



Delft University of Technology

Methodology on Active Teaching and Learning on Open SDI

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Methodology on Active Teaching and Learning on Open SDI

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Short Description:

This report looks at different methods of active teaching and learning and the application of these methods at the partner universities of the SPIDER project. Different methods of on-campus and online teaching are presented and reports on experiences in their application at the partner universities are discussed. In combination with the results from Intellectual Output (IO) 4, this results in best practices for Open SDI Education.

Keywords:

Spatial Data Infrastructures (SDI), Open SDI, education, academic courses, active teaching and learning

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1 Introduction

1.1 The SPIDER project

In the past 20 years, European public authorities have invested considerable resources in the development of spatial data infrastructures (SDIs). With the European INSPIRE Directive as an important driver, national SDIs were developed throughout Europe to facilitate and coordinate the exchange and sharing of geographic data. These SDIs initially focused on data sharing among public authorities. Together with the implementation of open data policies to make government data available and reusable without any restrictions, public administration started to make a shift towards the establishment of an open SDI, in which also non-government data and actors are considered as a key to the performance of the infrastructure.

The concept of Open SDI is about openness to new stakeholders in the spatial data ecosystems, besides the traditional mapping agencies that have been dominant for many years. SDI development and implementation should not only involve the traditional data producers, but also key stakeholders outside the government, such as citizens, companies, and small and medium-sized enterprises (SMEs) in particular, NGOs and education and research institutions, which could be both producer and user of spatial data. Open SDI also is linked to developments and trends in other domains and fields, such as open government, open data, open science, open data, and open software. This new paradigm on SDI means that new, particular skills are required, which currently are not offered by traditional SDI education. Open SDI Education requires a shift in both the ways of teaching and learning, which should become more active, and in the content of education, include new concepts and topics. Furthermore, collaboration between higher education institutions (HEIs) is essential, since implementing - and teaching on - Open SDI requires a multidisciplinary approach, involving experts from different fields. The main objective of the SPIDER project is to promote and strengthen active learning and teaching towards Open SDI. Sub-objectives of the project are 1) to explore, develop and implement the concept of Open SDI as a new paradigm to SDI education; 2) to promote and facilitate active and multidisciplinary learning and teaching on Open SDI; and 3) to drive the exchange and update of Open SDI teaching and learning resources by teachers and students.

1.2 Methodology on Active Teaching and Learning on Open SDI

In a constantly changing society, it is necessary to rethink teaching methods on a regular basis. The technical changes that have taken place in recent decades have changed our everyday life to such an extent that our thinking structures have evolved, and problems are approached differently today. Therefore, existing teaching methods must be reconsidered and adapted to the development of our society. Passive frontal (face-to-face) teaching no longer seems appropriate, as numerous studies have already questioned its effectiveness (Bonwell & Eison, 1991; Renkl et al. 2002; Michel, et al., 2009).

Students, who participate in active learning activities, are engaged in higher-order thinking tasks such as analysis, synthesis, and evaluation. Recent studies show that students engaged in active learning learn more than they thought compared to traditional lectures (Deslauriers et al. 2019). In addition, the increasing number of online offerings in schools and especially universities make previous teaching methods more difficult to apply. Teachers, therefore, feel more responsible for adapting their teaching methods and to align their teaching methods with higher-order learning processes. One goal of the SPIDER project is to promote and support active learning and teaching on Open SDI.

Therefore, the SPIDER project worked on a Methodology on Active Teaching and Learning on Open SDI. This methodology builds upon theories, approaches, methods and best practices on active teaching and learning, and will inspire and support teachers and trainers involved in SDI education and training to make their teaching on - Open - SDI more active. From a student perspective, the Methodology on Active Teaching and Learning on Open SDI aims to promote the creation of knowledge by the students themselves, as an alternative to the traditional transfer of knowledge from teachers to students. For students to learn, they should be active instead of passive, and the focus in teaching and learning should be in the student, instead of the teacher. The SPIDER methodology will support teachers and trainers in designing and implementing active teaching and learning on Open SDI, allowing students to construct their own knowledge through experiences

1.3 Structure of the document

The document is structured as follows. After this introductory section, the Methodology provides a short, but clear explanation and discussion of what active teaching and learning are, and what benefits it provides in section two. The third and fourth section provides guidance through the different steps of the active teaching and learning process, and an overview of different active teaching and learning methods that can be used. The Methodology will include examples and best practices in active teaching and learning, not only from the SDI domain but also from other fields and domains.

The best practices in the domain of SDI will mainly consist of practices developed under Intellectual Output 4.

2 Introduction to Active Teaching and Learning

2.1 The Concept of Active Teaching

Active teaching and active learning is a broad concept. Roughly speaking, active teaching refers to the methods that will dynamically involve students in the learning process (Meneske et al. 2013). Active teaching focuses on the communication between students and teachers. Interactive teaching methods constantly integrate the students into the teaching process, whereby the students, often subconsciously, guide the lessons. Thus, teachers adopt more of a role of being a coach for students to guide them towards acquiring knowledge. The aim is to set up a learning environment that supports learning activities that are aligned with the desired learning outcomes (Biggs 2003). The different methods for actively involving students are broadly diversified. These include, for example, the use of modern media, well-known group work, presentations, open discussions or even role-plays. In Chapter 3, we describe a number of the more commonly used potential active teaching methods. Teachers themselves are sometimes unaware of how many methods of active learning they have already used, as they have never been familiar with the concept of active teaching. (Hackathorn et. al., 2011)

2.2 The Impact of Active Teaching and Learning

Active learning and its effectiveness have been studied in many educational disciplines. Studies have shown that although active learning appears to have better learning outcomes, there are also studies showing opposite effects, see e.g. Meneske et al. (2013) for an overview of such studies. Meneske et al. (2013) found that active learning methods may have more significant effects on learning in an engineering course in which higher levels of learning are needed to succeed. Chi (2009) developed a taxonomy framework in which active learning methods are divided into three modes of activities: *interactive*, *constructive*, and *active*. This framework was further refined as the so-called ICAP framework defining cognitive engagement activities differentiated into four modes: Interactive, Constructive, Active and Passive (Chi & Wylie 2014).

Interactive learning usually refers to methods involving students interacting with a computer system or other tools, such as interactive videos. Interaction can also relate to a dialogue between people or between a student and a system (Chi & Wylie 2014). A student has some degree of control over the system, control over timing and duration of a presentation without necessarily having to give a response. Interactive may also refer to a system that does allow room for feedback, e.g. a tutoring presentation and test, in which feedback is provided for the (in)correctness of the provided answer. Interactive learning, according to Chi (2009) refers to a system rather than the interaction between a student and a system. In interactive learning, students build on knowledge of others, e.g. co-students and teachers, to incorporate this knowledge into their own bank of knowledge.

Constructive learning is defined as meaningful learning in which a learner actively builds a mental model of the system (s)he is to learn (Mayer & Wittrock 1996). Constructive learning is often associated with discovery learning, i.e. students construct the rules and the relationship they need (Chi, 2009). In constructive learning, students often must engage higher-order thinking skills, such as constructing a map, analysing, and reflecting on a problem, or generating a hypothesis. In the process, students acquire new knowledge by integrating new information with existing knowledge.

Active learning is associated with an entire system of activity involving the teacher, the student, the teaching materials, software, and the physical environment. Thus, active learning can be viewed to mean learning with interactions as a whole rather than just as a system (Chi, 2009). The students are carrying out a physical activity during class, e.g. geo-caching rather than just watching a video, in order to activate existing knowledge and apply that knowledge in practice.

After a literature review and reinterpretation of experimental studies, Chi (2009) found that all three modes are better than the passive mode in terms of student learning, but that there were also differences. Chi's study indicated that interactive activities were likely to be better than constructive activities, which were in turn better than active activities: $I > C > A > P$. Where Chi (2009) compared types of activities pair-wise, Meneske et al. (2013) carried out experiments in which all three forms were combined. They found that students performed significantly better in a constructive and interactive learning environment. Freeman et al. (2014) carried out a meta-analysis of 225 studies that reported data on examination scores or failure rates when comparing student performance in undergraduate science, technology, engineering, and mathematics (STEM) courses under traditional lecturing versus active learning. Their meta-analysis indicated that average examination scores improved by about 6% in active learning sessions, and that students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning. These studies show that a constructivist student-centric approach appears to be more effective than a transmission-intensive teacher-centric approach, at least for STEM courses, such as SDI courses. This does not mean that there is no room for traditional lectures as a teaching method nor does it mean that all students are engaged all of the time in active learning methods (Cao et al. 2020). It does indicate that active learning activities should be at least integrated in traditional - more passive - teaching methods.

2.3 Online Active Teaching

Modern teaching requires innovative teaching methods to meet today's requirements. Educational institutions can no longer rely solely on face-to-face events but must adapt to the digital world. The increasing number of distance learning courses, the urge to combine family and studies, as well as the trend towards self-study put the focus on digital offerings.

This poses great challenges for many educational institutions but pays off in special situations such as the Covid-19 pandemic (see Chapter 4), where face-to-face education and events are no longer

possible. Digital teaching offers new possibilities for educational exchange around the globe. The location factor of the students is no longer decisive, and the exchange of knowledge is optimized. The SPIDER project strongly benefits from this fact. It opens the possibility of conceptualizing Open SDI and raising awareness on Open SDI Education on a European level and increasing a Europe-wide exchange of know-how.

Besides the benefits especially for the SPIDER project, the obstacles of online active teaching must nevertheless be considered. Digitization or access to broadband internet is not at a uniform level throughout Europe. While some universities are pioneers in digital learning, others are not even adequately equipped with computers and stable internet. Furthermore, not all teachers - or even students - are sufficiently trained for digital issues. Additionally, through digital teaching, the social component of active learning is coming under pressure. Students tend to interact less with each other, and it is more difficult for the teacher to get feedback on his teaching. If these problems are not addressed, a Europe-wide exchange will remain difficult. It is therefore important to use the appropriate active teaching methods in digital teaching.

Chapter 3.2 deals with a variety of Online Active Teaching Tools. Even though we are aware that the technical and educational conditions are different in each EU country, this issue shows some instruments that experience has shown to work well. The following Intellectual Output 4 (IO4) will show how each partner university uses these tools in daily teaching. It can serve as a guideline for other universities to follow.

3 The Active Teaching and Learning Process

The active teaching and learning process consists of three stages:

1. Orientation
2. Active processing, and
3. Evaluation and feedback.

3.1 Orientation

The main aim of the orientation phase in education is to motivate students to actively participate in the teaching and learning process. Motivation can be considered as the amount of effort a person is willing to exert in pursuit of a goal (Keller, 2006). A key challenge in education is to ensure and improve the motivational appeal of educational activities and materials.

It is the task of the teacher to gain the attention of their learners, but also to hold it throughout the entire lesson or class. Insights in the key elements and determinants of human motivation, is helpful to be able to motivate and stimulate students (Keller, 2006).

In this context, the ARCS model (Kelly, 1987) is a valuable tool to better understand the major influences on the motivation to learn, and to identify and solve problems with learning motivation. ARCS stands for Attention, Relevance, Confidence, and Satisfaction, which are the four major conditions that have to be met for people to become and remain motivated (Kelly, 1987).

In the orientation phase of active teaching, especially the aspects of relevance and confidence should be addressed. It is important that students are convinced of the relevance of what they have to learn, but also that they are confident that they are able to successfully complete the course.

Specific strategies exist to address each of the four conditions (Kelly, 1987). Examples of strategies focusing on the relevance of the education include:

- Experience: tell students how new learning will build further on and use skills they already have, and relate the current learning to prior experience and to the student's interests
- Present worth: clearly explain the current value of what will be taught
- Future usefulness: relate the teaching and learning to future goals

Strategies addressing the confidence of students include:

- Learning Requirements: Advise students of requirements (goals & objectives).
- Difficulty: Sequence activities in increasing difficulty with continual but reasonable challenge.

3.2 Active processing

Active processing refers to the learning activities themselves. Through these activities, students are actively engaged with the content, and this leads to the construction of knowledge. Because students do not just passively receive information from the teacher but actively process it, they better remember, understand, and acquire the relevant knowledge.

Activating students can be done in different ways, and not always requires a lot of modifications to existing – more traditional – teaching practices. Students can be invited to actively think along or to actively work. This can be expressed on a continuum of four categories of activation, depending on the extent to which modifications are needed:

1. Students think along
2. Students participate individually (individual action)
3. Students participate in pairs or in groups (group action)
4. Students participate outside the contact moment

These four categories of activating students can be linked to the different levels of learning according to Bloom's Taxonomy (see Figure 1). For each of these four categories, multiple teaching methods both on-campus as well as online can be used.

