 1999). Engagement in learning activities promotes deeper cognitive processing, enabling students to connect new information with prior knowledge, understand complex concepts, and develop essential problem-solving skills. When students are actively involved, they are more likely to be motivated and take ownership of their learning (Parsons & Taylor, 2011). Existing higher education research also shows that the extent to which students are engaging in activities is linked with high-quality learning outcomes (Krause & Coates, 2008), and have an impact on the learning experience, competence development, and, ultimately, life success (Bundick et al., 2014). Moreover, a higher level of engagement is characterized by students producing additional outputs or products beyond the provided learning materials (Du et al., 2020). This suggests that designing suitable learning activities that stimulate students' thinking and reflection is essential for fostering meaningful learning experiences. Biggs's three-level teaching model (Biggs, 2003) further enriches this understanding.

With the overarching goal of enhancing students' active engagement during lectures, this study proposes a student engagement toolbox comprising adaptable tools suitable for diverse teaching contexts and designs. Each tool emphasizes student-centered practices, which have the potential to increase learners' interest and engagement. The toolbox is the result of a collaborative effort based on the authors' teaching experiences during the University Pedagogy (UP) Programme at Aalborg University (AAU) in 2024. This programme is a comprehensive, research-based pedagogical competence development course designed for early-career academics.

The development of the student engagement toolbox is motivated by the authors' shared experiences with challenges encountered in teaching at AAU. At AAU, problem-based learning (PBL) serves as the core pedagogical approach at the curriculum level (Aalborg University, 2015). The Aalborg PBL Model emphasizes collaborative, problem-oriented learning, where students work in groups each semester to develop projects, drawing on theoretical and methodological insights from their courses, with students placed at the center of the learning process as they take responsibility for identifying and solving problems, while teachers serve as facilitators, guiding and supporting their learning (Kolmos et al., 2004). However, based on the authors' teaching experiences and peer discussions, traditional teacher-centered approaches are still commonly used in lectures to deliver content. This presents challenges for students in actively engaging during lectures and in making meaningful connections between lecture content and their project work. As a result, the potential of lectures to support project development may be diminished, which limits opportunities for reflection and deep learning.

The proposed student engagement toolbox offers a flexible framework, which allows educators to select and implement the tools that best align with their specific teaching goals. The structure of the paper is as follows: Section 2 presents the overall framework of the proposed student engagement toolbox. Section 3 provides an example of its implementation. Section 4 discusses the practical implications of the toolbox and the authors' reflections, and Section 5 concludes the paper.

2 Teaching design - Student engagement toolbox

The tools included in the proposed student engagement toolbox are described below. This toolbox was developed primarily based on teaching experiences gained from the authors during the one-year University Pedagogy Programme, as previously mentioned, and supplemented by insights from other teaching contexts. The authors, though from the same department at AAU, come from diverse academic backgrounds and teach in different programmes. The tools were collected, discussed, and implemented across various courses, including those with a focus on engineering education. However, due to page limitations, only one example of the implementation of the toolbox is presented in Section 3 later on.

2.1 1-2-Team Model

The 1-2-Team model, developed through empirical research and teaching practices in a PBL context at Aalborg University (Hansen & Christensen, 2024), offers a structured approach to enhancing student

engagement in both classroom activities and teamwork. This model operates through three interconnected phases: individual creative thinking, paired sharing, and team discussion. This allows students to reflect, share ideas, and make decisions collaboratively in a playful and supportive environment. The model emphasizes two steps for operation, including open mode and close mode (Hansen & Christensen, 2024). The open mode involves individual thinking, pair sharing, and group sharing, during which students are not required to comment on others' ideas; instead, the focus is solely on idea sharing with everyone's engagement. This mode fosters free expression and collaboration, encouraging innovation by allowing students to explore diverse perspectives. In contrast, the closed mode involves analyzing, commenting on, and suggesting improvements to ideas, as well as making decisions. This structured approach emphasizes analytical thinking, ensuring clarity and workflow efficiency. By separating these modes, the model enables students to balance creative exploration with focused problem-solving, enhancing overall learning outcomes. In practice, students are typically divided into small groups of 4–6 members to tackle key questions posed by the teacher. The learning process begins with individual reflection, where students formulate their own thoughts. This is followed by the pair phase, where students share and refine their ideas in smaller groups of two, creating opportunities for peer-to-peer learning. Finally, during the team discussion, all students come together to share their insights, facilitating broader participation and collective decision-making. This progression allows every team member to engage meaningfully, ensuring that all perspectives are considered in a supportive and dynamic classroom environment.

