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Summary

There have been, and still are, considerable efforts to stimulate interdisciplinary research to tackle interesting research questions and address some of the complex societal challenges we are facing in the 21st century. Therefore, the current STEM education needs to provide opportunities for students to develop an interdisciplinary mindset and to actively engage them in solving societal issues early on during their degree. With these goals in mind, we designed a set of three interdisciplinary courses focused on the physics of social systems, or Sociophysics, using Challenge-Based Learning (CBL) as an instructional approach. Our aim was to offer students the freedom to define their projects while supporting them with a robust framework capable of helping them rapidly define their challenge (via CBL) and efficiently work on it (via Scrum). Since CBL is a new educational framework for most students and it relies on the students-driven initiative, we designed a learning dashboard specifically aimed at providing efficient feedback and supporting the development of students' research and teamwork skills. We found our dashboard to be highly effective in providing both qualitative and quantitative support for students' progress in their self-defined projects, allowing scaling-up of CBL-based educational settings.

Keywords: learning dashboard, (peer) feedback, physics education, interdisciplinary education, challenge-based learning;

Type of contribution: Best practice extended abstracts

1 Designing a CBL course in Sociophysics

To make students aware of the complex interplay between scientific and technological innovation with societal and ethical aspects the USE (User, Society and Enterprise) learning line trajectories were introduced at the Eindhoven University of Technology (TU/e), typically consisting of three subsequent courses across three quartiles (3 x 8 weeks). A good example is the unprecedented availability of data in modern society, which has led to a vast number of applications of physics (e.g., Schweitzer 2018) that require collaboration with other disciplines to produce valid solutions. Therefore, we (led by the first author) designed an elective USE learning line on the physics of social systems, where students are taught how to bring mathematical, physics-based (model-driven), and machine learning (data-driven) modeling approaches together with ethics and psychology and apply them, for example, to modeling of crowd movement around busy spots in cities (e.g., Pouw 2020). While quantitative approaches inspired by fluid mechanics or statistical physics can be used to model crowd movement, understanding human perception, experience, motivation, and decision-making, as provided by psychological theory and methodology, is needed to improve interpretation and speed up modeling efforts. At the same time, one needs to be knowledgeable of the ethical and legal restrictions when establishing and processing large datasets, especially now that these increasingly tend to cross the threshold of personal privacy.

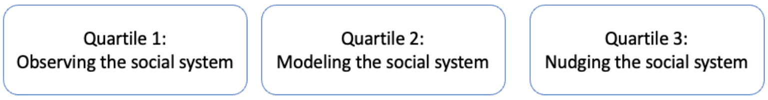

Figure 1: The three Sociophysics courses make up a full learning line focused on solving challenges around safe and efficient crowd control on busy train platforms.

1.1 Challenge-Based Learning

The students taking the learning line come from diverse backgrounds, mainly in their second year of study with majors in physics, mathematics, electrical engineering, and computer science. The structure of the three courses is rather similar and students work through each course (over a quartile period) on slightly different aspects of the same project, to be completed at the end of the third course of the learning line (see Fig. 1). For our learning line, it was important to involve a societal stakeholder (in this case, a railway company) that could provide a real-life case presenting an open-ended challenge ("The Big idea") for students to solve. To help students define their research question (rather than being given one), we have set up a pedagogical framework that ended up aligning closely with CBL (see Fig. 2), a relatively new teaching approach defined by Apple Inc. (Nichols & Cator 2008), which has since been applied to higher education as well (Gallagher & Savage 2020).

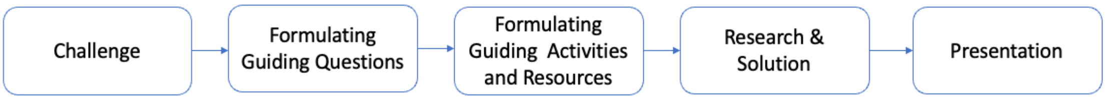

Figure 2: For each of the 3 courses students go through the same challenge-based learning set-up (sketched above).

By working on a challenge *defined by the students themselves*, students acquire and apply the relevant technical skills from physics and psychology to model social systems (e.g., human crowds) by re-formulating the stakeholder's problem into research (guiding) questions that also incorporates considerations from ethics and psychology. This creates engaging learning environments in which students are active participants rather than passive "absorbers" of knowledge. Furthermore, by defining their own research questions, the students take ownership of their learning, which is shown to be beneficial for success and retention of STEM students (Rodenbusch et al. 2016). The students' teams work on their challenges supported by academics from each of the disciplines (physics, ethics and psychology). Day-to-day team support is given by teaching assistants (TAs) who act as CBL coaches and help facilitate teamwork (as "Scrum masters"). The project results are delivered as a report and presented to the stakeholders at the end of each quartile period.