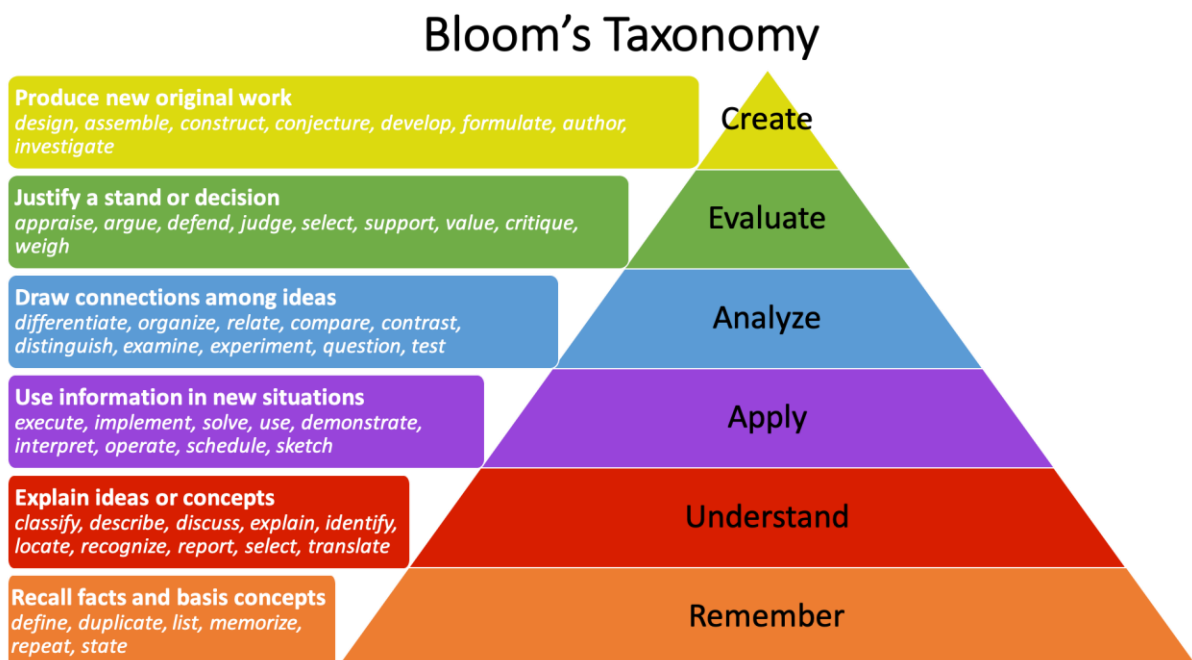


Figure 1: Bloom's Taxonomy indicating levels of learning (source: <https://www.bloomstaxonomy.net>)

3.3 Evaluation and feedback

The active teaching and learning process does not end with the processing stage. The third stage of evaluation and feedback is also crucial in activating the students, even after the learning activity itself.

The evaluation and feedback stage deals with discussing the outcomes of the learning activity and providing feedback to the students. Although feedback is an essential aspect of active teaching and learning, teachers often spend very little time on it, as they tend to focus mainly on the actual teaching activities. When planning education and teaching, enough time should be foreseen for evaluation and feedback.

A key advantage of active teaching and learning is that it allows teachers to regularly (even constantly) evaluate and provide feedback to students on how well they are doing. Students are not only assessed at the end of the course – when it is too late to intervene – but will be evaluated while they are engaging with the material. As students will be actively working with the course material, they directly receive information on how well they are doing. In addition, the teacher receives this information and constantly sees how well the students understand the material.

The feedback provided to students during the learning process is formative feedback, which is different from the summative feedback provided mainly at the end of the course. While summative feedback has an impact on the grade of a student, formative feedback is used to support the learning processes, and has no consequences on the grade.

Some key strategies exist for organizing evaluation and feedback in such a way that students will be activated:

- Students should be given the opportunity to share their outcomes or answers. This can be organized in different ways, as it is not always necessary that every single student shares its answer.
- It is not necessary to provide feedback to every single student. By providing feedback on a set of answers, other students can check their own answers based on this feedback. Students can also give feedback to each other (peer feedback) or it can be automated via online tools such as BuddyCheck, which can be integrated with online education platforms.
- Providing feedback is not only about giving the correct answer, it also deals with tackling common mistakes and explaining why certain answers or outcomes are wrong. It can be automated with the help of ICT or students can be provided with the right answers so they can check for themselves.

3.4 Teaching environments

Teaching can take place in different teaching environments, which can be on-campus, online and a hybrid environment. Van der Zanden et al. (2018) distinguish four different types of teaching classifications:



Frontal Teaching is teacher-centred. The teacher, situated at the front of a teaching room, elaborates on a subject, shows presentations and/or uses the board, and explains topics. Students take home individual work or group assignments.



Mixed practice is student-centred. Students follow classes with alternating practices, such as a frontal introduction and subsequently working in student groups on assignments. The teacher and assistants walk around to help where needed.



Collaborating focuses on teamwork and group assignments. Students have to apply their knowledge in projects and learn to communicate, collaborate, and cooperate in teams while they are coached by the instructor.



Testing is for students to demonstrate what they have learned, either as paper-based or digital testing. Digital testing has the advantage to support both campus exams and tests for online classes and MOOCs. Digital exam halls can also be used for computer practicals.

For Science, Technology, Engineering and Mathematics (STEM) courses, such as SDI courses, mixed practice and collaborating or even testing often take place in a Lab, a dedicated area on campus with specialist facilities, such as software and/or hardware. In Labs, students can develop practical skills hands-on, test conceptual knowledge, work collaboratively, learn to interact with specialist facilities, perform analysis on experimental data, and learn by trial and error (cf. Nedic et al. 2003).

4 Active Teaching and Learning Methods

As with all teaching methods, it is important that appropriate methods are selected to match the intended learning outcomes. It is equally important to select matching assessment methods to gauge how well the selected teaching methods have matched the intended learning outcomes (Biggs 2003), see Figure 2. Therefore, it is important that when intended learning objectives are formulated, a distinction is made between the different levels of learning according to Bloom's Taxonomy. It is also important to bear in mind that for teachers the final outcome of teaching is that students acquire the knowledge needed to meet the intended learning goals with the assessment only a means to test this and arrive at a final grade. However, for students the assessment is the most important factor. Students will learn what they think they will be assessed on and not on what the intended learning goals are (Ramsden 1994). The assessment criteria will be the starting point for students, whereas for teacher's assessment is the finishing point.

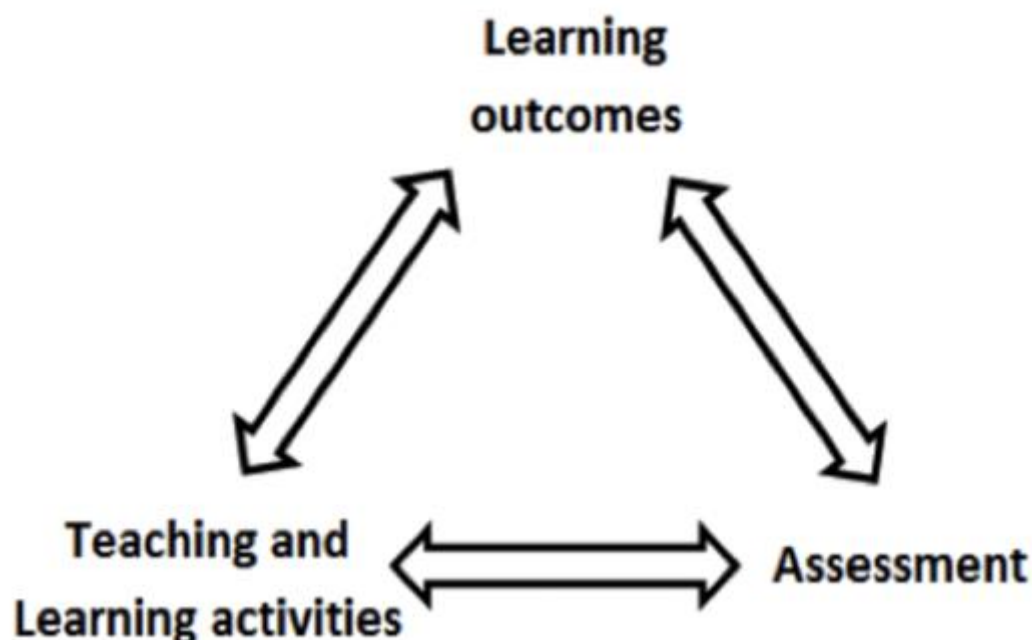


Figure 2: Constructive alignment of learning objectives, learning methods and assessment

Constructive alignment is relevant to passive teaching methods as well as to active methods, and to on-campus teaching as well as online teaching.

As shown in Section 1.2, implementing active teaching methods appear to be more effective than traditional passive teaching methods, at least for science, technology, engineering, and mathematical courses. From our literature research, we find many different active learning activities that can be

incorporated in teaching methods. These active learning activities can be adapted to address different levels of learning according to Bloom's Taxonomy.

Chapter 1 illustrated that active learning is more effective in engaging students to participate in acquiring knowledge. There are, however, many forms of active learning activities, and it is not always clear what the difference between the different active learning activities are. In addition, various active teaching methods can be mixed within one class session. In the next section we provide a description of a number of active teaching activities that can be used in higher education. These active learning activities can be grouped by the different categories of activation (students think along, participate individually, participate as pairs, participate in a group, and participate outside class). This overview is by no means exhaustive.

4.1 Active Learning Activities

The activities described below are based on on-campus attendance of students in frontal teaching and mixed practice environments but can be adapted to an online environment. The description of the methods builds on the educational programmes of Michigan State University¹, UC Berkeley Center for Teaching & Learning², the State University of Florida³, Delft University of Technology⁴, and KU Leuven⁵. In Table 1 we show active learning activities categorised by levels of activation.⁶

Table 1: Active learning categories categorized by levels of activation

students think along	students participate		
	individual activities	pair/group activities	activities outside classroom
concept map by teacher	concept map/ mini map by student(s)		
making thought process more explicit	asking questions	jigsaw	flipped classroom

¹ <https://omerad.msu.edu/teaching/teaching-strategies/active-learning-strategies#collapseFifteen>

² <https://teaching.berkeley.edu/active-learning-strategies>

³ Office of Distance Learning. (2011). *Instruction at FSU. A guide to teaching and learning practices* (7th edition), Florida State University: 224. Retrieved from <https://odl.fsu.edu/sites/g/files/>, October 8, 2020.

⁴ <https://ocw.tudelft.nl/courses/development-teaching-active-learning/>, October 8, 2020.

⁵ <https://www.kuleuven.be/english/education/leuvenlearninglab/academic-year-2020-2021/blended-learning/didactic-formats>

⁶ For a more comprehensive list of active learning activities for all levels of education, see e.g. <https://www.uis.edu/ion/resources/instructional-activities-index/>.

demonstrations	active listening	brainstorm	site visits / excursions
examples	active writing for reflection	class discussion	
rhetorical questions	classroom assessment techniques	student presentations	
guest speakers	portfolio	cases / role play / simulation	
		Peer Assisted Learning (PAL)	
		group work	

4.1.1 Students think along

These activities help the students to mentally process the information they are offered during classes. These activities can easily be adapted to online teaching.

Concept map

A concept map is a visual representation of content and core concepts, e.g. of a programme component or of a chapter. It shows how these contents relate to each other (interrelationships) in a knowledge network. A teacher can draw a concept map to explicitly show the content structure and correlation of the course topics. This could be a living document expanding with each new topic or zooming in to individual components for each new topic.

Making thought process more explicit

Students, unlike teachers who possess extensive domain-specific knowledge and who use shortened reasoning processes for problem-solving and can quickly make connections, often do not yet have this expertise. Therefore, students need to be more explicit in order to learn to interpret information, assignments, and tasks correctly. Teachers need to encourage students to mentally participate in the reasoning process and to make explicit why certain steps are taken by the students. Students are allowed to make mistakes, so that they can learn to reason in a logical way and can learn from their mistakes.

Demonstrations

A picture tells a thousand words, especially when complex processes or abstract concepts have to be explained. Research has shown that the effect of a demonstration can be enhanced when students not only observe, but also predict what the outcome of the demonstration may be and discuss the outcomes of the demonstration with other students (Crouch et al. 2004).

Examples

A similar activity to demonstrations is for the teacher to show examples of what is taught during classes. Such an example could be used throughout the entire course as a common thread. Another option is to let the students look for examples themselves.

Rhetorical questions

A teacher may trigger the thinking processes of students by asking a rhetorical question at the start of a lecture. Such a question may be a prelude of the contents of the lecture, a reference to the previous lecture or may be posing a certain problem. which the students can (help to) solve during the lecture. The strength of a rhetorical question is that students do not have to provide an answer immediately but that the question helps them to orientate themselves.

Guest speakers

As a way to link theory to practice, guest speakers could be involved in the course. Guest speakers may be involved in e.g. preparation of a case study project to provide more (hands-on) information. Academic experts or practitioners may be invited to tell the students about their specific field of expertise to broaden the horizon of the students.

4.1.2 Student participation as an individual action

Concept maps and mini maps

Concept maps, as a way of described above, can also be drawn by students, either as an individual activity or in small groups. By drawing a concept map, the prior knowledge of students is activated, and allows an insight into the way students structure the information. This activity may be carried out during class or outside class as a mental summary.

Mini-maps are similar to concept maps, but students are given a relatively short list of terms (usually 10 or fewer) to incorporate into their map. To use this approach, students are provided with a list of major concepts or specific terms and are asked to arrange the terms in a logical structure, showing relationships with arrows and words. The mini-maps can then be shared and students can clarify any confusing points.

Asking questions

By asking questions during class, students are encouraged to be actively involved with the subject matter during class. The advantage of this form of interaction is that the teacher receives a quick insight into whether students are still on board and that students receive feedback in an indirect way. It is important that the questions match the level of the intended learning outcomes of the lecture, i.e. match Bloom's taxonomy. In addition, it is important that students are aware that answering questions is part of the teaching method, that students are given sufficient time to think about an answer and that students are allowed to make mistakes. → *see also: class discussion, Think-Pair-Share TPS, online polling*

Active Listening

Active listening provides students with the opportunity to practice restating what they have just heard. By restating concepts in their own words, they gain a deeper understanding of the material and also recognize where their understanding of the material is insufficient. This activity can, for instance, be done by pairing the students. One student then explains a concept to the other student. The other student paraphrases what the first student had just said and asks questions to clarify what the first student meant. This exercise teaches students to listen and reflect without trying to analyse, judge or lead the direction of the discussion (Office of Distance Learning 2011).

Active writing for reflection

Active writing provides students with the opportunity to reiterate and reflect on what was said during lectures or what was stated in a textbook or journal article. Usually this activity will involve an assignment in which students are asked to write a summary or a short essay about a specific topic. By putting into writing what was said during classes or stated in the provided literature, students are able to clarify the material for themselves and see what they still need to make sense of the concept. By sorting and organizing the material so that they can comprehend the contents, students are able to see the bigger picture and help them to see relationships between the selected topic and other subtopics. Active writing can be useful to gauge student learning as students are required to study course material in depth and remain attentive during classes. Peer review by students can be very constructive as the students will gain an insight into the processes of reviewing and assessing academic writing. Below, we provide a few examples of active writing exercises.