A significant strength of the 1-2-Team model lies in its ability to address the limitations of traditional classroom dynamics, where discussions are often dominated by outspoken students. By incorporating individual reflection and small-group interactions, the model ensures that quieter and introverted students have the time and space to articulate their ideas, fostering a more inclusive learning environment. This approach prevents the learning experience from being dominated by a select few, promoting equal participation and ensuring that all voices are heard. Moreover, the model promotes a sense of social connection by providing a structured, safe space for students to engage with their peers. This sense of belonging is critical for maintaining student motivation and attendance, which in turn supports both academic success and retention(Jensen & Cross, 2021; Verdín et al., 2018). Ultimately, the 1-2-Team model creates a dynamic, student-centered classroom where all students feel valued, empowered, and motivated to actively participate in the learning process.

2.2 Digital Interaction Tools

Digital tools help transform the classroom into a more inclusive and interactive learning environment (Moorhouse & Kohnke, 2020). Various digital tools—such as Slido, Mentimeter, Teams Whiteboard, and Quizlet, enhance in-class interactions by promoting active student participation, providing real-time feedback, and enabling dynamic learning experiences. Platforms like Slido and Mentimeter support anonymous participation, encouraging students—especially those hesitant to speak in traditional settings—to share their ideas more comfortably. These tools integrate seamlessly with PowerPoint, allowing teachers to visualize results instantly. Educators can engage students by using features like live polls for multiple-choice questions and word clouds for collecting text responses.

Additionally, collaborative platforms such as Teams Whiteboard and Padlet provide spaces for students to co-create knowledge, discuss ideas, and explore course material more deeply. These tools are particularly valuable for asynchronous participation, enabling students to engage in discussions or group work at their own pace beyond scheduled class hours. As a result, they are also supportive tools for online courses, enhancing both flexibility and collaboration in digital learning environments.

2.3 Teamwork on Cases

Teamwork on cases uses small, fictionalized problems to stimulate creativity, engagement, and critical thinking. By adding humorous or exaggerated elements, students navigate group dynamics in a light-hearted

yet impactful manner. This approach enables students to explore key topics in PBL like conflict management and task delegation through interactions with characters exhibiting extreme personality traits. The use of fictional characters provides emotional distance, enabling students to reflect critically on their behaviors, reactions, and interpersonal dynamics. For example, a 3x3 grid with nine different fictional characters can be used in a PBL course on conflict management, where student groups can be given a hypothetical scenario and asked to consider their perspectives and actions as if one of the fictional characters was a group member. Despite the humorous nature, observations showed that the 'third other' (i.e., the fictional group member) can provide a valuable reference point for students to discuss challenging topics, such as team members' lack of effort, tardiness, rudeness, and the balance between sociability and professionalism. Overall, this 'Teamwork on Cases'-tool promotes meaningful discussions and self-awareness in a playful, interactive environment.

2.4 Random Interviews

Random interviews, though a relatively small intervention compared to the other tools, are highly effective in capturing students' attention, especially when the discussion topic is controversial and involves diverse opinions. The teacher can present a multiple-choice question to the class using digital tools like Mentimeter or Slido and randomly select students to explain the reasoning behind their choices. The question can be open-ended, without a fixed correct answer, which allows the students to explore the consequences of each option during the discussion. Since the selection process is random, students may feel slightly nervous but, at the same time, remain highly engaged and attentive. This method fosters critical thinking and encourages active participation, and helps students develop their ability to defend their viewpoints.

2.5 Various Flipped Classroom Activities

The classroom can be flipped via some fun student engagement activities where the students are the main actors instead of the teachers, and the students can play the main role in a relatively relaxing atmosphere. The potential flipped activities include Role Play, Pecha-Kucha Presentations Task, Board Games and other Game Workshops such as LEGO Serious Play, etc. Each of these activities is briefly introduced below.

