Research Article

Christian Mercat*

Introduction to Active Learning Techniques**

https://doi.org/10.1515/edu-2022-0010
Received Apr 14, 2021; accepted Nov 22, 2021

Abstract: This introduction presents Active Learning Methodology, surveying its history, main existing tools and supporting evidence, with an emphasis on mathematics and higher education, in particular engineering studies. This work is part of the DrIVE-Math project, developing innovative mathematical teaching strategies in engineering studies.

Keywords: Active Learning, higher education, teaching, mathematics for the engineer, student centered education, evidence, motivation, problem-based learning, university, mathematics, engineering, science, skills

1 Active Learning Methodologies: a survey

The DrIVE-Math project is financed by the European Commission under the Erasmus+ framework. It aims at developing a novel and integrated framework to teach math classes in engineering courses at the university level. New teaching methodologies have been experimented by the four partners: the coordinator is the Polytechnic of Porto [1] from Portugal, the Slovak Technical University in Bratislava [2] from Slovakia, the Technical University Chemnitz [3] from Germany and Claude Bernard Lyon 1 from France.

Introduced in the nineties, Active Learning methodologies aim at giving responsibility to the student of his/her own meaningful learning, engaging him/her in meaningful learning challenges that require higher-order thinking such as analysis, synthesis and evaluation. Faced with massification of higher education [4], involving a more heterogeneous audience and a shortening of the life cycle of technologies, higher education had to reform itself. Traditional teaching methodologies of massive quiet amphitheater lectures where teacher is the only source of knowledge and students are passive, was in crisis. Indeed, students not only need to acquire *knowledge* but rather *competencies*, especially *higher order thinking skills* [5]. And this shift, in order to gain deeper learning rather than shallow surface knowledge, requires more engagement, contribution and participation. Analysis of case studies, discussions, synthesis require finer applications of knowledge on the part of students, but as well more guidance on the part of instructors.

After thirty years of evolution, Active Learning has stabilised. The informal network *Active Learning in Engineering Education (ALE)* [6], founded in 2001, is the meeting place of practitioners, stressing that political organisations, like UNESCO, or accreditation boards such as SEFI, ABET and ENAEE recommend AL in engineering curricula. It is no longer seen as yet another educational fad that will disappear without trace, but, although it has proven its benefits, it is not yet widely adopted in Engineering courses. As Prince [7] states, *Some of the evidence for Active Learning is compelling and should stimulate faculty to think about teaching and learning in nontraditional ways.* There is no magic wand but some improvement and joy in teaching and learning can be found in the *Active Learning* approach, so let's go through some different active methodologies and their features [8, 9].

2 Main features

We list here the main incentives to use active methodologies in your class before studying in more details how they are put into action in different strategies and their actual proven effects.

Active Learning is a *student* centered instruction approach rather than focusing on *content* alone [10]. It is particularly interesting for engineering studies where team skills and life-long learning mindset are paramount [11].

The first surface interest of active methodologies is to get students *attention* in order to increase their *motiva-*

***Corresponding Author: Christian Mercat:** Christian Mercat, Univ Lyon, Université Claude Bernard Lyon 1, UR 4148 S2HEP, F-69622, LYON, France; Email: christian.mercat@univ-lyon1.fr

** DrIVE MATH - Development of Innovative Mathematical Teaching Strategies in European Engineering Degrees, 2017-1-PT01-KA203-035866

tion [12, 13]. Changing the rules, introducing novelties, using technology, can help for a while catching students' attention. But this has to be clearly for the benefit of learning and take into account students. Then it can lead to an improved attitude and perception of the field by students, yielding *engagement* and *accountability* in a *meaningful learning* [14].

Active Learning has its roots in constructivism where knowledge is gradually constructed. Showing respect to students relies first in knowing their prior knowledge and allowing them to build on top of it, scaffolding from an existing solid base rather than on the sand of dreamed up alleged prerequisites [15]. Misconceptions should not be left unattended, dismissed or scorned at but should rather be positively identified and openly addressed. Active methodology is used to *assess* your students in a trusted environment where making mistakes, not knowing or not understanding something is a recognized part of the learning process [16].