(1) One-minute papers

Students are asked to write a one-minute paper during class, in which they write about what they have learned. Time during classes can be used by students to discuss their papers. This activity can also be employed during classes by asking students to write down everything they know about the topic and then have a few students share their results as an input for a class discussion. This activity can also be assigned to student groups whereby each group peer- reviews and/or edits each other's

work. The one-minute papers can also become input towards a paper to be submitted at the end of the course. This can be a good way of coaching students towards writing a scientific paper.

(2) One-sentence summary

At the end of the discussion or class, students have to summarize the overall concepts in a one-sentence format: What, how, why? The one-sentence summaries will stimulate the students to formulate the essence of what was just treated in class from their own perspective.

(3) Muddiest point

This is a variant of the one-minute paper, in which the students are asked to describe what was the most difficult point of the lesson, by e.g. asking them “What questions remain uppermost in your mind as we conclude this class session?”. This technique challenges students to think about what they have not yet understood and to make this explicit. This technique is particularly interesting when a large amount of new subject matter was treated during class.

(4) Formulating questions

Students can be asked to formulate an exam question based on the content they have had to study. This exercise can either be done individually, or as a group activity. This exercise is a good way to gauge what the students consider to be important elements of the class or course. and whether they are able to match intended learning outcomes with the assessment. By asking students to answer each other’s questions, a teacher can gauge the level of processing the learning materials.

Classroom assessment techniques

Classroom assessment is a formative rather than a summative approach to assessment. Its purpose is to improve the quality of student learning, not to provide evidence for evaluating or grading students. Classroom assessments provide feedback about the effectiveness of teachers and give students a measure of their progress as learners. Such classroom assessments are created, administered, and analysed by teachers themselves. Examples are one-minute papers, 1-sentence summaries, muddiest point, quizzes, students formulating exam questions, etcetera.

Portfolio

A portfolio is a goal-oriented collection of material created by a student that reflects his or her efforts, progress and achievements in a particular domain and will foster the integration of theory, action, self-reflection, and assessment. The way in which this is done, and the content of these assignments vary according to the focus of the portfolio. Roughly speaking, you can distinguish three types of portfolio: a showcase portfolio, an assessment portfolio, and a learning portfolio (cf. Fitch et al., 2008).

- A Showcase portfolio is mainly used within art-related directions in which the exhibition of collected artefacts is central.

- The emphasis in an Assessment portfolio is on the collection of assignments that are fully designed by the lecturer.
- In a Learning Portfolio, the emphasis is on the student's learning process in terms of both knowledge and skills. Competencies, reflection, feedback, and student ownership are important aspects here.

4.1.3 Student participation as a group action

Group work is beneficial to students' deeper learning and enables students to divide complex problems into smaller tasks, improve time management skills, cooperative and communicative skills (see e.g. Oakley et al. 2004). Group work often occurs in three forms: (1) cooperative learning, in which students cooperate in small groups on an assignment and, thus, give meaning to new information; (2) collaborative learning, in which students and teachers work together to create knowledge (e.g. a group paper); and (3) problem-based learning (PBL) in which an authentic and complex problem forms the starting point. Group work activities encourage students to articulate and examine newly formed connections. It also engages all students in thinking and writing, not just the active few.

(1) Cooperative learning

Think-Pair-Share (TPS) is a cooperative learning activity that can work in any size classrooms and in any subject. Instructors pose a question addressing higher order learning, students first contemplate the question (THINK) prior to being instructed to discuss their response with a person sitting near them (PAIR). Finally, the groups SHARE what they discussed with their partner to the entire class and discussion continues. Similar to class discussions, students get time to think critically, work in groups towards a common goal and increase their own and others' understanding (Lightner & Tomaswick 2017). A shorter version of TPS is the 'Turn-and-Talk' approach, in which the students are asked a higher order question and then have to turn to their partner to discuss.

A similar technique is the snowball technique where students first think about the assignment themselves, then in a group of two, followed by a group of 4, then 8 until in the end the discussion is with the entire class. An example assignment may be to discuss, convince and decide on the question what is the most valuable geographic dataset for an SDI? Student 1 thinks a parcel dataset, is then convinced by student 2 who favours a topographic dataset. Together they convince another group of two that it is topographic data. In the end, the entire class discusses and decides.

Class Discussions

Students learn more by participating in discussions as discussions provide an opportunity to express their opinions, brainstorm, share ideas and exchange experiences orally. Class discussions are widely used as an active teaching method to stimulate critical thinking of the students. Important issues related to class discussions are that:

- the concept to be discussed is introduced in advance so that students can prepare themselves and submit questions via an online discussion forum.
- the discussion leader sets the ground rules and structure for the discussion, as well as having explicit learning goals of the activity.
- all students are encouraged to participate rather than letting the discussion be dominated by just a few students. Therefore, small-group discussions, i.e. dividing a large class into groups of 3-4 students may be more effective.

A variety of active learning methods are available to stimulate class discussions. Here, we discuss a few methods, (1) debates, (2) idea line up, (3) catch-up, (4) four corners, (5) fish bowl, and (6) mystery quote. This list is, however, neither exhaustive nor are these methods limited to only class discussions.

a) Debates

Debates can be incorporated during classes. Debaters, or a team of debaters, are asked to debate a specific issue based on verifiable evidence. The debaters have to clearly state their point from a given perspective and to be persuasive. Other students can be assigned to be the judges of the debate. The judges can either draft their own criteria or be given a list of criteria on which they will base their verdict. A third group of students could be assigned to record at least one point that the debaters of each side should have made but failed to do so.

b) Idea line up

In the idea line up, the instructor chooses a question with a range of responses, e.g., “how old is your mother”, or “what is the impact of flying”. Students are tasked to stand in a line in an order. Online you can ask students to place themselves on a virtual number line instead.⁷ In SDI education, an example could be for students to rate openness of their NSDI on a scale from 1 to 10.

c) Catch-up

In a Catch-up activity, the teacher stops at a transition point in the lecture and asks the students to turn to their partner or work in a small group to compare notes and ask clarifying questions. After a few minutes, the teacher opens the floor to discuss the students’ questions.⁸

d) Four corners

Similar to the line-up idea, in Four Corners students will consider four given, but different responses to a question. For example, a teacher might ask, “What generation SDI is the SDI of Country X?” Responses (i.e., corners of the room) for consideration might include, “first”, “second”, “third”, and “open”. “Students are asked to go to the corner of the classroom that has the claim they agree with

⁷ Source: <https://www.nureva.com/blog/education/15-active-learning-activities-to-energize-your-next-college-class>; Clark & Sampson, 2007; <https://teaching.berkeley.edu/active-learning-strategies>

⁸ Source: <https://teaching.cornell.edu/resource/examples-collaborative-learning-or-group-work-activities>

most. If they think more than one answer is correct, they should just pick one of the corners they agree with. If they do not agree with any claims, they should go to the middle.”⁹

e) Chain notes

Another variety is ‘Chain notes’. Several questions are written on pieces of paper and passed each to a student. Students are asked to add a response and then give the sheet to another student. After all students (or a part of the group) has completed the exercise, the teacher will use the answers as input for the discussion.¹⁰

f) Fishbowl

In a fish bowl setting, there will be two groups: a small group of students sitting in the middle of the class (the inner circle) and the rest of the students observing the group (the outer circle). The inner circle discusses ideas and concepts, the outer circle only observes and takes notes. In the end the outer circle evaluates the discussion and decides which sides was most convincing.¹¹

g) Mystery quotation

This method tests how well students can apply their understanding of an issue or theoretical position. After they have explored a topic, the teacher shows them a quotation about it they have never seen before. Their task is to figure out the point of view of the person behind the quotation – and justify it to the class. Students can debate this issue in small breakout groups before beginning a whole-class discussion.¹²

Students have to be aware of the importance of the group discussion as a contribution to the learning objectives. Often, class discussions are incorporated with other teaching activities, such as lectures. The outcomes of the class discussion could be integrated into subsequent lectures or other activities.

Student presentations

Students have to do a presentation on a specific topic, either as a short presentation during the course or as a longer presentation at the end of the course. The presentation could be a slide presentation or a poster presentation. By having students present their work in front of their peers, they can practice oral communication skills and boost their self-confidence. The other students can practice their listening skills as observers (Sander et al. 2002). By providing students responsibility for (part of) the

⁹ Source: <https://teaching.berkeley.edu/active-learning-strategies>

¹⁰ Source: <https://www.nureva.com/blog/education/15-active-learning-activities-to-energize-your-next-college-class>

¹¹ Source: <https://teaching.berkeley.edu/active-learning-strategies> and <https://teaching.cornell.edu/resource/examples-collaborative-learning-or-group-work-activities>

¹² Source: <https://www.nureva.com/blog/education/15-active-learning-activities-to-energize-your-next-college-class>

course, students become involved and motivated. In addition, students can show whether they have gained insight into the course and the learning material (Clement & Laga 2006; Sander et al. 2002).

Quescussion

Quescussion is similar to Jeopardy. You will provide an answer/ statement and students have to provide the question. Such a game can be inspirational for the rest of the lecture. In an online setting make sure that all students are unmuted and that your audio system is picking up student voices clearly.¹³

Idea speed dating

Have students cycle through your space, or through breakout rooms in Zoom or Google Meet, sharing insights about a topic or their elevator pitch for an upcoming project. As they present their learnings multiple times on several 'speed dates' students' presentation skills and perspectives will grow.¹⁴

Real-time reactions

When students are watching a video, a mini lecture or another student's presentation, have them share their real-time reactions. This helps students spot trends and consider new points of view. You can set up a hashtag to allow for live tweeting, or use the chat function in the conferencing software.¹⁵

(2) Collaborative learning

With collaborative learning learners actively engage to process and synthesize information and concepts, rather than using rote memorization of facts and figures. Learners work with each other on projects, where they must collaborate as a group to understand the concepts being presented to them. There are many examples of collaborative learning activities, such as Jigsaw, Group Investigation (student groups narrow down a new and broad topic into smaller subtopics, each group researches their chosen subtopic and all subtopics are presented in class), developing a joint report or proposing exam questions, peer review.

Jigsaw

In this category of group work, students are divided into 'expert' groups of 3-6 students with the goal to acquire knowledge and expertise of a specific concept or question around a single topic. Each

¹³ Source: (<https://www.nureva.com/blog/education/15-active-learning-activities-to-energize-your-next-college-class>)

¹⁴ Source: <https://www.nureva.com/blog/education/15-active-learning-activities-to-energize-your-next-college-class>

¹⁵ Source: <https://www.nureva.com/blog/education/15-active-learning-activities-to-energize-your-next-college-class>

‘expert’ group is given a set amount of time to work on their assigned concept/question. After this time, the ‘expert’ groups are joined in a ‘home’ group and each group explains their ideas to the other groups.¹⁶

Brainstorming

During brainstorming sessions, students are encouraged to generate as many ideas about a topic as possible without judgement or criticism. The generated ideas can be physically posted on a board by using post-it notes or can be digitally posted on a discussion board. The posts can then be sorted, accepted, or rejected by the students. Students can use brainstorming as an opportunity to freely associate and to recognize that they have been engaging in a topic in ways they had not been aware of before. The outcomes of the brainstorming session can become the input for class discussions and/or active writing. Brainstorming sessions can be incorporated during lectures when the teacher stops the lecture and asks groups of students to reflect on a specific question. Brainstorming is most effective when carried out in smaller groups (2-4 students).

An alternative form of brainstorming is brainwriting. In this approach, students are given time to come up with their own ideas individually before sharing them out loud or posting them to an online whiteboard or other shared platform. Building in space for individual reflection leads to better ideas and less groupthink.¹⁷

Peer Assisted Learning (PAL)

Students can be asked to participate in teaching or supervising activities. Examples of such activities are mini lectures by students, peer instructions, peer reviewing or peer tutoring.

a) Mini lectures

With mini lectures some students are asked to present a mini lecture in front of their group or the entire class. Students can either pick a topic of their own interest, e.g. a mature-aged student sharing real-life approaches to a specific problem. Or students select a topic from a narrow list of topics provided by the teacher. The students will have to be guided in which teaching methods they have to use and be reassured as many students are very uncertain when having to stand up in front of their peers. However, this method can be very effective in that the students not only have to do research on the topic in advance but also on the most suitable teaching method to do so. If the students are asked to refrain from using traditional PowerPoint presentations, their creativity is triggered as well. Thus, it provides the student with a better appreciation of what teaching, i.e. transferring knowledge, is all about.