Role Play is an activity where the students are divided into different groups and assigned different roles within a given scenario, with the teacher or students acting as facilitators. **Pecha-Kucha** is a presentation style in a structured format where presenters show 20 slides in 6 minutes and 40 seconds (each slide displayed for 20 seconds). The teachers can organize a Pecha-Kucha task for the students on a given topic for students to present in the course. Different **Board Games and Game Workshops** can also facilitate learning if the content is integrated into the course. For example, two games available for the students in the energy field include CATAN New Energies and REWARDHeat Serious Game.

3 Example of toolbox implementation

The toolbox was implemented by the authors in various courses across different disciplines at AAU, spanning both bachelor's and master's levels, as part of the University Pedagogy Program during 2024. A brief example of its implementation in a master course is presented below. Further details of course design, data collection and analysis of other courses can be found in Ref. (Chen et al., 2024).

3.1 Teaching context

An example of the teaching practice took place during a two-hour lecture in the Energy System Analysis course for first semester master students enrolled in the Sustainable Energy Planning and Management Program at Aalborg University in autumn 2024. The class consisted of 13 students, with a gender balance of 54% female and 46% male, and a diverse mix of backgrounds, including 30% international students. Before implementation, a questionnaire via Mentimeter was sent to the students to assess their self-perception of course engagement. Results showed that 75% of the students were moderately engaged in the lecture by

sometimes reflecting, joining the discussions, or asking questions. In contrast, 25% of students were slightly engaged in the course by mainly paying attention to the lectures but rarely joining discussions.

3.2 Course design and data collection

Three interventions based on the 1-2-Team Model were designed for the lecture, as shown in Table 1. These interventions, placed at the beginning, middle, and end of the lecture, gradually increased complexity. In the first and second interventions, students work in teams to find answers to a given problem through individual thinking, group discussion and class presentation, considering time limitations. A digital interaction tool Mentimeter (live vote polls), was used in the first intervention. The third intervention consists of two rounds, where students first find a problem themselves and then solve it. A digital questionnaire, also designed on Mentimeter, was shared at the end of the lecture to gather student feedback on their level of course engagement, the effectiveness of specific interventions on learning outcomes, and overall course satisfaction.

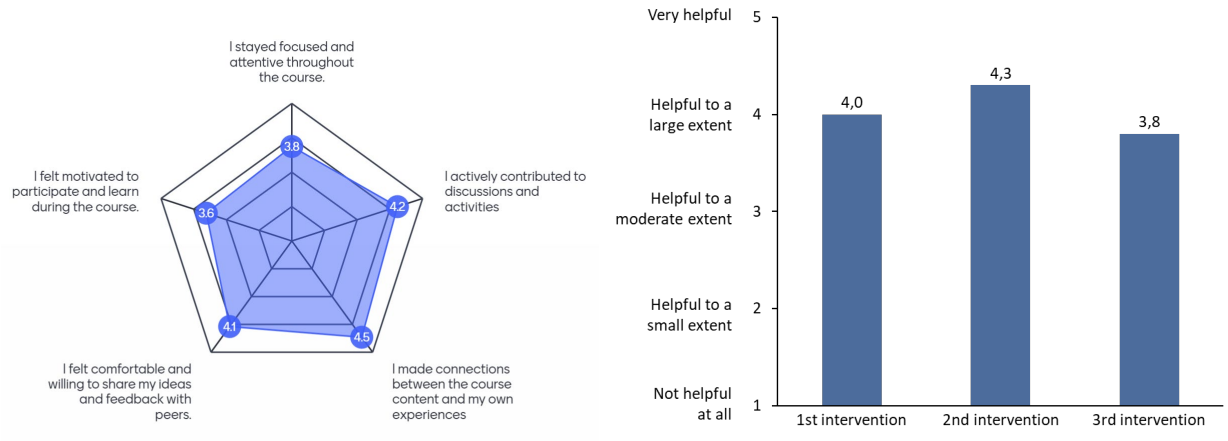
Table 2: Intervention design

No.	Problem to be investigated	Intervention implementation steps	Complexity
1st	Which renewable energy source accounts for the largest share of the total RE supply in EU? (Close question)	Step 1: Individual thinking Step 2: Group discussion and vote in Mentimeter Step 3: Show vote result & group presentation	Simple
2nd	Is biomass really sustainable and what are the potential risks? (Open question)	Step 1: Individual thinking Step 2: Group discussion Step 3: Group presentation	Medium
3rd	What challenges does solar PV face? Each group prepares three challenges for another group to choose and solve. (Open question)	*Round 1* Step 1&2: Individual thinking & Group discussion Step 3: Each group proposes challenges to another group in turn for *Round 2* *Round 2* Step 4: Group discussions to find solutions to the challenge Step 5: Each group presents solutions to the opponent group and receives peer-feedback	High

