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Showcase of Active Learning and Teaching Practices in Spatial Data Infrastructure (SDI) Education

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Abstract. The new concept of Open Spatial Data Infrastructures (Open SDIs) has emerged from an increased interest in open data initiatives together with national and international directives, such as the EU Open Data Directive (Directive (EU) 2019/1024), and the large investment of European public authorities in developing SDIs for sharing spatial data within public authorities. Open SDIs have the potential to boost reaching SDIs' general aims and goals of facilitating the exchange and sharing of spatial data to support planning and decision-making by including public participation and increased openness in all aspects of SDIs, including Open SDI Education. The open SPatial data Infrastructure eDucation nEtwoRk (SPIDER) project aims to address Open SDI Education by particular emphasis on studying Active Learning and Teaching (ALT) methods for SDI education. This article provides a theoretical basis of ALT for SDI methodologies. We show in which way ALT practices were already implemented in SDI education at the Partner universities before the COVID-19 pandemic. We also describe how the pandemic functioned as a catalyst for implementing ALT practices to an online environment, and how students evaluated these practices.

The outcomes of our research can serve as an inspiration for SDI education in other countries.

Keywords. Spatial data infrastructures, Open SDI, education, active learning and teaching methodologies, ALT practices

1 Introduction to the SPIDER Project

1.1 Open SDI education

In the past 20 years, European public authorities have invested considerable resources in the development of spatial data infrastructures (SDIs) to share data within 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. Open SDI development and implementation should also involve key stakeholders outside government, such as citizens, companies, especially small and medium-sized enterprises (SMEs), NGOs, and education and research institutions. These stakeholders could be both producers and users of spatial data. Open SDIs are also linked to developments and trends in other domains and fields, such as open government, open data, open science, and open software. This new paradigm of SDIs 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 of learning. These methods should become more active, and in the content of education, include new concepts and topics. Currently, SDI education is characterized by single disciplinary or siloed views missing out on opportunities of a holistic, multidisciplinary view on SDIs. In addition, the recent Open SDI trend is not reflected in SDI curricula yet. Moreover, teaching methods are often limited to traditional teaching in the classroom. As a consequence, there is barely any international exchange of educational material and approaches on open SDI among higher education institutes (HEIs). Collaboration between HEIs is essential, since implementing Open SDI (teaching) requires a multidisciplinary approach, involving experts from different fields.

1.2   Aims of the SPIDER Projects

The Erasmus+ SPIDER: open Spatial data Infrastructure eDucation nEtwoRk Project – partnered by Bochum University of Applied Sciences (BO), Delft University of Technology (TUD), KU Leuven (KU), Lund University (LU) and the University of Zagreb (UNIZG) – aims to address the required paradigm shift in open SDI education. The main objective of the SPIDER project is to promote and strengthen active learning and teaching towards Open SDI. One of our goals is to provide a methodology for active learning and teaching (ALT) on Open SDI, that could be used by teachers and trainers involved in SDI education and training for making their teaching on – Open – SDI more active.

1.3   Active learning and teaching methodology

In a constantly changing society, it is necessary to rethink and evaluate teaching methods on a regular basis. Passive frontal (face-to-face) teaching methods no longer seems appropriate, as numerous studies have already questioned its effectiveness (Bonwell and 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.

1.4   Methodology of this research

In 2020, we carried out a literature review into active learning and teaching (ALT) methodologies and evaluations. Next, we made an inventory of practices of which ALT practices are already applied in the SDI courses taught by the project partners. The selected practices were further developed in the last quarter of 2020 and the first quarter of 2021 to increase their 'active' components. Bearing in mind Bloom's taxonomy of learning levels (Fig. 1.1), the practices were selected in a way to cover higher levels of Bloom's Taxonomy, which are less attended in teaching methods. The COVID-19 pandemic provided an opportunity for the SPIDER partner universities to evaluate the selected practices in online education and to include these experiences in our research.