¹⁶ see e.g. <https://omerad.msu.edu/teaching/teaching-strategies/active-learning-strategies>

¹⁷ Source: <https://www.nureva.com/blog/education/15-active-learning-activities-to-energize-your-next-college-class>

b) Peer instruction

In peer instruction, groups of two to four students consult briefly with each other during a class on a concept question or assignment given by the lecturer. The concept question may be provided in a multiple-choice format to stimulate the creative processes. Students are given 1-2 minutes to think and to provide an individual answer via e.g. an online polling app. The teacher shows the distribution of the various answers. Students then discuss their answers in their assigned groups and resubmit an individual answer. The teacher shows the distribution of the second round of answers and discusses the 'correct' answer in class, see Figure 3. Peer instruction, when used effectively, goes beyond 'talk about this with your neighbour'. It is important to pay attention to the question you present, the instruction you give and the organisation of the peer instruction moment as part of a lecture.¹⁸

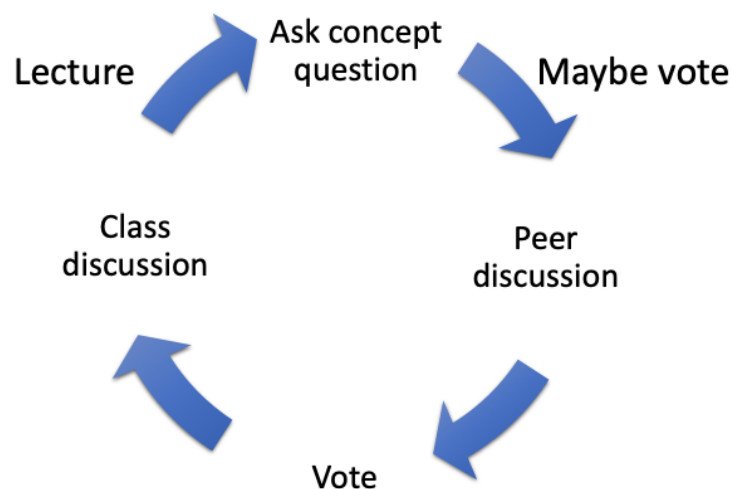


Figure 3: Peer instruction Model (source: Mazur, E. (1997). Peer Instruction: A User's Manual. New Jersey: Prentice Hall)

c) Peer review

In Peer Review, students have to provide feedback, usually on a written text. Research has shown that providing feedback is both beneficial to the student receiving feedback (receivers) as well as for students providing feedback (givers) (Lundstrom & Baker 2009), especially when this process is carried out more than once (Huisman et al. 2018). Providing peer feedback is considered beneficial to students' writing as it stimulates them to actively consider the task-specific processes and criteria, such as problem detection, problem diagnosis and revision strategies (Huisman et al. 2018). Peer review of students' presentations provides a simple and effective way of engaging student involvement in each other's presentations (Baranowski & Weir 2011). Peer review exercises can be incorporated in classes, e.g. as a pressure cooker peer review. In this exercise, groups of students are

¹⁸ See also <https://mazur.harvard.edu/research-areas/peer-instruction?page=1>.

either provided with a written text or exchange their work. Students are also provided with a matrix form that is to be used for scoring the text. Students then have a very short time (e.g. 30 seconds) to find specific details, such as a problem statement or research objective. The teacher rings a bell every 10 seconds. A score of 3 is provided when the detail is found in 10 seconds, a score of 2 for needing 20 seconds, a score of 1 for needing 30 seconds and a zero for needing longer than 30 seconds. The results are discussed plenary for e.g. 15 minutes (what made a detail clearly identifiable? what not?). After that, the groups discuss how the feedback provided plenary will assist their own work. Another exercise, which is especially useful at the start of a course, is to provide students with one text in different paragraph styles, let the students rate the different styles and then discuss why certain styles are more appealing. Exercises that are of more benefit to further into the course are for instance to ask the student to write a 200-word “making of” text in which the student reflects on her/his progress so far. Questions such as, what has been your strategy thus far, what feedback have you received during the course and how have you processed this feedback, are you happy with your progress so far, why (not), what do you still need to do, on what point(s) do you not need feedback right now, can be addressed in this 200-word paper. Alternatively, students are asked to formulate three open questions for their reviewer/teacher. The reviewer will address these questions in their feedback, in addition to the checklist criteria. Please make sure to ask open questions. Software, such as <https://feedbackfruits.com/peer-review> can be used to create peer review assignments for students to provide feedback to their peers on deliverables. Apps, such as <https://greatlibrary.app/> can be used to gamify the review process and to build feedback communities whilst remaining anonymously.

d) Peer tutoring

In Peer tutoring, groups of first-year students (tutees) meet at regular intervals (e.g. weekly) for an hour with one or two older students (usually second- or third-year students), the so-called PAL coaches or tutors. They support first-year students in improving their study methods. During these sessions various activities are possible such as comparing notes, making exercises together, summarising, working together, discussing certain topics.

(3) Problem-based Learning (PBL)

The theory behind this activity is that students benefit from constructive activities. By solving problems students learn to develop procedures that they can reuse in future, similar situations. Problem-based learning starts with a problem prepared by the teacher, which cannot be easily solved without doing research, collecting information and mastering subordinate skills. The teacher helps the students to formulate the problem, draft appropriate questions and to make effective decisions but the students are self-directed in their learning. By having to develop solutions to address a complex problem, their motivation is stimulated. Especially when working in groups, students learn to work collaboratively and gain analytical skills they can use in their future work.

There are many forms for problem-based learning. Students may work on a case study, in which students have to address a real problem in a real-life setting, or students may work on a simulated

problem. The structure can be predefined, or students may be allowed to determine their own structure. The problem may be approached from a single discipline or from an interdisciplinary perspective. Examples related to SDI education could be to (re)design an organisational SDI or a Digital Twin City.

Cases, Role Playing, and Simulations

Cases, role play, and simulation are all different forms of letting students engage with a (real-life) situation. In a case, students read about, listen to or watch a situation and characters from a distance. With role play and simulations, students experience what it is to be in the position of a certain character. Students are immersed in a replication of the real world where they are confronted with a situation or problem to which they have to respond. The focus of role play is to empathize with character, simulation interactions and different perspectives. Simulations go beyond role play in that - apart from the roles of the characters - situations, systems, phenomena and/or processes are also imitated. Students gain insight into the implications of their actions and decisions, and how different factors are connected. Students do not take on a role as individuals, but are part of a group, party, interest group or organisation.

a) Cases

Cases allow students to experience real-life situations such as complex and wicked problems in a safe environment. By working with cases students can use their analytic skills and propose solutions without direct consequences in real-life. Students also develop generic skills, such as having to consider different perspectives, stimulate empathy and learn that there may not be one simple solution. Often, it is the first opportunity for students to face a more realistic arena of what they have learned. In addition, deeper learning is stimulated by encouraging students to make connections between different contents, to integrate concepts from other subjects and to build on previous experiences.

b) Role Play

Role play can be an effective way for students to put theory into practice. "In a role-playing exercise, either a small group of students or the entire class are given a description of a scenario and their role in that scenario. They are then asked to assume they are in that situation and to respond to both the situation itself and to the actions of other role-players. Following the role-play, a guided discussion focuses attention on what happened during the role-play and provides performance feedback. This simulated interaction gives participants an opportunity to practice and receive feedback on important behaviours within the classroom." (Beard, Salas, & Prince, 1995 in Thong, 2016, p. 35-36). Although a scenario is provided, the students have the freedom to determine the outcomes. An example of role play in SDI education is a mock court, in which teams of lawyers moderated by one to three judges (small student groups) have to convince the jury (the rest of the students) of the application of the General Data Protection Regulation on a specific type of geographic data (e.g., Google maps/ aerial

imagery). A similar set up can be implemented in a debate on the merits of open data versus cost recovery regime, or to determine which high value datasets must be prioritized.

c) Simulation exercises and games

Simulations can be used as an active writing exercise by e.g. letting students write a short paper whilst in the role of another person or a short paper aimed at a different audience with different levels of knowledge on a specific topic. This way, students have to consider what that another person would do and for which reasons. The short papers could then become input for class or group discussions. Forms of active simulations are applications such as Minecraft, whereby (groups of) students are asked to recreate their neighbourhood or the university campus and indicate their favourite spots. This can be an effective exercise for newly-formed student groups to get to know each other.

Simulation games, also known as serious games or educational games, can be described as experimental, rule-based, interactive environments, where players learn by taking actions and by experiencing their effects through feedback mechanisms that are deliberately built into and around the game (Mayer 2009, p. 825). Serious gaming can be a powerful method to develop an understanding of highly integrated, large-scale systems with many actors dealing with deep uncertainties (Lukosch et al. 2018). In serious games, students can test their theoretical knowledge in a virtual practical environment. Serious games can vary from individual assignments to large groups, depending on the level of complexity and multi-actor involvement. For examples of serious games for research and education.¹⁹

4.1.4 Student participation outside the classroom

Flipping the classroom

A commonly used strategy for active teaching is to 'flip the classroom'. In traditional teaching strategies, the teacher is the focus during classes to disseminate information, answer questions, and to provide feedback to students. Outside the classes, students engage in other, independent activities, such as doing assignments or carrying out group work. In traditional learning, lower levels of learning, such as remembering are attained during classes and activities that involve higher levels of learning are acquired outside the classroom. By flipping the classroom, the focus shifts towards the student. Time during classes is used to introduce new concepts, explore topics more in-depth and to guide students, whereas time outside the classes is used to watch videos of the lectures and/or read background information. Thus, students can attain the lower levels of learning before the class and engage in higher levels of learning during class, see Figure 4.

¹⁹ See <https://seriousgaming.tudelft.nl>

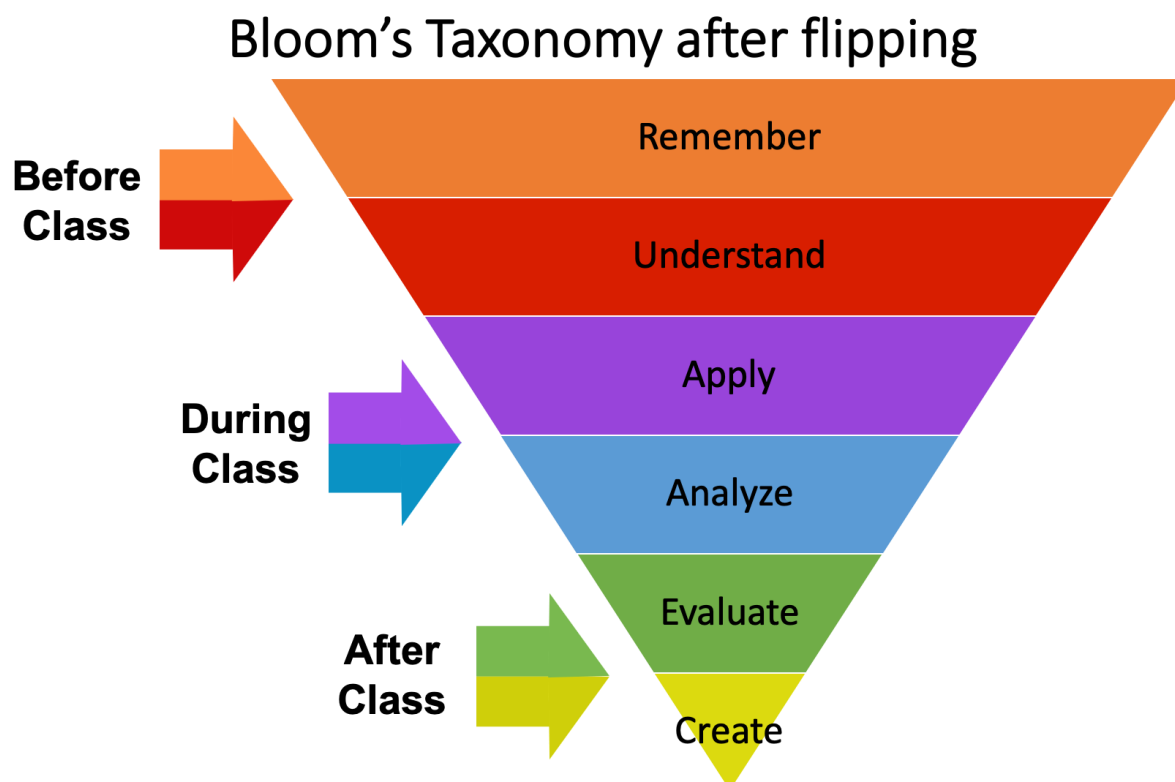


Figure 4: Revised Bloom's Taxonomy in a flipped classroom²⁰

Visual-based active learning

In these activities visual media are used to deliver a specific message. This could be in the form of pre-recorded lectures that students are asked to watch in preparation for a class. The advantage for students is that videos / clips can be stopped or paused at any time. Students can also be asked to develop a visual representation of an abstract concept, such as a chart or a concept map.

Alternatively, this method can also be used to let students prepare a visual presentation of a project they are working on, such as a poster or a video. Another activity is that students are asked during class to use an online whiteboard to write down any questions or comments during a lecture. This can be an effective exercise especially if the teacher makes a deliberate mistake, thereby triggering the students to react immediately.

It is vital though that using visual media are incorporated with other methods, such as students being provided with questions beforehand to be answered while watching the videos, class discussions or online quizzes afterwards, to ensure that this activity remains an active exercise. Asking students to

²⁰ Source: <https://omerad.msu.edu/teaching/teaching-strategies/27-teaching/162-what-why-and-how-to-implement-a-flipped-classroom-model>

use media technology to present their own ideas, triggers their creativity and can be beneficial for cohesion within a student group as students are able to demonstrate other skills they may have.

4.2 Online Active Teaching Tools

As described in the previous section, active teaching activities have become an important part of education now-a-days, proving their efficiency to have a greater impact on student's knowledge. Over the last year,, due to COVID-19 pandemic, educational methods have shifted towards online education, and new ways of active teaching had to be introduced. Although many of the active teaching activities described above can also be done online, they require different tools or software. Many teachers face the challenge of how to interest their students in active participation in online lectures in their home environment, so given below are some tools that are already in use around the world.

4.2.1 Break-out rooms for smaller discussions

Break-out rooms are a virtual replacement for small groups or pairs used in in-person training activities. This teaching tool offers the ability for groups to have internal discussions related to assigned tasks, and to come up with better ideas even when lessons are made online. When a class is divided into break-out rooms, the teacher can only be in one group at the time. Therefore, students must be focused on the problem at hand and be precise when presenting questions to the teacher in the given time. This way, student's engagement is empowered, which will directly lead to more active and progressive learning (also known as brainstorming). On the other hand, time needed to address a certain problem or question in break-out rooms is hard to determine, if only because it takes time for students to switch to their designated or selected break-out room. Differently skilled students will take different amounts of time to solve the problem, especially when there is no teacher or teacher assistant to guide the process. Because of that, preparation of the lesson should be carefully planned in advance.

4.2.2 Real-time online presentation and polling software

Real-time online presentation and polling tools are designed to ease the interaction between a speaker and the audience to make lectures more interactive and inviting. Such software tools can be used for interaction with students by employing different quizzes and questions or for polling opinions in real-time. The link to the online platform can be integrated in a slide show students watch in real-time. That way, a teacher can get instant feedback and, if necessary, explain certain things better. Students are able to express their opinion (anonymously), show their knowledge, and share ideas. The idea behind such tools is to engage students to speak up freely, discuss ideas and participate actively in online lessons as their reactions are anonymous. Examples of real-time online presentation and polling software tools are Mentimeter, Kahoot, PollEverywhere or Slido, each with their own possibilities and limitations (e.g. maximum number of questions per session).