3.3 Data analysis

Figure 1 (a) evaluates the level of student engagement from five different dimensions. In the results, “1” represents “not engaged at all”, while “5” represents “very engaged”. Results indicate that the scores of all dimensions are above 3.5, which means that the students were engaged in the lectures at a quite good level in their own self-perception. The students scored relatively higher on “make connections between the course content and own experiences” and “I actively contributed to discussions and activities”, which are 4.5 and 4.2 respectively. Figure 1 (b) quantifies the effectiveness of different interventions in enhancing learning outcomes. The results indicate that all interventions contribute to students’ learning, however, their varied effectiveness is identified. An average score of around 4 for the three interventions shows that the student finds the interventions helpful to enhance their learning gains to a large extent. A little decreased effectiveness was observed in the third intervention compared to the first two interventions, which involve peer feedback. According to a talk with the students, one possible reason could be the psychological safety issue. The setup of proposing challenges to another group made the students feel like competitors, which poses challenges of psychological safety because the lecture was placed at the beginning of the first semester

and the students were still in the early stages of building relationships and trust with each other, and they are reserved with engaging with unfamiliar peers.



(a) (b)

Figure 1: Results of student self-perception of course engagement and learning gains. (a) The level of student engagement. (b) The impacts of the interventions in enhancing the learning outcomes

4 Practical implications of the student engagement toolbox

Besides the example presented, Table 2 summarizes additional practical implications of implementing the student engagement toolbox. Educators in various contexts can use this table as a reference. The effectiveness of student engagement, potential application scenarios, possible risks, and corresponding risk mitigation strategies for each tool are summarized based on the authors' experience.

Table 2: A summary of the toolbox

Tools	Class size	Advantages	Potential risks	De-risk suggestions
1-2-Team	S	• Boost in-depth brainstorming • Offer opportunities for quiet students • Process can be adjustable and flexible	• Time-consuming for full process • Quality of group formation is critical	• Only take part in the process if time limits • Ensure diversity in group formation
Digital interaction tools	S/L	• Increase interactivity • Support anonymity • Facilitate teamwork • Support online teaching	• May not be feasible in resource-limited areas • Potential technical issues • Requires technical literacy	• Use non-digital alternative in resource-limited areas, e.g., sticky notes
Teamwork on cases	S/L	• Opportunities for sharing perspectives • Safe space to discuss expectations	• Potentially time-consuming • No tangible output unless exercise is expanded	• Set time limits and ask specific questions to avoid confusion and uncertainty

		• The fun aspect makes cases approachable and light-hearted	• Not all students respond well to fictional scenarios	• Clarify on a meta-level how this exercise is helpful and productive
Random interview	S/L	• Attract attention effectively • Facilitate discussion in complex open topics	• May cause student anxiety	• Create a psychological safe environment • Gradual implementation
Various Flipped Classroom Activities	S	• Boost learning in a fun atmosphere [a,b,c] • Improve communication skills[a, b] • Encourage teamwork & collaboration [a, c]	• Time-consuming [a,b,c] • May challenge psychological safety for introverts [a, b] • Resource limitations in a large class, e.g., purchase of games, lack of teaching assistant [c] • Students may focus on winning than reflection [c]	• Allocate a dedicated session with enough time [a, b, c] • Create a psychological safe environment [a,b] • Organise class reflection session [c]

Notes: In Class size, S represents small class with fewer students while L denotes large size; Marks applied to Role Play (a), Pecha-Kucha (b) and Fun Games (c)

The context of the course matters significantly when choosing specific student engagement tools. For example, for first year students, it would be good to keep a fixed group formation and use anonymous digital tools if needed. A good course design requires periodic student engagement without disrupting lecture flow, so it can be helpful to combine some small interventions (e.g., questions) with larger ones (e.g., think-pair-share) in a lecture. Also, the complexity of interaction ideally increases gradually from the beginning of a course to the end.