We used an online questionnaire to obtain the opinion of students of the ALT practices included in the courses. Students received a link to the questionnaire immediately after the teaching activity. The survey was open for two weeks, with one reminder sent at the end of the first week.
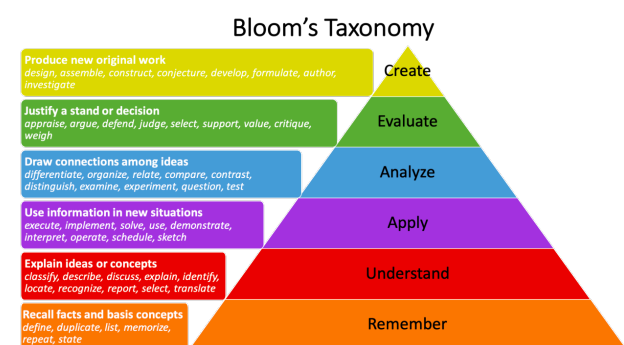

Figure 1.1: Bloom's Taxonomy indicating levels of learning (source: https://www.bloomstaxonomy.net)

We presented our research findings for feedback during a transnational meeting with a panel of experts in 2021.

This research will lead to the further development of ALT practices in a standardized and open manner as a tool for other teachers, trainers and students.

1.4.1 Data and software availability

No data or code was collected, developed, or used in this work. Our research generated a database of literature related to open SDIs and ALT methodologies and evaluations. We consolidated the outcomes of our literature review and the inventory of practices already applied by the partner universities in (Pitz *et al.*, 2021) In (Mansourian *et al.*, 2021) we provide a description of the ALT practices applied in online education and their evaluation. Both reports are available from the project website under an open licence.

1.5 Reading guide

In Section 1, we provide the background of our research, introduce the concept of active learning and teaching (ALT) practices and describe the methodology for this research. In Section 2, we go deeper into the concept and impact of ALT, and explore their application into online education. Section 3 continues with an inventory of ALT practices already implemented in the five partner universities. In Section 4, we show how the ALT practices evolved during the COVID-19 pandemic. We collected a showcase of a number of these practices and evaluated these practices by students and by teachers. Section 5 provides our conclusions and a reflection.

2 Active Learning and teaching (ALT)

2.1 The concept of ALT

ALT is a broad concept. Roughly speaking, active teaching refers to the methods that will dynamically involve students in the learning process (Menekse *et al.*, 2013). Active teaching focuses on the communication between students and teachers, and constantly integrates students into the teaching process. Students, often subconsciously, guide the lessons, and teachers adopt more 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. And active teaching and learning methods are not limited to face-to-face teaching but can also be implemented in an online environment.

2.2 Impact of active learning and teaching

ALT and its effectiveness have been studied in many educational disciplines. Studies have shown that ALT appears to have better learning outcomes. (Menekse *et al.*, 2013) found that ALT 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 ALT methods are divided into three modes of activities: *interactive*, *constructive*, and *active,* and further refined as the so-called ICAP framework defining cognitive engagement activities differentiated into four modes: Interactive, Constructive, Active and Passive (Chi and Wylie, 2014).

Interactive learning usually refers to methods involving students interacting with a computer system or other tools, with people, or between a student and a system (Chi and Wylie, 2014). A student has some degree of control over the system, without necessarily having to give a response. 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 refers to meaningful learning in which a learner actively builds a mental model of the system (s)he is to learn (Mayer and 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, thus, acquiring 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 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: $I>C>A>P$. Menekse *et al.* (2013) carried out experiments in which all three forms were combined and found that students performed significantly better in a constructive and interactive learning environment. (Freeman *et al.*, 2014) found 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 (science, technology, engineering, and mathematical) 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 learning and 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 challenges for many HEIs but pays off in special situations, e.g., the COVID-19 pandemic, where face-to-face education was 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.

2.4   Active learning and teaching process

The ALT process consists of three stages:1) orientation, 2) active processing, and 3) evaluation and feedback.

The aim of the *orientation* stage is to motivate students to actively participate in the teaching and learning process. 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.

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.

The *evaluation and feedback* stage deals with discussing the outcomes of the learning activity and providing feedback to the students. A key advantage of ALT is that it allows teachers to regularly evaluate and provide feedback to students on how well they are doing during the course rather than only assessment at the end of the course. In addition, the teacher receive feedback constantly on how well the students understand the material.