2 Designing a custom-made learning dashboard to support learning

After the initial delivery of the courses (Sep 2020 – Apr 2021) we experienced difficulties in monitoring the effective way of working of the student teams. It is essential to provide feedback to the students efficiently, especially during the first few weeks of the course when they need to define, through iterations, their guiding questions. If their guiding questions are too broad, too vague, or too specific (e.g., they assume already part of the solution), it is then difficult or even impossible to translate them into concrete (guiding) activities for students to work on. And if this is not addressed early enough, it causes cascading problems as the student teams progress through the learning line. For that reason, we developed, a fully in-house, custom-made learning dashboard to enable: 1) a faster turnaround of student-to-teacher-to-student feedback, 2) real-time monitoring of student teams' performance, and 3) provide a transparent teamwork framework that enables peer feedback.

2.1 The key features of the learning dashboard

Faster turnaround of feedback: As mentioned before, one of the main characteristics of the CBL approach to learning is that students are not given a pre-defined question but must think of "guiding" questions to solve themselves, based on the challenge they chose. Since the quartiles are only eight weeks long, guiding questions need to be finalized within about two weeks, to leave enough time for getting through the rest of the CBL process (Fig. 2). The dashboard is, therefore, used to enable students to upload questions and seek faster feedback at any point, rather than wait for scheduled class time (4-hour blocks twice a week).

The lecturers can then check the dashboard on a regular basis and provide frequent succinct feedback. The guiding questions are given zero to five stars rating based on the considerations such as: is this question relevant to the challenge or specific enough, are there enough questions asked to provide a solution to the challenge, etc. The students can then review the feedback quickly and submit updated questions (see Fig. 3, left). The average of the ratings should be increasing over the weeks based also on the qualitative feedback that students receive as well. This way the lecturers can address a lot of students' questions in a short period of time and the students can get feedback faster, enabling them to fine-tune their guiding questions in a short period of time (Fig. 3, bottom right).

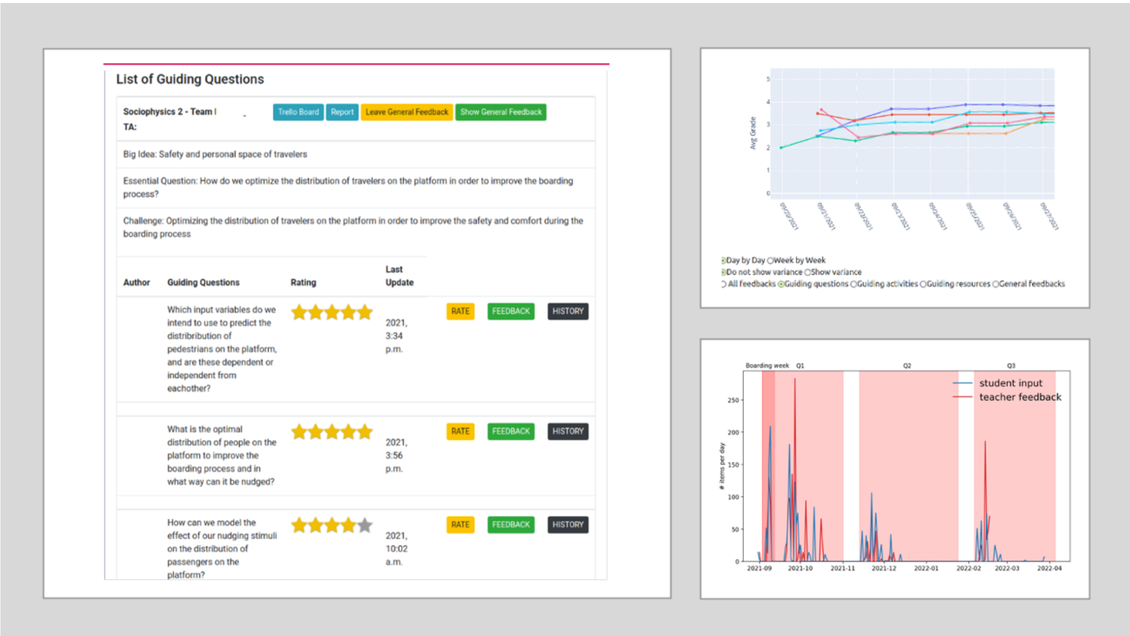

Figure 3: (left) Instructor's view of the learning dashboard for each team – the guiding questions are rated quickly from zero to five stars, and by clicking on the "feedback" button in the tab, the lecturer can leave written feedback as well. (top right) The lecturers and TAs can also monitor the weekly average rating of the team to identify as soon as possible groups requiring additional support. (bottom right) The number of questions (blue) and answers (red) per day over a period of three quartiles during the 2021-2022 academic year with 5 student teams (28 students). The most intense question-feedback period is at the start of each quartile, especially quartile 1 (Q1) when defining the guiding questions is conducted for the first time.

Real-time monitoring: The second key function of the dashboard is that the responsible lecturer can monitor in real-time how student teams are progressing throughout the course by viewing the average rating score (Fig. 3, top right). This helps identify early possible signs that the team is experiencing difficulties or underperforming consistently so that the lecturer can engage more with those students and provide additional specific support.