It was also found that psychological safety plays a significant role in ensuring that the interventions can be implemented as expected. The teachers ideally focus on building a safe and inclusive environment where students feel comfortable when making mistakes, as this can reduce anxiety and encourage student involvement, regardless of the personality and gender of the students.

5 Conclusion

This paper presents a practical student engagement toolbox for systematic PBL setting in higher education, integrating various student-centered tools to enhance student participation and stimulate active learning based on constructivism theory. The toolbox offers flexibility through tools such as the 1-2-Team, digital interaction tools, and flipped classroom activities, making it adaptable to diverse teaching contexts. The findings suggest that creating a psychologically safe classroom environment is crucial for maximizing the effectiveness of these tools. A safe environment fosters student involvement, reduces anxiety, and encourages meaningful participation. Additionally, tailoring interventions to the course context and gradually increasing the complexity of activities contributes to a more engaging and dynamic learning experience.

References

Aalborg University. (2015, November). *Problem-based Learning (PBL) at Aalborg University*. https://prod-aaudxp-cms-001-app.azurewebsites.net/media/mmmjbthi/pbl-aalborg-model_uk.pdf

Biggs, J. (2003). Aligning teaching and assessing to course objectives. *Teaching and Learning in Higher Education: New Trends and Innovations* , *2*(4).

Bundick, M. J., Quaglia, R. J., Corso, M. J., & Haywood, D. E. (2014). Promoting Student Engagement in the Classroom. *Teachers College Record: The Voice of Scholarship in Education*. https://api.semanticscholar.org/CorpusID:140349901

Chen, J., Friedrichsen, D., Yuan, M., & Jiskani, I. M. (2024). *Improving Student Engagement in a Systematic PBL Setting: Design, Practice, and Interventions*.

Du, X., Chaaban, Y., Sabah, S., Al-Thani, A. M., & Wang, L. (2020). Active learning engagement in teacher preparation programmes - A comparative study from Qatar, Lebanon and China. *Asia Pacific Journal of Education*, *40*(3), 283–298. https://doi.org/10.1080/02188791.2020.1717436

Hansen, S., & Christensen, J. L. (2024). *1-2-team: Til gruppen der vil, tør og gør - kreativt gruppearbejde*.

Hendry, G. D., Frommer, M., & Walker, R. A. (1999). Constructivism and Problem-based Learning. *Journal of Further and Higher Education*, *23*(3), 369–371. https://doi.org/10.1080/0309877990230306

Jensen, K. J., & Cross, K. J. (2021). Engineering stress culture: Relationships among mental health, engineering identity, and sense of inclusion. *Journal of Engineering Education*, *110*(2), 371–392. https://doi.org/https://doi.org/10.1002/jee.20391

Kolmos, A., Fink, F. K., & Krogh, L. (2004). *The Aalborg PBL model : progress, diversity and challenges*. https://api.semanticscholar.org/CorpusID:15269313

Krause, K., & Coates, H. (2008). Students' engagement in first-year university. *Assessment & Evaluation in Higher Education*, *33*(5), 493–505. https://doi.org/10.1080/02602930701698892

Moorhouse, B. L., & Kohnke, L. (2020). Using Mentimeter to Elicit Student Responses in the EAP/ESP Classroom. *RELC Journal*, *51*(1), 198–204. https://doi.org/10.1177/0033688219890350

Parsons, J., & Taylor, L. (2011). Improving Student Engagement. *Current Issues in Education*, *14*(1). https://cie.asu.edu/ojs/index.php/cieatasu/article/view/745

Verdín, D., Godwin, A., Kirn, A., Benson, L., & Potvin, G. (2018). Understanding How Engineering Identity and Belongingness Predict Grit for First-Generation College Students. *School of Engineering Education Graduate Student Series.*

Wedemeyer, C. A. (2010). *Learning at the back door: Reflections on non-traditional learning in the lifespan*.

Wright, G. (2011). Student-Centered Learning in Higher Education. *The International Journal of Teaching and Learning in Higher Education*, *23*, 92–97. https://api.semanticscholar.org/CorpusID:154833238