3   Active learning and teaching practices

It is important that appropriate methods are selected to align with the intended learning outcomes (LOs) and to select matching assessment methods to gauge how well the selected teaching methods have matched the intended LOs (Biggs, 2003), see Fig. 3.1. We should bear in mind that for teachers their final outcome 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, 2005). The assessment criteria will be the starting point for students whereas for teachers, assessment is the finishing point.
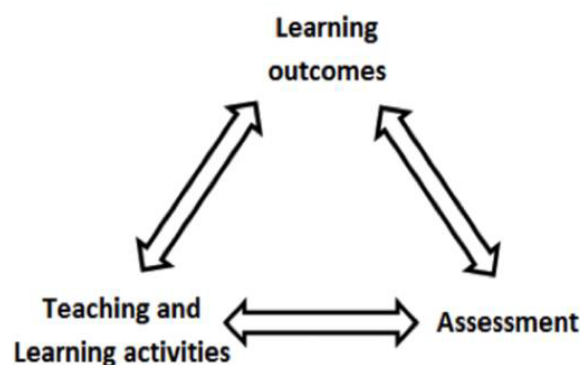

Figure 3.1: Constructive alignment of learning objectives, learning methods and assessment

Section 2.2, shows that ALT methods are more effective than passive teaching methods. From our literature research, we find many different ALT activities that can be incorporated in teaching methods. These ALT activities can be adapted to address different levels of learning according to Bloom's Taxonomy. There are many forms of ALT activities that can be mixed within one class session. In the next chapter, we provide a description of a number of ALT activities that can be used in higher education. These ALT activities can be grouped by the different categories of activation. This overview is by no means exhaustive.

3.1   Active learning activities

The activities described below are based on on-campus attendance of students but are adaptable to an online

environment. The description of the methods builds on the educational programmes of Michigan State University (https://omerad.msu.edu/teaching/teaching-strategies/active-learning-strategies#collapseFifteen), UC Berkeley Center for Teaching & Learning (https://teaching.berkeley.edu/active-learning-strategies), the State University of Florida (Office of Distance Learning, 2011), Delft University of Technology (https://ocw.tudelft.nl/courses/development-teaching-active-learning/), and KU Leuven (https://www.kuleuven.be/english/education/leuvenlearninglab/academic-year-2020-2021/blended-learning/didactic-formats). In Table 3.1 we show active learning activities categorised by levels of activation. 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/. For a detailed description of the ALT activities, we refer to (Pitz *et al.*, 2021)

Table 3.1: Active learning categories categorized by levels of activation

Students think along	Students participate		
	Individual actions	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
Demonstrations	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	

3.2 Students participating outside the classroom

A commonly used strategy for active teaching is to 'flip the classroom'. In traditional teaching, 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 activities, e.g., assignments or 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 3.2. Apart from watching videos, other ways to use visual media for active learning are asking students to prepare a presentation, e.g., a poster or a video or using an online whiteboard, in order to trigger their creativity. It is vital that using visual media are incorporated with other methods, e.g., providing students with questions to be answered while watching the videos, class discussions or online quizzes afterwards, to ensure that this activity remains an active exercise.
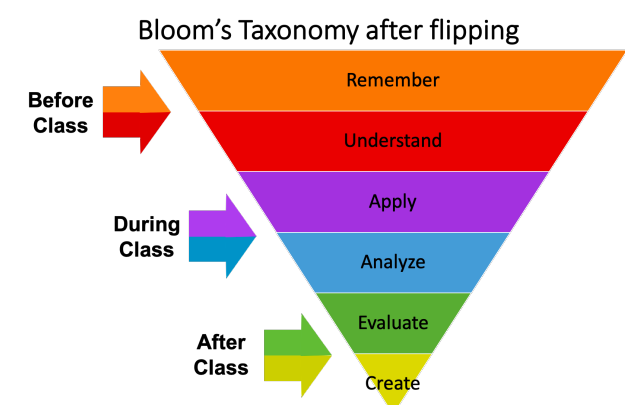

Figure 3.2; Revised Bloom's Taxonomy in a flipped classroom (Source: https://omerad.msu.edu/teaching/teaching-strategies/27-teaching/162-what-why-and-how-to-implement-a-flipped-classroom-model)

3.3 Online ALT activities tools

Due to COVID-19 pandemic, educational methods had to shift towards online education, and new ways of active teaching had to be introduced. Although many of the ALT activities described above can also be implemented online, they require different tools or software. Many teachers face the challenge of how to engage their students in active participation in online lectures from their home environment. Available tools are, for instance, the use of breakout rooms for group discussions or think-pare-share activities, real-time polling software for short quizzes during online lectures, online whiteboards for brainstorming or concept maps and wikis. Some of these tools are already incorporated in education platforms.