4.2.3 Online collaboration software

Online collaboration software can be used to post or embed content in a large variety of file types. Such software can be used for brainstorm sessions by e.g. posting digital sticky notes on a canvas or whiteboard, for mind-mapping or for co-creation of research and designs. Such software can also be used for providing feedback on documents, by e.g. posting sticky notes. Examples of such applications are padlet.com or miro.com.

4.2.4 Online collaboration platforms

In addition to collaboration platforms provided via institutional digital education platforms, there are external platforms, such as The World Café and Wikis. The World Café is a powerful active learning method which engages people in deep, thought-provoking conversations. It is a social technology for engaging people from research, education, and the private sector to exchange ideas, knowledge and research based on a philosophy of conversational leadership (<http://www.theworldcafe.com/about-us/>).

Wikis are part online database and part collaborative content management system. Wikis pool together the knowledge of a group of people to create the best possible resource available on the web, making a wiki both a source for information gathering and a place to share knowledge and to collaboratively work on a (single) project (<https://www.lifewire.com/what-is-a-wiki-3486702>). Wikis can be incorporated in the institutional digital education platform or can be external platforms.

4.2.5 Interactive Textbooks

Interactive textbooks represent digital textbooks with additional interactive tools. The interaction consists of multimedia, different active questionnaires, text highlighting, page zooming and rotation, etcetera. Interactive textbooks enable students to learn more about the topic presented in their own personal way. The presentation of the interactive textbook is the same as the classic ebook. However, it was shown that ordinary, static, ebooks cannot hold a student's focus for a long time. With this active learning method, students are able to interact with the content, hold their attention and learn more. For these reasons, this active teaching method becomes more and more popular.

Living textbooks are a special category of interactive textbooks. A living textbook consists of a collaborative website (textbook), accompanied with an interactive diagram (concept map) showing the course's concepts and their relationships (Augustijn et al. 2018). Students using a living textbook are provided with a direct overview of the course content and how the concepts are linked to other topics, see Figure 5 for an example. Testing results of Twente University in the Netherlands showed that the development of an ontology forces teachers to rethink their course content, to make links with topics of other teachers explicit and to remove redundancy (Augustijn et al. 2018).

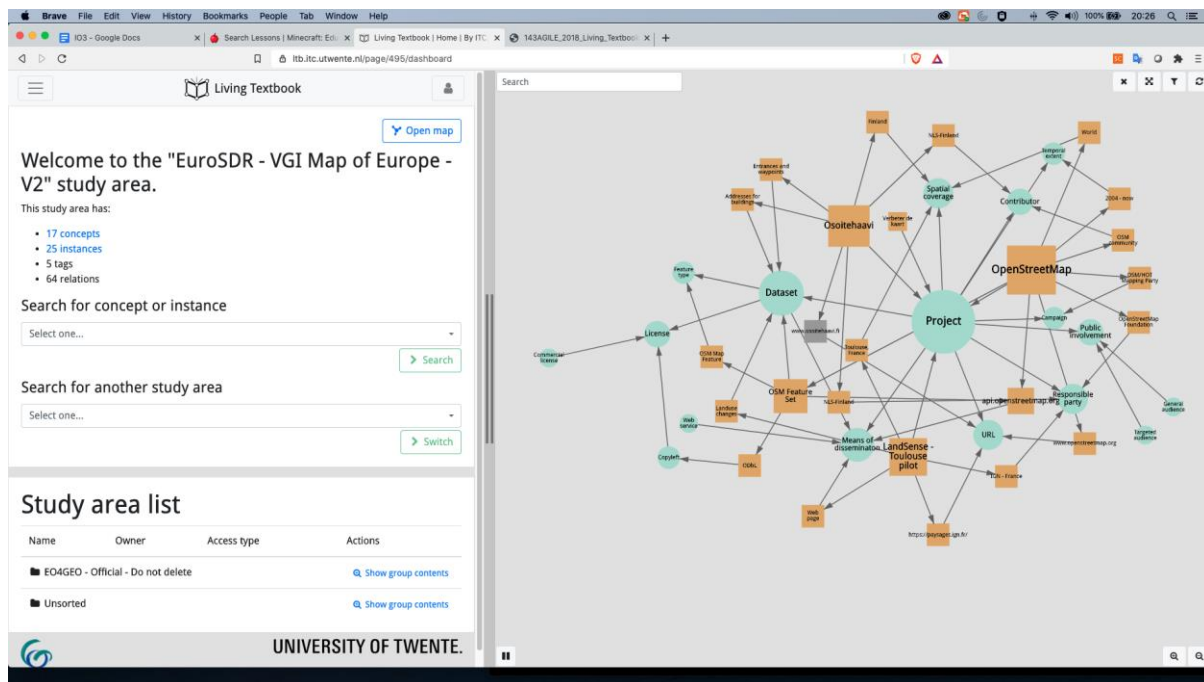


Figure 5: example of a living textbook, source: <https://ltb.itc.utwente.nl/>

4.2.6 Virtual Labs

Virtual Labs are an online environment whereby by means of different simulators and calculating models, students can test their ideas on the computer (internet) and obtain results. This kind of education is very popular in technical sciences and is finding its way in other sciences as well. This is mainly because of the benefits it can provide to a student. Compared to traditional labs, a number of advantages can be pointed out. For example, simulations can be performed for unlimited periods of time, simulators give students insights into other possible solutions, etcetera. All of this makes this teaching method suitable for mass lectures, especially in a virtual, home environment.

4.3 Summary and categorisation of active teaching activities and tools

In the following, the different active learning methods and tools are summarized in a table and categorized under the learning levels according to Bloom's taxonomy.

Table 2: Active learning activities categorized by levels of learning, and as in-classroom and outside classroom activities

Learning level according to the taxonomy by Bloom	on-campus teaching session	online teaching session	outside teaching sessions
Remember	demonstrations examples guest speakers in-class quizzes/polls	demonstrations examples guest speakers in-class quizzes/polls	clips podcasts class recordings short quizzes/ self-tests
Understand	asking questions active listening / paraphrasing one-minute paper / one-sentence summary brainstorm / brainwrite jigsaw catch-up four corners / chain notes in-class quizzes/polls mind map	asking questions active listening / paraphrasing one-minute paper / one-sentence summary brainstorm / brainwrite jigsaw catch-up four corners / chain notes in-class quizzes/polls mind map	literature / reader short quizzes / self-tests mind map
Apply	debate student presentations idea line-up four corners / chain notes fishbowl mystery quotation quesdiscussion concept map	debate student presentations idea line-up four corners / chain notes fishbowl mystery quotation quesdiscussion concept map	exercises serious games concept map

Analyse	muddiest point concept map / mini map active writing class discussions cases / role play / simulation think-pair-share / turn & talk / snowball group investigation as collaborative learning	muddiest point concept map / mini map active writing class discussions cases / simulation think-pair-share group investigation as collaborative learning	concept map
Evaluate	peer instruction peer review peer tutoring classroom quizzes	peer instruction peer review peer tutoring classroom quizzes	self-tests portfolio
Create	formulating exam questions mini lectures	formulating exam questions mini lectures	research paper case study / project formulating exam questions

5 Application of Active Teaching

Modern technologies and the increasing pace of technological changes strongly influence our society and the opportunities these technologies have to offer. Students have become familiar with using such technologies and their social media network to look for information at the moment they need it (instant need) rather than acquiring knowledge in advance (see e.g. Veen & Vrakking 2006). In addition, these days students experience more external stimuli and obligations, such as combining student life with family, (part-time) jobs and stricter university rules related to completing courses within a set period. Globalisation, a growth in international mobility and rising enrolments are leading to a larger student population and increased pressure on university staff and facilities. The intrinsic motivation of students seems to be more difficult to stimulate, which makes it more difficult for teachers to be productive. On the other hand, teachers realise that if they want to make their courses more inviting to students, they should apply new, more active ways of teaching, and to make students more responsible for their own learning process. Traditional teaching methods are proving to be insufficient to support new education standards. That is one of the reasons why active teaching is getting more and more public attention these days.

In Sections 5.1, we will describe how the partner universities have already integrated active learning in their current courses. Examples will be provided of active teaching practices being applied prior to the COVID-19 pandemic. Section 5.2 will provide a description which adaptations to teaching practices were made as a result of the pandemic at partner universities. In Section 5.3 we will summarize the experiences of the partner universities.

5.1 How have the partner universities applied active teaching so far?

In this section we will describe which active teaching practices are already part of the SDI courses of the partner universities. In addition, we will describe which education platforms and tools are used to deliver active teaching practices.

5.1.1 Bochum

Formal/ informal policy at university/faculty level

The vision statement 'Teaching and Learning 2019' (see <https://www.hochschule-bochum.de/studium-lehre/lehre-profil-qualitaet/leitbild-lehre-und-lernen>) of Bochum University of Applied Sciences emphasizes that teaching at the university not only addresses the transfer of knowledge but also practical competencies, personal development and self-motivation. In the vision active learning and teaching with a variety of methods, including problem-based learning and students' projects are mentioned explicitly. This statement is accompanied by several activities on

university level like in-house courses offered by the institute for didactics (ISD), external courses by the 'network for university didactics' (HDW), the yearly didactic week and the prize for best teaching.

Current SDI courses

At Bochum University of Applied Sciences a module 'GDI-DE und INSPIRE' is offered in German language for master students of 'Geoinformatics' and 'Land Survey'. For Bachelor students of 'Geoinformatics', several course modules for specific aspects of spatial data infrastructures are mandatory, ranging from technological aspects ('Web-GIS'), relevant OGC and ISO standards ('GIS Standards und Normen') to data models and relevant data structures ('Geobasisdaten').

Platforms and tools used for active teaching activities

The common teaching platform 'Moodle' with lectures, videos, exercises and quizzes is the key platform for active teaching. All material – for offline and online teaching – is available on the platform and assignments are exchanged and rated here. Additional tools like the hosting of Jupyter Notebooks (JupyterHub), test servers for mapping (ESRI or geoserver) are realized by the faculty IT.

Active teaching practices already implemented

Examples of active teaching:

The 'GI Projects' play a prominent role in the curriculum of the BSc of Geoinformatics. Each student has to choose 3 projects during their studies, with each project having a workload of 120 h. Based on real life scenarios (e.g. by public administrations, internal projects or cooperation between faculties), small teams of students (5-7) develop solutions under supervision of teachers. Examples of projects are 'routing solutions based on new OGC rest interfaces' (idea and data from the INSPIRE 2019 data challenge), 'flexible pedelec routing' (cooperation within the university), 'spatially enabled CRM' (request from university administration). Those projects are usually highly motivating, the students take responsibility for specific tasks and share their knowledge in the teams.

In technical lessons, esp. programming and spatial data analytics, some lectures have been supported by interactive textbooks ('Jupyter Notebooks'). Those notebooks are proven useful for small exercises, e.g. in parallel to the normal teaching, as they offer a very lightweight access to hands-on programming and data analytics.

For lectures on political or economic aspects of spatial data infrastructures, several attempts on 'flipped classroom', 'peer teaching' or 'poster sessions' were made – with ambivalent results. Some of the assignments seemed to be really motivating, when the 'level of difficulty' and the thematic topics match well with the interests of the students. On the other hand, esp. 'poster sessions' or 'peer teaching' was extremely demotivating if students felt uncomfortable with the exercises, either on too challenging or too easy jobs.

5.1.2 Delft University of Technology

Formal/ informal policy at university/faculty level

TU Delft has formulated a formal strategy for active teaching at the university. The TU Delft Vision on Education for 2017-2024 envisages that diverse and active teaching methods are to be stimulated. Students are expected to make effective use of the time of academic staff providing instruction, coaching and supervision. Academic staff are expected to have the didactical and organisational skills to provide high quality courses, are open to learn new (evidence based) teaching and assessment concepts for engineering education, and continuously strive to develop and improve themselves as teachers, supervisors and educational leaders (TUDelft 2017, p.12). To facilitate these aims, TUDelft has, *inter alia*, invested in a Teaching Academy offering Teaching Labs, online platforms and on-going training for academic staff. The Teaching Academy provides support for teachers to help with a transition to active teaching remotely. In TU Delft's University Teaching Qualification programme - compulsory for all new university teaching staff - ample attention is paid to active learning and active teaching methodologies to be integrated in classroom teaching.

Current SDI courses

TU Delft offers SDI courses as part of two MSc Geo information programmes: 'Geomatics for the Built Environment', and 'Geo Information and Management Applications' (GIMA). GEO1009 Geo-information Organisation and Legislation (5 ECTS), part of the Geomatics program. GEO4-GIMA3 Management in Organisations (10 ECTS), part of the GIMA program taught as a blended learning course in cooperation with three other Dutch universities.

Platforms and tools used for active teaching activities

TU Delft provides all course material and course information in digital education platforms. In these digital education platforms teachers post course information and procedures, learning objectives, lectures, relevant literature, assignments, assignment feedback, grades, etcetera. Students use the platforms to hand in assignments, do online quizzes, evaluate courses, and perform surveys in an online environment. In the GIMA program, students also use the platform to do their final exam. For Geomatics, Brightspace is used as a digital education platform, whereas for GIMA Blackboard is used.

Active teaching practices already implemented

Prior to COVID-19 we introduced the 'flip the classroom' concept in some of the Geomatics courses. Students are provided 5-10-minute clips or instruction videos, which they have to watch before the lecture. In the lecture, the teacher discusses the clip with the students, or the students can ask questions about the instruction video and/or work on the assignment. In more traditional lectures, active learning activities, such as class discussions, think-pair-share, online polling via Mentimeter, and exercises during which students have a short time, e.g. 5 minutes, to find a specific dataset online or

to collect information to be used as arguments in a class debate. Also active writing and peer review of draft and final papers are active learning methods implemented in this curriculum.