Based on this, most learning is viewed not as simply knowledge which is passively acquired but rather as *problem solving skills* that deepens students' understanding of concepts as tools to solve problems, individually or in group. Students then study for meaning rather than mere recall. Hence, although theory is needed to clarify concepts, and abstraction to bring to light unifying perspective on seemingly unrelated phenomena, *applications* ought to be brought to center stage, with some occasional relevance to *realistic* professional context such as genuine case studies. But it has to be noted that for this approach to work, tutors have to sufficiently direct and master their subject: Casual self-directed learning and shallow foundations of factual professional knowledge on the part of non expert tutors is detrimental to the *Problem-Based-Learning* approach [17, 18].

Collective phases, with communication, synthesis and decision making opportunities, develop critical thinking, collaborative, cooperative and interpersonal skills, while maintaining individual responsibility and accountability in learning [19].

But success in solving a problem might not lead to learning. Learning only occurs if the underlying unifying theory is understood and internalized. Assessing this at different scales in time and depth is paramount. Assessments are manifold, through final exams of course but as well portfolio, projects and assignments; they can be individual or collective, shallow or deep, immediate or elaborate, oral or written, summative (exercises get marks that are summed up into a grade) or formative (to know whether a subject is mastered or should be reviewed again). Assessment should lead to a positive attitude and healthy working habits rather than last minute rush revision [14, 20, 21].

Different learning contexts yield different opportunities, like the size of the class or groups therein, synchronous or asynchronous work, online or in presence... Small groups are more flexible in terms of spatial organization. Building a set of like minded students is important but it has to be disrupted from time to time in order to vary perspectives and learning strategies [22].

2.1 Active Learning Methodologies

Flipped learning: Direct instruction happens outside the classroom. During class, "the educator guides students as they apply concepts and engage creatively in the subject matter" [23–26, 113]. *Just-in-Time* is one of many such strategies belonging to this trend, where students collect information to answer warm up questions, handing their answers the day before class, allowing the instructor to adapt the lesson accordingly.

eduScrum: Students are working in self-managing teams and making their learning visible. The tutor (product owner) provides the *what* and *why* of the activity, the students (team) decide the *how*, a captain therein leads the team, especially the review of each student's work. Regular retrospectives round up the work done, celebrate achievements and identify improving venues [27–29, 122].

Pause and Share Teacher stops instruction for the students to *pause* and *share* their understanding of the issue at stake. This has proven effective as a very minor change in traditional lecture where students simply clarify their notes in small groups [30].

Think-Pair-Share: Students individually *think* for a while on the issue at stake, then discuss in *pair* to confront and elaborate their thoughts and finally *share* their findings with a larger group. Propose a complex enough problem that requires some engagement. Leave sufficient time for students to elaborate, insist on particular forms, such as containing the word *because*. Also called *1-2-All*, this technique simply formalizes a very well established teaching strategy [31].

Case Studies: Students are presented with a situation that they have to analyze. The teacher introduces questions when the students need some impetus to keep producing or simply to formatively assess students understanding of the content matter. More and more complex case studies can be introduced as students get used to working this way. Without burying the big picture into too many details, a good case study should not have an obvious decisive answer and would require additional infor-

mation, connections and perspectives to be gathered by students in order for the problem to be solved [32].

Jig-Saw: Students groups are presented related but different perspectives, say A, B, C, on an issue. After letting them work for some time on a given perspective, groups are dissolved and reassembled in another way mixing perspectives. These should be understood as complementary and providing salient points of the same big picture answer on the problem at stake [33, 34].

Peer-Review: Assign students with one or two other students draft production to study. Then discuss rules for non violent, constructive and supportive expression that create mutual confidence and trust. Distribute guiding reviewing questions, with key elements or form to answer. In a second time, organize review, offering peer feedback among students, preferably in written form, followed by brief oral 1-1 discussion. Allow room for revision or for an *Author's Chair* or *Hot Seating* session where one student's work is the focus of attention of a whole group and the author answers feedback. For lighter evaluation, a simpler peer review process is the *Two Stars and a Wish* protocol where, in each production, two good features should be pointed out and one wish expressed in order to enhance the work [35].

Post-it Parade: An established classic of brainstorming put to educational use. Students silently write on a post-it an idea, an example, a solution, a question to a given problem. Many different variations exist, the core phases being the Kawakita Jiro technique of individual thinking, collective sharing, clustering and final voting or prioritising. On paper, it can take the form of the *ABC Brainstorm*, creating an alphabetized list of words related to a question in order to get an overall picture of students prior or retained knowledge. In *Buzz Groups*, the issue is discussed in small groups for a few minutes then one idea from each group is shared and written on the board. It is a more collective way to brainstorm [36, 37].