External platforms can also be used for students to interact and test ideas, such as Discord, Virtual Labs or The World Café, where students can interact with other students, researchers and the private sector (http://www.theworldcafe.com/about-us/).

In Table 3.2 we provide a summary of ALT activities categorized by the levels of Bloom's Taxonomy.

Table 3.2: Active Learning and teaching activities according to Bloom's Taxonomy

Learning level according to Bloom's Taxonomy	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 in-class quizzes/polls mind map	asking questions active listening / paraphrasing one-minute paper / one-sentence summary brainstorm / brainwrite jigsaw in-class quizzes/polls mind map	literature / reader short quizzes / self-tests mind map
Apply	debate student presentations concept map	debate student presentations 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

3.4 Implementation of practices in partner universities

To assess in which way ALT practices are already part of the SDI courses of the partner universities, we identified which support is available, in terms of formal policies and courses for teachers at University / Faculty level. We assessed whether this support was passive (limited to a policy document) or active, such as offering courses for teachers. We identified which platforms and tools are in use for (online) teaching, and which ALT practices are already implemented in SDI courses. All partner universities already used a digital education platform for their courses pre-Corona. All these education platforms are used for out-of-class activities, such as uploading documents and videos, exercises and quizzes, and assignments. In addition, the platforms allow students to set up forums, and exchange documents but the platforms do not facilitate real-time and simultaneous editing. External tools, such as Mentimeter for real-time polling, were already used during lectures. Table 3.3 provides a summary of support for ALT practices, SDI courses and education platforms in use.

Table 3.3: implementation of ALT practices in partner universities

University	Support available at University Level	SDI course and level	Platform and tools	ALT practices in SDI courses
BO	Vision Statement promoting ALT practices In-house and external courses for teachers	MSc. GE-DE und INSPIRE BSc. several modules for specific aspects of SDIs	Moodle Jupyter Notebooks Zoom and BigBlueButton for online lectures	Interactive textbooks (Jupyter Notebooks) Flip the classroom Peer teaching Poster session Quizzes during lectures PBL / group research
TUD	Vision on Education stimulating ALT practices ALT practices integral part of UTQ programme Teaching Academy Teaching Labs	MSc. Geomatics for the Built Environment MSc. Geo Information Management and Applications (GIMA) (blended learning MSc of 4 universities)	Geomatics: Brightspace Mentimeter Zoom & Jit.se for online lectures GIMA: Blackboard MS Teams for online lectures and feedback sessions Mentimeter	Flip the classroom During lectures: Classroom discussions Asking questions Realtime polling (Group) exercises Group discussions / Snowballing Active writing Class debate Role play Guest lectures PBL / case studies Student presentations where students are not allowed to use PPT
KU	Strategic Plan stimulating ALT practices Learning Lab Micro-support for specific projects	Geospatial Data Infrastructures course	Blackboard Blackboard Collaborate Ultra for online lectures	Examples / demonstrations Asking questions Exercises
LU	ALT practices integral part of compulsory pedagogic courses	MSc. Online SDI course PhD. SDI course 2 Web GIS courses (online and on-campus)	Canvas Zoom for online lectures, incl. Zoom polls Mentimeter	Students' videos Online polling Lab activities Class discussions Think-pair-share Active writing PBL / complex exercises
UNIZG	e-Portal for Learning and Teaching in Higher Education Guidelines for ALT practices ALT practices are optional	BSc course Geoinformation Infrastructure MSc course Open Geoinformation	Moodle MS Teams for online lectures	PBL / group research (in competition with external groups) Service learning project Quizzes during lectures

4 Adaptations due to COVID-19

Prior to 2020, most partner universities provided only face-to-face lectures. TUD have already used video conferencing tools for feedback session for the blended learning course (GIMA) students for over a decade. LU have one SDI and one WebGIS available as online courses for a decade.