In the GIMA course, problem-based learning constitutes a significant part of the off-campus period. Student groups have to design a change strategy for an organizational spatial data infrastructure for a real-life organization. In preparation of their main project, the students have to address statement explanations. They are confronted with a quote that they have to clarify, analyse, and explain arguments in favour and against this statement. This exercise provides the students with insights needed to develop their proposed change strategy. Active writing is also a part of the course, as students are required to submit a summary of the online group meetings, in which progress reports of their case study are discussed. This allows the teacher to check if the students have understood the feedback provided during the meeting.

In addition, we invite the students to present the final results of their project in an activating format with only one requirement: to express their main message without using a traditional slide presentation with sentences/ text. Prior to this approach, we had 10 to 12 group presentations of 30 minutes, each with very similar formats. The new approach results in short 10 minutes clips, quizzes, role plays, recorded drama, etcetera, which is very entertaining for all and the main message of all projects is much better remembered. This approach also allows students to use their imagination and to use skills not always called upon in a technical degree course.

In other courses, we use(d) role plays. For example, in one role play, the case 'open data versus cost recovery for national mapping agency (NMA)', students were divided into two groups. The first group was tasked to argue in favour of the introduction of open data policies for a national mapping agency. The second group would argue in favour of maintaining a cost recovery policy. The teachers represented the board of the NMA deciding on the policy. Students had to study the documentation of both sides of the story (for their own arguments and to counter the arguments of the opponents), and to formulate clear statements to convince the board of the NMA.

In another role play, we used the snowball method. Students were assigned to determine which two open datasets should be classified as high value datasets. Each student prepared arguments for two datasets that should get the status of high value dataset. First, they discussed their choice with another student and again selected two datasets (so dropping two). Then, in a group of four the same process was repeated, then eight, etcetera. We also introduced the role of the 'mole'. In this variety, two students had an additional task: to ensure that a certain dataset would *not* be listed on the final list of the proposed high value datasets. The role plays were highly valued by the students, making them aware of the (limitations of the) political process (including hidden agenda: the 'moles') that often influences the development of National Spatial Data Infrastructures.

In the Geomatics Synthesis project course students are working in groups of 4-6 students on an assignment of an external client.

5.1.3 KU Leuven

Formal/ informal policy at university/faculty level

The Strategic Plan for KU Leuven comprises five key areas, which are transversal and have an impact on several domains. Among these components is the provision of future-oriented education, and KU Leuven applies a future-oriented teaching model based on activation. In the Strategic Plan, the choice for future-oriented and active teaching is further explained:

- 1. Future-oriented education is activating education. This consists of various aspects. It is active, cooperative, and solution-oriented. It uses contemporary feedback and evaluation methods. Somewhat too easily put, future-oriented education is less focussed on listening to and cramming than on actively constructing and having knowledge.*
- 2. Scientific (meta) research shows that a deeper activation of students leads to a higher quality of education. Activation starts from a number of variables, both on the lecturer's side as on the student's side.*
- 3. Activating education is not limited to working and evaluation methods. Our learning goals, which go further than memorising and reproducing, also contribute to this. Furthermore, the nature of the intended knowledge can be more, or less activating.*
- 4. Activating education is supported by scientific research, but also by clear choices made by the supervisory government. The government expects the universities to opt for activating education. This expectation implies that the universities do not let their efforts towards activating education depend on the efforts of a single lecturer. Instead, they should incorporate this vision for education in their policy.*

KU Leuven supports the design and implementation of active education in many different ways. As part of its funding programme for educational development and innovation, a dedicated call was organized to fund projects for the advancement of activating education at KU Leuven by means of educational micro-support. The goal of the approved projects was to assist the involved teaching staff and programme directors with innovative initiatives regarding activating working methods at the level of individual courses and programmes. KU Leuven Learning Lab promotes and supports active education by showcasing best practices, offering training sessions and workshops on active education, and providing different types of support materials.

Current SDI courses

Also in its education on geographic data and spatial data infrastructures, KU Leuven strongly applies active teaching and learning methods. The course on Geospatial Data Infrastructures (3 ECTS) has a strong component of practical exercises and assignments (1 ECTS in total), on topics such as the design,

creation and management of object-relational geospatial data repositories; the interpretation and production of UML class diagrams for a number of geodata themes; the conversion of UML class diagrams into object-relational databases; the discovery and exploration of geodatasets by means of metadata and web services; the production and publication of metadata; the setup of web map and web feature services; and the analysis and evaluation of existing SDI implementations.

Platforms and tools used for active teaching activities

KU Leuven uses Blackboard as its web based virtual learning environment. In response to the increased need for online communication possibilities, Blackboard Collaborate Ultra recently was introduced, which is a realtime video conferencing tool with a strong focus on education. Especially for its online teaching activities, this allows for better activation of the students. In addition to the Blackboard environment, KU Leuven supports various other tools for more active ways of teaching, including wiki environments, polls and brainstorming tools, annotation tools, discussion forums and blogs.

Active teaching practices already implemented

Active teaching practices are implemented in both the lectures and exercise/assignment sessions of the course 'Geospatial Data Infrastructures'. The lectures strongly make use of examples and demonstrations, in which existing SDIs (e.g. INSPIRE, national SDIs, the Flemish SDI, etc.) are used to increase the students' understanding of different SDIs components.

In the lectures, also several discussion rounds are foreseen, in which students are given the opportunity to reflect and/or ask questions on the topic of the lecture. Lectures also include some small teaching activities, in which students need to provide answers to questions related to the topic. This can be done to introduce the topic or to test whether students fully understand and master the topic and have achieved the proposed learning objectives.

Exercises are the most active components of the course and deal with topics such as data quality, data models and network services. Many of these exercise sessions consist of different smaller exercises, in which students have to complete these exercises step by step. An example of this is the setup of different types of network services for the same spatial dataset.

5.1.4 Lund University

Formal/ informal policy at university/faculty level

Active teaching and learning is a well-known approach in Lund University. Almost all teachers are aware of the concept. The compulsory pedagogic courses for teachers, held by Lund University, teaches, focuses, and motivates implementation of this approach by teachers in the university. As a result, almost all programmes in Lund University implement some of the methods, mentioned in Section 3.1 to apply active teaching in the courses.

Current SDI courses

Lund University has different courses related to SDI or with SDI and data sharing components. There is an online SDI course (5 ECTS) for master studies that introduces the concept of SDI and its fundamental models and components. A PhD course on SDI (5 ECTS), introduces more advanced technical aspects of SDI including e.g. semantic Web, big (geo-) data, and Open SDI concept. Two Web GIS courses (one on-campus and one online, each 7.5 ECTS) teaches technical skills for the implementation, application and use of geospatial Web services for data sharing in an interoperable environment; The course also includes teaching other skills for developing Web GIS and geospatial web services. The Open-Source GIS course (7.5 ECTS), which is also online, introduces open-source tools and licenses, including those for Web GIS and data sharing.

Platforms and tools used for active teaching activities

Canvas is the platform used for all on-campus programmes/courses. The online courses are currently based on the Moodle platform and AC, developed by Lund University, but the plan is to transfer them also to Canvas by Autumn 2021. Different tools are being used for active teaching activities among them, Zoom poll, Zoom break rooms, Mentimeter, and short video lectures (recorded by the students) are more popular for classroom activities. Forums and break rooms, besides other technical GIS tools, are used for lab activities.

Active teaching practices already implemented

For the GIS and RS master/Geomatics programme at the Department of Physical Geography and Ecosystem Science, “class discussion”, “Think-Pair-Share”, “Active writing”, and “problem-based learning” are the most popular methods that are used by the teachers.

The first two methods are often used in lectures, where students are asked to discuss a topic and then present the result to the class. The presentation is moderated by the teacher, who may ask questions and then motivate students to answer or ask each group to present shortly the outcome of group discussion.

“Active writing” is a method which has been used less. It is implemented in the form of asking students to answer questions or write a short report for the exercise, the seminar, and/or the projects they have done.

“Problem-based learning” has been applied mainly in the exercises and the final project of the courses. For the exercises, students are given a task/problem, with instructions on how to solve. However, few details are not mentioned in the instruction in order to make students find solutions by searching or discussing with other students. The teacher is also available to give hints to the students. However in the final project, the students are asked to formulate a problem (project topic), the teacher ensures the problem is big and complicated enough to make the student learn new skills/knowledge, and when

the teacher approves the topic the student should implement the project by receiving minimum help from the teacher. Projects are usually implemented in group work.

5.1.5 University of Zagreb

Formal/ informal policy at university/faculty level

At the university level, University of Zagreb (UNIZG) has established an e-portal for Learning and Teaching in Higher Education as a support for curricula development, defining learning outcomes, choosing adequate teaching practices, etcetera (see <http://www.unizg.hr/studiji-i-studiranje/cjelozivotno-obrazovanje-i-usavrsavanje/podrska-nastavnicima/ucenje-i-poucavanje-u-visokom-obrazovanju-upravo/>) . Although there are some guidelines on how to make teaching and learning more active, it is still optional whether to include it in the courses or not. At the level of Faculty of Geodesy, there are no guidelines, so it is up to any lecturer to decide on and implement active teaching practices. Many of the teachers are already aware of its benefits, so, the number of 'active' courses is growing yearly.

Current SDI courses

The Faculty of Geodesy offers two courses fully oriented towards (open) spatial data and spatial data infrastructures: 'Geoinformation Infrastructure' and 'Open Geoinformation'. Geoinformation Infrastructure (5 ECTS) is an elective course as part of BSc in Geodesy and Geoinformatics where passive teaching is still a dominant activity. The other course, Open Geoinformation (2ECTS) is also an elective course, MSc in Geoinformatics, where several active teaching activities have been introduced: class discussion, collaborative learning group and learning by teaching. Students show great interest for the course so it's being held every academic year.

Platforms and tools used for active teaching activities

Active teaching so far has been supported by Moodle platform as a central place for students to get information about courses, submit their assignments, etcetera. Individually, at some courses, other tools, such as Kahoot, have been introduced to increase student's engagement. Most of active teaching and learning activities are still related to person-to-person mode so the existing Moodle platform is being sufficient for those purposes.

Active teaching practices already implemented

Some already implemented active teaching practices rely on student's participation in solving certain problems by doing research on their own. One example of these practices is that students do group research work which is later treated as a business project. They are competing with the rest of the groups for a chance to present their work at some event, which is also open for professionals outside

the education community. Only the best team gets to win, and the winner is picked among themselves by each group grading the rest of the groups. This way, students are motivated to work, interact with the team and the teacher, compete, and to present their results at the end. Another example of an active teaching method used at UNIZG is service-learning projects where students use their knowledge to contribute to the community. Students do crowd-sourcing by collecting field data, followed by data manipulation, visualization and, at the end, presenting results to the public. This active teaching method motivates students to do their own research, analyse results and improve their skills. As for other active teaching methods, the methods are usually focused more on doing certain practical exercises. There, students must adopt a practical approach to use theoretical knowledge gained from lectures to solve the problem. They do not carry out independent research on the topic, instead, build a model on how to solve the given problem within existing skills. All the examples given before are more likely to be included in the practical part of the course than in the theoretical one. For the lectures themselves, some teachers introduced active teaching modules such as quizzes to assess the quality of the lectures and knowledge students have acquired.

5.2 How has Covid-19 changed the situation at the partner universities?

The year 2020 will be remembered by some as one of the worst years in our recent history mainly because of the Covid-19 pandemic and its impacts on global society. Even though there are numerous negative effects, the pandemic has also taught us to think outside of the box and to rapidly adapt to unexpected situations. One of them is moving education to fully online mode, which could be considered as one of the biggest education milestones in a long time. Looking back at this new normal situation and its effects on education methods, some reviews can now be made. SPIDER partner universities all shared their experiences on how they overcame this challenge from both technical and educational perspective while referring to the success of such an implementation.

5.2.1 Bochum

Changes to education method

The first peak of the Covid-19 pandemic occurred immediately before the start of summer-semester 2020. After a phase of uncertainty, the ministry of education (MSB NRW) and the university's directors decided on a delayed start of the semester as an 'online-semester'. This means, all lectures and courses took place, but had to be translated into a digital format in a really short time/during the semester.

Changes to online tooling and platforms for its education programs

At Bochum University of Applied Sciences, Moodle as a digital education platform was established a while before the pandemic, and most teachers already used it for the provision of lecture notes, assignment of exercises or additional material. The limited capacities of the existing video conferencing systems led to a rapid installation of an open-source web conferencing system (BigBlueButton - BBB) on the existing server infrastructure of the university. After scaling issues during the first weeks, this platform runs stable, is well integrated into the existing Moodle platform, allows break-out rooms and presentation of slides. Compared to other systems, limitations in working on shared documents, less flexible discussion groups or good screen sharing are obvious.

Teaching Practices and Experiences in Geoinformatics and SDI Education

Several courses – e.g. ‘Introduction to GIS’ (BSc Civil Engineering), ‘Advanced GI’ (BSc Land Surveying), ‘GI Standards’, ‘Base data’, ‘Spatial Analytics’ and ‘WebGIS’ (all BSc Geoinformatics) - were transformed to digital formats with different positive and negative experiences.

Online-live lectures

Due to a lack of preparation time and a lack of experience, most lectures have been transferred from standard classroom lectures to similar ‘online-live’ lectures with ‘Power-Point’ slides. The lectures were broadcasted as BBB sessions and the slides were – as usual - uploaded to the Moodle platform for preparation and wrap-up.

The experiences from those simply switched have been ambivalent. During lectures, there is very little communication with the students. This results in a higher teaching speed, but also a shorter receptiveness. The first conclusion from an evaluation are shorter lectures, more breaks, and more repetitions as well as simple exercises for a self-evaluation of the learning success.

Online-live-tutorials

Similar to the live-lectures, most hands-on exercises, which were previously held in the computer labs of the university, were switched into ‘online-live-tutorials’. In those dedicated BBB sessions, all students must work on technical assignments on their laptops, and a tutor demonstrates work steps and answers questions.

In practice, those modules tend to be clearly less effective than the regular hands-on sessions. There is only limited interaction between students and tutors, students cannot exchange experiences, it is difficult to consider different learning speeds and it is not possible to look over the students’ shoulder to discuss working steps or code individually.