Visual representation of student teamwork: The third key function of the dashboard is to provide a transparent framework and visualization for students' teamwork. Students are usually not enthusiastic about teamwork and instructors often do not formalize this aspect of learning (e.g., Dunne & Rawlins 2000). Students need to be aware of team processes and be accountable for their contribution to their team and their project (Tarricone & Luca 2002). Therefore, we introduced Trello boards and Scrum-like project management to formalize the project process, and we introduced the peer-review feature in the dashboard to help students be accountable to their teammates. Every week, the students rate each other and themselves (from zero to five stars) on six aspects: participation, leadership, listening, feedback, cooperation, and time management (this year we also added "quality of the work"). The students can also provide written comments that only the instructors can view (Fig. 4). This way the TA can become aware of any possible issues, which can then be discussed privately or with a whole team in weekly meetings. The responsible lecturer can again monitor in real-time how individual students are progressing and offer additional support to both the students and the less-experienced TA if needed.

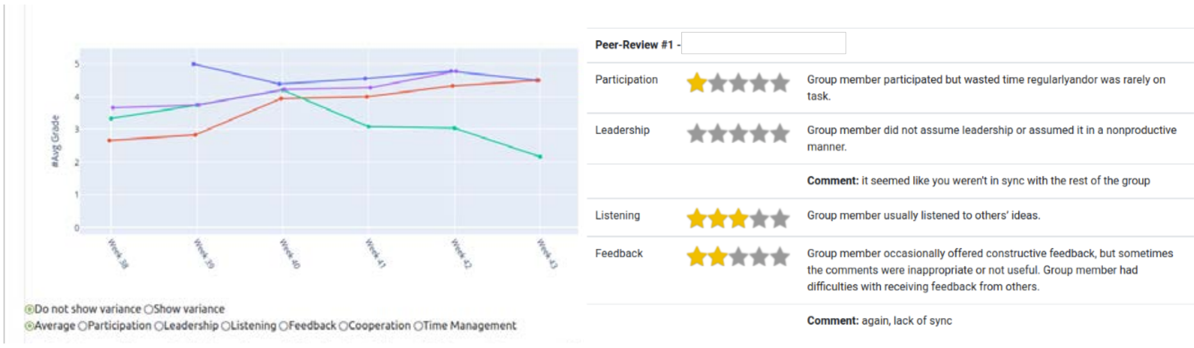

Figure 4: Instructor's view of the peer- and self-review feature of the dashboard. The quick overview of the weekly average rating (left panel) can help spot any issues within the team, and students' written comments can help the TA to facilitate more informed and efficient team meetings.

3 Results and summary

We wanted to investigate student perception of our courses, and thus with the 2021-2022 cohort (28 students), we collected quantitative data via an anonymous survey, of which 11 students (40%) responded:

- 80% of the respondents agreed that exploring how physics can be applied to societal problems was very important for them and that working with external partners was motivating for their learning;
- 70% of the respondents agreed that the possibility and freedom to shape their own project was motivating for them, helped them improve their interpersonal and team-working skills, and increased their ability to think about topics in an interdisciplinary way; and
- 90% of the respondents agreed that working on their projects in this course helped them gain useful skills for their future studies and career.

Rather than using commercially available platforms, we designed our learning dashboard in-house to be able to introduce new functionalities and quickly adapt the dashboard to our needs. The development of the dashboard has been conducted as the 2021-2022 courses were taking place, refined by the constant feedback provided by the instructors and the students. Therefore, from the 2022-2023 cohort with 80 students enrolled, we collected qualitative data via an anonymous survey containing two open-ended questions on students' perception of the dashboard functionalities, to which 43 students (54% of the cohort) responded. From the responses to the first question "Which aspect(s) of the learning dashboard do you find most useful?", we find that:

- 58% of the respondents listed the (rapid) feedback feature,
- 19% of the respondents listed the peer feedback feature,
- 17% of the respondents listed visual representation of the "CBL overview", which refers to the graphical representation of the link between the guiding questions, guiding actions and guiding resources, or in the words of one of the students "It helps you to think about what you want to investigate in more detail".

From the responses to the second question "Which aspect(s) of the learning dashboard do you think could be improved?", we find that: most suggestions were related to the way editing of the questions could be improved and streamlined, a couple of respondents suggested that peer feedback every week could be reduced to once every fortnight, and a couple of respondents suggested that there could be an email alert to the instructors after the students update their entries for even faster feedback response, as well as an email reminder for the students to complete their peer review.

Therefore, the advantages perceived by the students align well with the intended purpose of the dashboard and we see that there is an interest in the implementation of additional automation and scheduling functionalities.

In summary, our students have demonstrated a willingness to learn physics in a new way and build broader knowledge and skills than in a more traditional physics course. Our experience shows that a carefully designed learning tool has enabled scaling up a CBL course initially designed with a cap of 20-30 students to be scaled up to larger class sizes (around 100) while maintaining the quality of engagement between the lecturers and the students. We believe that this framework, instead of simply teaching physics to students, support them in learning how to become physicists and how to integrate quantitative approaches with ethics and psychology to tackle complex multidisciplinary societal challenges.

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