When a quick switch to online lecturing had to be made in 2020, the partner universities had to transfer face-to-face lecturing to online lecturing. Different video platforms are used as their digital education platforms lacked an integrated facility. While all video platforms prove to be suitable., it is vital though that the video platform contains integrated tools for ALT activities, such as breakout rooms, online polling and an online whiteboard. Even more important is that the teachers are familiar using the integrated tools.

4.1 Selected ALT practices

One of the main objectives of the SPIDER Project is to develop showcases of ALT Practices. Although not originally envisioned, The COVID-19 pandemic provided an opportunity to 'field test' these practices in an online environment. We selected ALT practices implemented in six courses at five partner universities. Bearing in mind Bloom's taxonomy, the practices were selected in a way to cover higher levels of Bloom's Taxonomy, which are less attended in teaching methods. For a more detailed description of how the ALT practices were implemented, see (Mansourian *et al.*, 2021).

We evaluated the practices, both as self-evaluation by the teachers as well as evaluation by the students. In order to harmonise the evaluation by students whilst allowing for the diversity of ALT practices, we developed two separate surveys forms: one for ALT practices implemented in online lectures and one for ALT practices in lab work. A link to the survey form was disseminated to the students immediately after the lecture or lab, with a reminder sent after one week. The surveys were open for two weeks. For all courses, the insights of teachers were collected as free text in order to receive wider professional perspectives on the practices. In the following sections, we provide more details on the ALT practices and their evaluation.

4.2 Assessment of ALT practices

BO and UNIZG assessed ALT practices implemented in lab work and to PBL activities. LU had to switch to online lecturing for campus programs implementing the ALT practices already in use. These included practical classroom activities during each lecture using licenced software available via the university's VPN. The implemented ALT practices mostly related to the design and evaluation of web services or an assessment framework. The students' evaluation showed that students were in general satisfied and appreciated the hands-on lab work approach, although they missed some guidance for the exercises. The teachers found that for online lab work / practical tutorials, a video platform proved to be less effective than physical presence, as teachers cannot walk around to observe whether students are struggling with a particular part of the assignment / practical work. BO have developed video tutorials for students, which has helped somewhat to provide guidance.

TUD and KU had already implemented many ALT practices prior to COVID-19, including flipping-the-classroom by some teachers. Although not initially embraced by all teachers, the switch to online teaching stimulated others to use a flip-the-classroom approach. Time spent on slide presentations during lectures is reduced, leaving more room for ALT activities, such as asking questions, online quizzes and in-class exercises. In addition, short video clips on specific topics are made available to students in advance. In Fig. 4.1, an example of an online in-class activity is shown. Students were asked to hold up an item of the colour corresponding to their answer. The responses were used as input for a class discussion. Students became very creative when using coloured objects, such as changing the colour of their background or holding up signs stating 'Red' in blue ink.
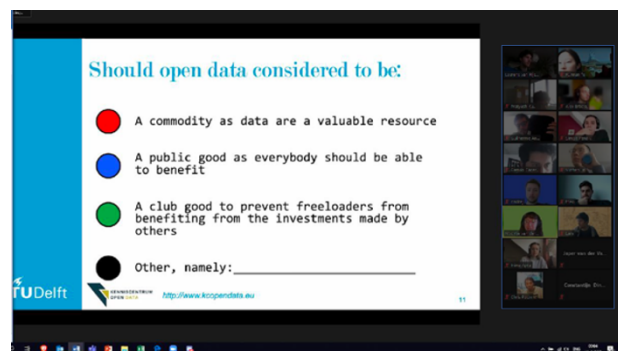

Figure 4.1: example of colour-coded questions and students indicating their responses (the image has been blurred to hide the students' names for privacy reasons)

TUD selected three ALT practices: Active Teaching including four ALT activities: asking questions, in-class quizzes / polls, class exercises and class discussion; a Class Debate to be prepared in advance; and Student Presentations. Students were very satisfied with the ALT practices to activate them during lectures. They appreciated working in breakout rooms as it provided interaction with other students. Their suggestions were to get more time to think when participating in class discussions and to receive clear instructions, when doing group work in breakout rooms, especially for the chair of

the group. Students also indicated that a group-size of at least five students is needed to generate sufficient input for a class discussion. They liked the use of build-in tools, such as the whiteboard, and the use of online quizzes. They suggested to add a competition element to online quizzes. The students appreciated that doing a pitch presentation gave them a better idea of what to expect for their case study and to share suggestions within the group.