After gaining those experiences, we developed several video-tutorials with some step-by-step explanations for the exercises, so that students can work on the assignments at their own speed. The BBB live-sessions were then used for discussing results and problems. This approach still seems to be less effective than on-site work but offers more space for discussions and allows students to work at their own speed.

Virtual machines as working environment

Several modules, especially for geospatial analytics, standard services, or programming in distributed environments, require complex technical setups. Those range from installation and configuration of OGC compliant servers, spatial databases, or dashboard applications – whereas the setup of such working environments is complex in an on-site situation, it was hardly feasible in the Covid-19 situation.

Expected developments in the near future

For that reason, we decided to provide virtual-machines (based on the free virtualization environment VirtualBox) for the students with all required Open-Source software, running servers and prepared datasets.

Again, the experience was ambivalent. On one hand, all students worked in the same environment, which allowed them to easily solve technical issues with software, configurations, or missing data. In addition, corrupted systems or datasets could be recovered quickly, and students could fall back on installed step-by-step solutions. On the other hand, several students – even students of GI – did not have sufficient hardware equipment to run the virtual machines with adequate performance. This led to some frustrations on system crashes or slow running software.

5.2.2 Delft University of Technology

Changes to education method

TU Delft already employs many different forms of active teaching and learning activities as described in the previous chapter. Where before Covid-19, classroom lectures and group work in studios/labs constituted a large proportion of teaching attendance, this has changed since the pandemic. The new teaching standard is a combination of the ‘flip the classroom’ approach and the digitisation of the traditional classroom lectures.

For the digitisation of traditional education, the teacher gives the lecture online (app. 20-30 minutes), students can ask questions through the chat, or live and the lecture is recorded so students can watch the recorded lecture any time. Depending on the group size, a second teacher or teaching assistant will be present to monitor the students’ questions via the chat or via raised hands and intervenes in the lecture if (s)he considers this to be appropriate. Teachers use online quizzes to assess whether

students understand the material. Quizzes are also used to stimulate discussions with students about the topic at hand.

Since the start of COVID-19, students are allowed to visit the university one day per week. On this day, they can do lab assignments with the support of teachers (physically present). Students have to sit at least 1,5-meter distance between them and another student. This is a maximum of 3 students per table of (approx. 5 meter). We use a mobile screen to ensure that teachers and students can respect the 1,5-meter social distancing requirement. If a student has a question, he or she can hook up their laptop to the mobile screen and ask the question (see Figure 6).



Figure 6: TU Delft students attending classes in their lab

Small group assignments are now facilitated through virtual break-out rooms. For students that have to work in pairs, the share screen option appears to work well.

Changes to online tooling and platforms for its education programs

For the different educational programs, MS Teams, <https://videobelpilot.surf.nl/> (based on jit.si), 'YouSeeU – Virtual Classroom by Bongo' (integrated in Brightspace) and Zoom (for graduation defences) are used as a virtual classroom, in addition to the streaming service Twitch. Lectures are approximately 15-20 minutes and interaction is possible through raising a digital hand, or through the chat box. We use quizzes (by Mentimeter or via Brightspace/ Blackboard) or ask students to show an object of the colour corresponding to the answer options to test the understanding of the students and to start a discussion on a topic. The lecture is recorded and published on the online digital platform (Brightspace/ Blackboard) so that students can watch the video of the lecture at any time. We also provide clips (online short videos of topics of interest) (use of Kaltura in Brightspace).

Communication between students and also between teachers and students is primarily through Discord. Students also have a WhatsApp group. Student groups can also use the chat function in the virtual break-out rooms created for their group.

Expected developments in the near future

For the coming academic year, the standard platform for all on-campus courses of the entire university will be Brightspace, in combination with MS Teams as a virtual classroom instead of Zoom. The use of Zoom will be faded out due to concerns related to a lack of personal data protection. For the GIMA blended learning course, MS Teams will be used for online lectures and activities as Blackboard, the digital education platform used for GIMA by all four universities, does not have an integrated application that can be used as a virtual classroom.

5.2.3 KU Leuven

Changes to education method

The spread of the coronavirus in Belgium has caused several changes in how education is provided at KU Leuven. A university-wide policy has been put in place, on how education will be provided in the 2020-21 academic year. Within this University-wide framework, each Faculty chooses the most fitting approach.

The main principle of the university's policy is that education is offered as much as possible on-campus, while always considering the latest safety measures. On-campus activity will be increased if the virus is not circulating heavily and safety allows for it but will be reduced in case the epidemic flares up and great caution is required.

The safety measures for higher education in Flanders are subject to a framework working with 'pandemic levels'. Within KU Leuven it is the Executive Board deciding on the colour code, but KU Leuven can never use a 'lower' colour code than the one established by the local crisis unit of the commune of the KU Leuven campus.

The framework consists of four pandemic levels:

- Zero risk: code green - in case of a successful vaccine or herd immunity
- Low risk: code yellow - low risk
- Medium risk: code orange - fundamental preventive measures are necessary
- High risk: code red - a lockdown (light) is necessary

Changes to online tooling and platforms for its education programs

The pandemic levels are mainly related to the organisation of teaching and learning: *how many people are allowed in a classroom? which types of teaching and learning activities are allowed? which types of internships and student mobility are allowed?*

A key element in the university's policy is that 'completely digital' will not become the new normal. Online education only should be considered for courses that lend themselves to this approach and will only be used in the way it works well: as effective support or in preparation of face-to-face education. Educational activities that are difficult or impossible to organise online – such as practical classes, seminars, skills training, tutorials, lab work and interactive lectures - should be offered on campus as much as possible.

For on-campus education, it is essential to consider physical distance in the auditoriums and classrooms. Two main strategies are proposed in order to allow to organise as many lectures as possible – partly – on campus. For some courses, we apply a rotation roster if necessary: each time, one third or one fourth of the students will be in the auditorium, while the others follow the lecture via live streaming. In other cases, the university opts for blended teaching. This, too, is a combination of online and face-to-face education: students are actively challenged in the online part to study the subject matter at their own pace, while there is room for in-depth discussions, exercises, case analysis, and more in smaller groups on campus.

KU Leuven currently offers one course on SDI and related topics: the course 'Geospatial Information Technologies' (6 ECTS, first term). This course consists of two separate blocks, which both include lectures and exercises: Geospatial Databases (1 ECTS lectures + 2 ECTS exercises) and Geospatial Data Infrastructures (2 ECTS lectures and 1 ECTS exercises).

Expected developments in the near future

Lectures and exercises of 'Geospatial Data Infrastructures' will take place from November onwards, and the preparation of these teaching and learning activities is still ongoing. Lectures will take place online, using the Blackboard Collaborate virtual classroom and online collaboration tool. Practical classes (exercises) will take place on-campus, but in separate sessions for smaller groups.

For the lectures, students will be invited to read and study the learning material prior to the (online) lecture, allowing the lectures to be more focused on discussions and providing answers to questions the students might have.

The content of the course and topics addressed will not change significantly. A – small – modification to the existing content will be to include some references to the COVID-19 pandemic to demonstrate the relevance and importance of particular SDI components. For example, challenges and issues related to the provision of statistics and the work on contact tracing will be used to demonstrate what harmonization is and why it is important.

5.2.4 Lund University

Lund University has a long-standing history of e-learning programmes in different subject areas. The Department of Physical Geography and Ecosystem Science has two GI-related master programmes: "GIS and Remote Sensing/Geomatics", which is an in-campus programme, and LumaGIS/iGEON, which is an e-learning programme. Both programmes include courses related to SDI.

Changes to education method

During COVID-19 outbreak, and based on the university's and the department's policies, the in-campus program has been migrated to Canvas platform to be offered digitally. Zoom and MS Teams are used as two other platforms for holding online lectures, group discussions, etcetera, to increase interactivity and manage active teaching and learning in distance mode.

All lectures are recorded as video lectures. A major issue is how to hold lectures in a way to keep students active and interact with them while they are sitting at home and their cameras are often switched off to avoid any disconnection due to internet bandwidth. Two strategies are usually used by teachers:

1. Teachers hold lectures using Zoom or MS Teams, according to the schedule, to implement more or less in-campus style of teaching, in distance mode. While teaching, teachers may raise questions and encourage or ask (by calling names) students to answer. Recorded video lectures are also published in Canvas, as support materials, e.g. for those could not attend the lecture.
2. Students should listen to the video lectures, and then participate in open/group discussions related to the lecture's topic, managed by teachers. This is an implementation of the "Active Listening" method besides "group discussion" and "Think-Pair-Sharing" methods. Tools such as Zoom Poll and Zoom Room are also used to manage discussions. At the end, students might be asked to prepare and submit a summary of the discussions ("active writing" method). Students are usually more active, and evaluations show that they appreciate this approach.

For each lecture, there is at least one practical exercise to be conducted by students. This guarantees active participation of the students in the course. Students have been given university VPN, to be able to install and use licensed software on their computers. In addition, they have been given the possibility to connect to lab computers, using Remote Desktop, if they cannot or do not want to install software on their personal computers. Supervision sessions are planned and take place online, besides answering questions and giving feedback via Canvas and email.

Changes to online tooling and platforms for its education programs

Courses also include seminars and projects to activate students further to study literature, design a project under supervision of teachers, implement the project (usually in groups) using skills and knowledge they have gained, and write reports. MS Teams is used as a platform for group meetings by students, while doing group work. Online presentation of the results and group discussions are a major part of seminars and projects.

Expected developments in the near future

In the near future, teaching will be in blended mode, partly online and partly on campus. COVID-19 situation made us use online teaching for the campus programmes and it pushed us to learn about the advantages of online education and tools for campus programmes. There is an agreement among the teachers that a blended approach could improve the quality of campus education, where you keep close contact and communication with the students through physical meetings and practices and take advantage of online tools for a better and more active style of teaching and education.

5.2.5 University of Zagreb

For many years, the Faculty of Geodesy (GEOD) has been using an online platform to support traditional in-person teaching. It was introduced to facilitate communication and gather all information in one place and to give students information about courses, course learning objectives, literature, attendance, assignments, deadlines, grades, etcetera. Furthermore, since students have access to the platform it has become a place where they submit their projects, papers, and all other types of assignments.

Changes to education method

Back in March 2020, when the COVID-19 pandemic had greatly spread, GEOD was already in a good position in terms of the technological aspect of educational methods. Open-Source software for a digital education platform, Moodle, was already in use and all teaching materials had already been uploaded to the platform. After the lock-down, all lessons were moved in the internet environment and there a problem was encountered. Moodle did not have all the necessary capabilities and new tools had to be found to fill the gap, so MS Teams was chosen for online lectures.

Changes to online tooling and platforms for its education programs

Lessons were completely moved to the internet environment. At first, it was difficult to adapt to the situation so many courses were just moved online but still being taught in a traditional way. That proved to be effective for the theoretical part of the course. After a while, many of Moodle's additional tools were used. For example, exams in the form of quizzes have become a popular way of examining students, different questionnaires were used to get feedback from students, etcetera. Finally, Moodle served as a platform for exchanging information and submission of tasks, and MS Teams as a virtual classroom for discussions and lecturing.

When it comes to the content of lectures, the theoretical part remained the same but in online mode where professors talked about the topic via webcam. Practical lessons, if possible, were held using MS Teams, and if not (field work) students had modified assignments that could be done at home (calculations). In addition to the theoretical and practical part of the course, many professors introduced additional research work that students had to do on their own, in the form of research papers.

In June, when pandemic restrictions eased slightly, education was partly moved back to the Faculty building. Still, students had to sit 1,5 m apart and be in the building only if necessary.

Expected developments in the near future

For the upcoming academic year, it was decided that teaching will take place in a hybrid form, partly online and partly face-to-face. Students are divided into two groups and will have alternating lectures (one week online, one week face-to-face and vice versa). Online teaching has now become a normal thing and even some ideas about its more active usage have emerged. Moodle and MS Teams have proven to be good enough for the general education vision of the Faculty, but some new tools can be introduced individually by certain professors. For instance, introducing additional tools such as Mentimeter or break-out rooms are being considered by some lecturers. All that should make lessons more inviting for students.

5.3 Summary

The paradigm of active teaching, as a trend in education, has already been implemented at Spider partner universities up to a certain level. Given the examples in the previous text it is clear some of the partners have invested a considerable amount of effort into making their education more active and thus can even be considered as leaders in the domain.

Such a mature level of active teaching at some partner institutions could find its roots in the existence of formal or informal internal education strategies. Having any kind of guidelines will no doubt help with the implementation of new practices or do improvements to the existing ones. Great examples of how strategies are aligned with the overall progress can be found at TU Delft, KU Leuven, Bochum University of Applied Sciences and University of Lund where active teaching was especially recognised as a future-oriented approach and included in the vision on education. In that direction, for example, TU Delft invested in a Teaching Academy and include active learning methods in the compulsory course for all new university teaching staff, Bochum decided to award ones with the best teaching and KU Leuven funds educational projects. The Lund University also introduced compulsory pedagogic courses for teachers to raise awareness of active teaching approach. University of Zagreb (UNIZG) follows the rest of the partners closely since teachers are already implementing active teaching methods, but with the difference that is only recommendable to do so, not mandatory. For instance, UNIZG established e-portal for Learning and Teaching in Higher Education as a support for specific educational purposes but it is up to teachers to decide on implementation of active teaching methods.

Since all Spider partners come from the geoinformation domain, active teaching methods reflect on SDI courses. There are different aspects of SDI covered so for instance Bochum University of Applied Sciences offers courses ranging from technological aspects (Web-GIS), relevant OGC and ISO standards (GIS Standards und Normen”) to data models and relevant data structures(‘Geobasisdaten’). TU Delft

teaches on the organisational and legislative segment of SDI (two courses: 'Geo-information Organisation and Legislation' and 'Management in Organisations'), KU Leuven is focused on design, creation, and management of object-relational repositories ('Geospatial Data Infrastructure'). Lund University offers many courses related to the concept of SDI or its data sharing components in online or on-campus mode (e.g. Web GIS courses) and UNIZG has two fully oriented spatial data courses concerning open spatial data and SDI ('Geoinformation Infrastructure' and 'Open Geoinformation'). It is worth to notice that these courses are offered across BSc, MSc, and PhD levels.