The teachers were in general also satisfied with the ALT practices. They also realized that online lecturing requires a second person to monitor chats and assist with breakout rooms. Teachers found that for in-class polls, a show of hands / colours is more effective than using external polling apps, due to the time lag. Moreover, a show of hands means that a teacher can activate all students, not just those that have access to the app. For the student presentations, a time-keeper must be appointed as nearly all students took too long. Teachers also found that shorter lectures always have to be followed by another activity for summative assessment, e.g., a quiz or an exercise. The most important message for teachers is that they must use a variety of ALT practices and regularly update examples and demonstrations.

4.3 Summary of showcase ALT practices

The practices implemented and assessed by the partner universities rely on a variety of ALT methods, including 1-Minute Paper/Summaries, Asking Questions, Demonstrations, Brainstorming, Short Lectures, Student Presentations, Breakout Discussions, In-class Quizzes/Polls, Class Discussions, Debates, Peer Review, Peer Tutoring, Implementations with instructions and Reviews. These ALT practices are used for summative assessment. The ALT practices are applied during online classroom activities and lab works, and are related to teaching both technical and non-technical aspects of SDI.

The overall results of the assessments by the students show that the adopted methods have stimulated active participation of students in (online) classes. A majority of the students believe that the methods have increased the interaction with other students and with teachers. The students were less positive whether the ALT practices had contributed to achieving the learning objectives. For the lab work, ALT methods helped students to get a better knowledge and understanding of theories and helped them to get required skills for applying studied techniques. In general, students are satisfied with using ALT methods and prefer them over traditional passive teaching methods.

5 Conclusion and reflection

In this paper, several active learning and teaching (ALT) practices on SDI and related topics were presented. The practices are all based on existing SDI teaching activities implemented by the partner universities. Our research showed that ALT practices are of added value for education, both for face-to-face teaching as well as in an online environment. Many ALT practices were already implemented in the SDI courses of the five SPIDER partner universities prior to COVID-19. The pandemic provided the research with an opportunity to 'field test' these practices in an online environment. The strength of the field tests is that we were able to take the students' opinions into account as well. In general, the students preferred ALT practices over passive teaching methods. It should be noted though that the students evaluated the ALT practices during a strict lock-down period. We did not evaluate whether students preferred online teaching over onsite teaching.

Although many HEIs had already implemented ALT practices in their teaching, the COVID-19 pandemic has completely changed the way education methods are perceived. With this new 'normal' situation, many new aspects have emerged and will be considered in the future. Shifting to online education has its advantages. The threshold for inviting expert as guest lecturers is lowered as they do not have to travel to a HEI. The same applies to students no longer have to travel, thus, overcoming geographical barriers and being able to balance their home situation with their studies. Students can watch recorded lectures again to ensure they have understood all the content and to better prepare for formative assessment.

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 the world. To actively engage students in an online setting, it is essential that students switch on their cameras during the lecture. However, this requires a need for broadband connectivity not available to all students. While some universities are pioneers in digital learning, others are not even adequately equipped with computers and stable internet.

Furthermore, not all teachers - or students - are sufficiently trained for digital developments. Since the COVID-19 pandemic, platforms that include facilities for online lecturing have taken a huge flight. More tools and apps are regularly added to these platforms. Becoming aware of these added tools already requires more preparation time, let alone mastering these tools. Preparing for online teaching requires extra resources, both for additional equipment and software, such as for video editing, as well for developing additional ALT

practices outside the class. In addition, it is essential that the developed content complies to accessibility guidelines, see e.g., (W3C, 2018) for inclusiveness of all students. The extra time needed for initial preparation is compensated by being able to reuse the materials in future courses. Extra human resources are required during online teaching, as a second teacher or teaching assistant (TA) is needed to monitor students' reactions. It is vital that ALT practices are included in online education. Without including and activating all students, their engagement during online lectures and lab work will be lower than in face-to-face education, resulting in low receptiveness, and in the end, to poor knowledge transfer. Using breakout rooms for group discussions and group assignments can overcome the lack of student interaction with each other. In-class quizzes and class discussions can overcome the lack of student interaction with the teachers during class.