As stated before, a high level of activity is present at partner universities' courses where different practices are in use. For instance, for BSc degree courses, Bochum University of Applied Sciences mostly relies on real life problem-based projects which small groups of students must carry out under supervision of teachers. It turns out to be highly motivating for students. A similar approach is used at Lund University where students are given a task/problem they must resolve, or at TU Delft where students have to design a change strategy for a real-life spatial data infrastructure. Another often used active teaching practice is related to class discussions related to a certain problem. This teaching method is used at TU Delft where students are provided with short videos related to the topic and later in the classroom it is to be discussed (flip the classroom concept). KU Leuven and Lund University both use this method in lectures to reflect on specific topics but with no prior video lecture. At Bochum University of Applied Sciences this method showed ambivalent results: in some cases it worked, in some cases did not. Among other used methods, there are also interactive textbooks used at Bochum University, step by step exercise at KU Leuven, role play at TU Delft, or active writing at UNIZG or Lund University. Step by step exercises are designed for students to become more engaged and to gain a better understanding of the concept. Role play divides students into two groups where each group has to argue in the favour of the given role, e.g. data should be available for free vs. data should be available under a fee. Active writing is in the form of student papers where they do research on their own. At UNIZG a group of students present their work to other groups, which is peer-reviewed by the groups, and the best group gets to present their work at an event open for the professionals outside the education community.

Active teaching practices provided in the previous paragraph reflect the state of activity at partner universities. All of these practices were originally designed for on-campus teaching, however, the year 2020 made us reconsider these practices and adapt to the new situation caused by COVID-19 pandemic.

In March 2020, when COVID-19 pandemic had greatly spread and caused a lockdown, many teachers faced a problem. While some universities had already been using digital education platforms, others had not, so they had to come up with a solution in a very short period of time. Moodle, as an Open Source software platform, had already been in use as a digital education platform at UNIZG and Bochum University of Applied Sciences, but it was not until the pandemic that Lund University introduced Canvas digital platform. Both Moodle and Canvas, have now become main education platforms where students can get informed about courses, course learning objectives, teachers,

literature, assignments, grades, etcetera. TU Delft already used Brightspace and Blackboard as digital education platforms prior to the Covid-19 pandemic. In addition, TU Delft introduced the “flip the classroom” concept prior to the pandemic situation which now had to be completely shifted to an online environment.

The digital education platforms were good enough until the lockdown when certain limitations of existing practices emerged. Neither Moodle nor Canvas support video conferencing needed for online lectures, and that is when new solutions had to be found. Some of partner universities, such as TU Delft, introduced Zoom application for video conferencing and thesis defences, but have later decided to drop it due to concerns related to lack of personal data protection. Other partner universities have decided to go with MS Teams which proved to be good enough for online lecturing. There was also experimenting with some other applications where, for example, TU Delft uses YouSeeU, integrated with the Brightspace education platform, as a virtual classroom, in addition to the streaming service Twitch, as well as MS Teams. Bochum University of Applied Sciences decided to go with the open-source web conferencing system BigBlueButton which is now well integrated in the existing Moodle platform. Lund University also suggests that MS Teams will become the main platform for group meetings, while KU Leuven uses Blackboard Collaborate for their online lectures.

When it comes to teaching practises, approaches differ from university to university and within universities. For example, TU Delft introduced a combined teaching standard whereby some lecturers embraced the “flip the classroom” approach whereas other lecturers choose to digitize the traditional classroom lectures. Lectures are given online and recorded for students to watch at any time. Similar practice is used at KU Leuven with the difference that students from KU Leuven use classic learning materials instead of videos. The strength of this teaching method is for students to be more focused on discussions and understanding the topic. In contrast, the rest of the partner universities used traditional teaching methods but in an online environment. For instance, Bochum University of Applied Sciences just transferred most lectures to online mode with “Power-Point” slides presented in an online session. As for online tutorials (for projects), students followed steps the tutor demonstrated on screen in real time. University of Zagreb used the same technique as some teachers from Lund University as well.

During 2020 when the pandemic continued for longer than originally expected, awareness of the quality of education has risen. That is why a number of teachers decided to implement more active teaching methods. For instance, teachers at TU Delft and UNIZG used online quizzes to assess whether students understood the material and to start a discussion on a topic. Students at Lund University participated in open discussions where, at the end, they might have been asked to prepare and submit a summary of the discussion. After evaluation, students indicated that they appreciated this kind of approach. In addition, to assure that students are actively included in the topic, Lund University introduced at least one practical exercise conducted by students, per lecture. Apart from that, additional seminars and projects are included to activate student’s interest in literature. Similar practice was performed at UNIZG where students had to do some research on their own.

As pandemic restrictions in some countries eased slightly in the Summer of 2020, education partly moved back to campuses. At UNIZG, students were allowed to come back to the Faculty building (only if necessary) but still following Public Health Organisation's recommendations. That meant they had to sit at least 1,5m apart and had to wear face masks. Almost the same rules were applied in The Netherlands. Students at TU Delft were allowed to visit the University one day per week, and on this day, they worked on lab assignments. They have to sit at 1,5m distance with a maximum of three students per table. To facilitate the communication, students could hook up their laptops to the mobile screen and ask a question. However, as from December 2020, the restrictions were tightened, and students are no longer allowed to be on campus unless there is no alternative.

For the upcoming academic year, many different models are developed. KU Leuven proposes the following model: online education should be considered for courses that lend themselves to this approach and will be used as effective support for face-to-face education. This means that exclusively online education is not even considered. To achieve this, they propose a hybrid strategy which focuses on on-campus education. By applying a rotation roster, each time there will be one third or one fourth of the students in the auditorium while others will follow the lecture via live streaming. This opens the possibility of face-to-face lecture with significant contribution to practical classes, seminars, or lab work education quality. UNIZG uses a different model and also in a hybrid form. Students are divided into two groups and will have alternating lectures; one week online, one week face-to-face and vice versa.

The fact is that COVID-19 has completely changed the way we perceive education methods. With this new normal situation, many new aspects have emerged and will be considered in the future. We can all agree that shifting to online/hybrid form has its advantages, but we should also be aware of its disadvantages; especially when it comes to engaging students. Student's engagement in online lectures is very low and it results in low receptiveness and at the end, in poor knowledge. That is why online education should not completely replace traditional face-to-face education. Because of all that, this new normal situation should be used for making progress in traditional teaching in order to improve quality. Inclusion of new technologies, applications, and new content in teaching methods will definitely raise the standard of education in traditional as well as in online form.

6 Conclusion and Outlook

This report has addressed the issue of active teaching methods and their integration into higher education.

It was clarified in advance that the changing thought patterns in today's society require constant adaptation of teaching methods and that Open SDI Education should be presented as an innovative and contemporary subject with modern teaching methods. Active teaching and learning, as a way of dynamically engaging students in the learning process (Meneske et al. 2013), tends to be more effective than passive teaching in getting students to participate in knowledge acquisition (Deslauriers et al. 2019). While the first part of this report deals with different methodologies of active teaching and their application, the last chapter, which follows, complements this analysis with the best practices of the partner universities in relation to Open SDI Education. This chapter is directly related to the results of Intellectual Output (IO) 4, which are still being collected. Although not every active teaching method is suitable for each topic and educational goal, it is already becoming apparent that some are suitable and purposeful for Open SDI Education.

Active teaching can be divided into three levels of activity: interactive, constructive, and active. Interactive teaching is based on interaction between students or with a computer system and builds on the knowledge of others. Constructive teaching involves using higher order thinking skills and integrating new information with existing knowledge while creating a mental model of the system. Active teaching is not just a method, but a whole system that includes several components such as students, programmes, and others to activate existing knowledge and apply this knowledge in practice.

The process of active teaching and learning is divided into three phases: orientation, active processing, and evaluation and feedback. The orientation phase serves to motivate the students. For this purpose, the objectives of the lecture should be clearly defined, and their relevance communicated to the students. They should also be given the self-confidence that they are capable of completing the task. In this context, it is necessary to be clear about the importance of assessment. For the teacher, the assessment of the students comes last, while for the students it is one of the main motivation. The aim is to arouse an intrinsic motivation to follow the lecture. Active processing describes the activities themselves. This involves the active processing of information by the students. This process can be divided into four classes: Students think along, Students participate individually, Students participate in pairs or groups and Students participate outside the moment of contact. These four classes can be linked to the different levels of learning according to Bloom's Taxonomy, which divides active processing into six hierarchical levels: create, evaluate, analyse, apply, understand, and remember. The final phase of evaluation and feedback involves discussing the results and giving feedback to the students. Constant feedback, also during the lecture, can contribute significantly to the learning success. In active teaching and learning there are different teaching environments. Lectures can be

on-campus, online or in a hybrid form. Here, the teaching forms are again divided into frontal teaching, mixed practice, collaboration, and testing.

In order to find the appropriate methods for active teaching and learning, the methods must be selected to match the intended learning outcomes. In this respect, it is important to keep in mind the constructive alignment, as the activities are associated with specific learning outcomes and assessment. The selection of methods in this analysis is exemplary and not exhausted.

The active teaching and learning methods are categorised according to the four activity groups that have already been mentioned.

The first level describes methods in which students think along. This includes, for example, the method of a concept map, which is a visual representation of content and key points that are connected via interrelationships to form a network. Furthermore, rhetorical questions are assigned to this level. At the beginning of a lecture, students are asked a rhetorical question that does not have to be answered immediately, but rather serves as a guiding question to guide them through the lecture and, if necessary, to address previous content.

The second level describes methods in which students participate as individuals. This includes, for example, asking questions to the course and active writing as reflection (e.g. one-minute papers, formulating questions).

The third level describes student participation as a group action, which is again divided into three groups. Cooperative actions are e.g. class discussions or student presentations. Collaborative actions include e.g. brainstorming or peer-assisted learning (students take the lead in class). Problem-based learning is concerned with problem solving, where students develop procedures that they can reuse later on. This includes, for example, role-playing or simulations.

The fourth level describes methods to engage students outside the classroom. One popular method is "flipping the classroom". Here Bloom's taxonomy is reversed: the process of remembering and understanding takes place before the lesson, that of applying and analysing during the lesson and that of evaluating and creating after the lesson. This results in a lower level of learning outside of class and a higher level of learning during class. In general, the focus is shifted from the teacher to the students.

Many of the teaching methods described are transferable to digital formats, although there are also active teaching methods specifically for digital teaching. Especially with digital formats, the audience's attention can dwindle due to the lack of personal contact. In general, it seems much more difficult to actively engage students online. Just turning on the microphone and camera in video conferences is a big hurdle for some participants. Break-out rooms can be a great help here, as they divide the learning groups into smaller sizes and thus better engage the students.

Covid-19 has put the learning environment in an exceptional situation. Many learning environments have been forced to move to online teaching. However, due to the aforementioned barriers to student engagement, the development of active teaching methods for the digital domain has advanced. New ways of active online teaching have emerged, like survey or online polling software such as Mentimeter. Using such software is comparable to voting by show of hands in face-to-face classes, but the anonymity tends to lower the barrier to participation. Another popular method is interactive textbooks. Here, digital textbooks are linked with additional interactive tools. This creates a hybrid learning environment.

After analysing the active teaching methods for both face-to-face and online teaching, these methods were categorised by the levels of learning according to Bloom's Taxonomy. This step made it clear that although the methods described here serve some levels only moderately, overall they are evenly distributed across all levels and cover both face-to-face and online formats.

In the further course of the report, the status quo of the application of active teaching methods at the partner universities was examined. For this purpose, two questions were addressed by each partner.

The first task was to classify the extent to which the university already applies active teaching methods. This showed that each partner has been using such methods for some time. This supports the assumption that the concept of active teaching and learning has not yet arrived in all pedagogical concepts, which is why many teachers are not even aware that they are already using them. In particular, the method of problem-based learning using real-life problems is already being used successfully at every partner university. This method is, among others, also used in SDI courses and has proven to be practicable there. This shows that the universities have developed good internal education strategies in the past. For example, TU Delft has set up a teaching academy that teaches methods for optimal teaching. In addition, Bochum University and TU Delft award a teaching prize every year to a teacher chosen by the students, and the University of Zagreb operates an e-portal for learning and teaching.

The second task relates to the changed learning environment through Covid-19. The partners were asked to explain how the learning situation at the universities has changed. A similar picture emerged at all universities. For example, many have already used digital learning platforms and digital teaching formats. However, many solutions were only good enough for occasional use. When there was no longer an alternative to convert teaching completely to digital and offer these solutions permanently, the last universities caught up and introduced digital learning platforms such as Moodle or Canvas and developed new, more effective ways of digital teaching.

However, new problems soon emerged, such as the fact that neither Moodle nor Canvas offer a video platform. A debate about the protection of personal data flared up, especially in relation to the Zoom video conferencing system. However, the platform developers have tackled some of these issues, thus

calming down the debate. Zoom is now also used at some universities, a wide range of conferencing systems has developed overall, from MS Teams to YouSeeU and BigBlueButton.

The development of digital teaching methods also varied greatly. In some cases, traditional, passive face-to-face teaching was simply transferred to an online format via PowerPoint and video conferencing, provided the learning objectives were met. Others transformed their active teaching methods, such as online tutorials or interactive textbooks, with the "flip the classroom" approach being used in many places and enjoying great popularity. At the beginning of the pandemic, these solutions were sufficient. Then doubts slowly arose as to whether the students were taking enough away from the lectures or whether they should be more involved. As a result, new online methods to actively involve the students were developed and applied during the pandemic (e.g. quizzes, practical exercises). As some digital formats have proven themselves and even improved teaching, the future will likely entail a hybrid teaching model with active teaching methods.

After incorporating best practices as well, this report will conclude by being able to provide a roadmap for good teaching in Open SDI Education.

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