Moreover, through online teaching, the social component of active learning is coming under pressure. Students tend to interact less with each other, especially outside classes. It is also more difficult for teachers to get feedback on their teaching. Online education should, therefore, not completely replace traditional face-to-face education but should be used as a complementary education method. 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. Issues related to inclusiveness and accessibility need to be addressed, else a Europe-wide exchange of SDI education will remain difficult.

References

Biggs, J. B. 2003. Aligning teaching for constructing learning. The Higher Education Academy.

Bonwell, C. C. and Eison, J. A. (1991) *Active Learning: Creating Excitement in the Classroom. 1991 ASHE-ERIC Higher Education Reports.* Washington DC: ERIC Clearinghouse on Higher Education, The George Washington University, p. 121.

Cao, S., Rangelova, E. and Detchev, I. 'Instructor-Student dynamics mapping protocol design for a Geomatics Engineering classroom'. *16th International CDIO Conference, hosted on-line by Chalmers University of Technology*, 328-342.

Chi, M. T. H. (2009) 'Active-Constructive-Interactive: A Conceptual Framework for Differentiating Learning Activities', *Topics in Cognitive Science,* 1(1).

Chi, M. T. H. and Wylie, R. (2014) 'The ICAP Framework: Linking Cognitive Engagement to Active Learning Outcomes', *Educational Psychologist,* 49(4), pp. 219-243.

Deslauriers, L., McCarty, L. S., Miller, K., Callaghan, K. and Kestin, G. (2019) 'Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom', *Proceedings of the National Academy of Sciences,* 116(39), pp. 19251-19257.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H. and Wenderoth, M. P. (2014) 'Active learning increases student performance in science, engineering, and mathematics', *Proceedings of the National Academy of Sciences,* 111(23), pp. 8410-8415.

Mansourian, A., Zhao, P., Keßler, C., Küppers, N., Vancauwenberghe, G., Lacroix, L., Welle Donker, F., van Loenen, B., Tomić, H. and Kević, K. (2021) *Showcase of Existing Active Teaching Practices.* Available at: https://sdispider.eu/wp/wp-content/uploads/2021/12/IO4-Report_2021_10_14.pdf (Accessed: November 1, 2021).

Mayer, R. E. and Wittrock, M. C. (1996) 'Problem-Solving Transfer', in Berliner, D.C. and Calfee, R.C. (eds.) *Handbook of Educational Psychology*. New York: Macmillan, pp. 47-62.

Menekse, M., Stump, G. S., Krause, S. and Chi, M. T. H. (2013) 'Differentiated Overt Learning Activities for Effective Instruction in Engineering Classrooms', *Journal of Engineering Education,* 102(3), pp. 346-374.

Michel, N., Cater III, J. J. and Varela, O. (2009) 'Active versus passive teaching styles: An empirical study of student learning outcomes', *Human Resource Development Quarterly,* 20(4), pp. 397-418.

Office of Distance Learning (2011) *Instruction at FSU. A guide to teaching and learning practices*: The Florida State University. Available at: https://odl.fsu.edu/sites/g/files/upcbnu2391/files/media/I%40FSU.pdf (Accessed: October 8, 2020).

Pitz, N., Schulze Althoff, J., Welle Donker, F., van Loenen, B., Vancauwenberghe, G., Mansourian, A., Zhao, P., Kević, K. and Tomić, H. (2021) *Methodology on Active Teaching and Learning on Open SDI* IO3). Available at: https://sdispider.eu/wp/wp-content/uploads/2021/03/IO3_02-03-2021_finalVersion.pdf (Accessed: November 1, 2021).

Ramsden, P. (2005) 'The context of learning in academic departments', in Marton, F., Hounsell, D. and Entwistle, N. (eds.) he Experience of Learning: Implications for teaching and studying in higher education. Edingburgh: University of Edingburgh, pp. 198-207.

Renkl, A., Atkinson, R. K., Maier, U. H. and Staley, R. (2002) 'From Example Study to Problem Solving: Smooth Transitions Help Learning', *The Journal of Experimental Education,* 70(4), pp. 293-315.

W3C (2018) *Accessibility.* Available at: https://www.w3.org/standards/webdesign/accessibility (Accessed: November 1 2021).