Affinity Cluster: Grouping the production of a brainstorm by themes, as a *List, Group, Label* activity. It is an interesting analysis challenge, to put items into consensual sets and to name them. The clustering is done with students being assigned a cardboard with an item written in it, moving around the class to discuss with peers in order to convince some to join when they see a link or to split if a sub-cluster seems more appropriate. In the debrief, students have to justify their classification system [38].

Card Ranking: In a wealth of items, each group prioritises them by selecting the five most important ones and share this list with the class, justifying it. Repeat until collective agreement. Some variations names include *Diamond Ranking* and *Ideas Funnel*. A simpler version is to tag items with *Plus, Minus and Interesting* dots, whether individually or as a group [39].

Dotmocracy: When a matter raises several viewpoints, lay them on the wall in different places and have students vote for their favorites with dots (stickers, checkmarks) in order to have a visual clue regarding the distribution of opinions, multivoting with equal or ranked dots such as *Plus, Minus and Interesting* dots. Discuss and repeat [40, 119].

Snowball: A cascading Think-Pair-Share where an agreement has to be reached when pairing. Repeat until all the class tallies a common result. Restrict the time and the number of items to agree upon like the three most important issues. As the size grows, roles should be proposed such as spokesperson, time-keeper, scribe… [41]

Respond, React, Reply: In small groups, each student *responds* to a challenging common prompt in a short individual written form. Then this response is read aloud and shared with the group, in turn. Secondly, each student in turn *reacts* in a constructive and supportive way to each participant's response in the group. A third round allows every student to *reply* to the reactions [40].

Memory Game: A task is described at the tutor's desk. One student from each group can read the sheet only once during thirty seconds then comes back to the group to inform of the task and work on it. After a while, a second viewer from each group can come and read the sheet for more details and so on. Memorizing and explaining orally what is written as mathematics, understanding what is crucial to remember compared to what is not so important, communicating with peers, are skills worked in this method [42].

Round Table: Arranged in a circle, students, in a *Go Around Robin*, comment a complex issue raised by the instructor without being interrupted or pass, if they wish not to comment. It can be used as a check-out technique with a *one phrase close* [43].

Complete Turn Taking: Arrange a small group in a circle. A student asks a question (prepared beforehand) aloud. The student to his/her left gives her/his thoughts for at most one minute without being interrupted, finishing by "OK, I'm done", then the next person on the left follows the same protocol, in an additive and non repetitive way. When three persons have shared their thoughts, the conversation is opened-up to the rest of the circle for two minutes. Then the student to the left asks a question and so on [40].

Fishbowl: A small group of volunteers is observed by the rest of the class tackling a given task, commenting aloud their thoughts and actions. After a certain amount of time, roles are exchanged, the inner ring joins the ob-

servers while a group from the outer ring dives into the fishbowl, whether elaborating on the same activity or being assigned a new activity [40, 44].

Think Aloud: Students work in reader/listener pairs. When working on a task, the reader thinks aloud and comment on what she/he is doing and thinking. Swap roles when finished. Bringing the groups together, in front of the class, the instructor does his/her own think aloud exercise and students are asked to add their own thoughts and comments. Finally ask for a reflective discussion on what the exercise brought along [45].

Each One Teach One: Every student works on an individual item alone (can be in a flipped context) then moves around the classroom to share this work with fellow students and to hear from their own, pointing out the difficult points. This can continue with an *Affinity Cluster* activity where students should group along commonalities of their work. This is an example of the broader *Learning by Teaching* trend [46].

Group Text Reading: A difficult text is split in 1-2 paragraph sections given to small groups. After discussing for 15 minutes in groups, each group in turn presents their part of the text. The instructor listens, writes down, corrects and adds to students responses as needed. This might not be so easy to do on mathematical content, which is structured in a more rigid way than other types of materials, and might be rather used in flipped context or on project preparation [47].

Debates: A certain matter is presented with two opposite viewpoints. Students are assigned one side and have to prepare an argument in order to defend it. Ensues a series of exchanges of arguments, one at a time, listened, analyzed and answered by the other party. This can be based on the results of a *Fact Finding Mission* or an *Inquiry Challenge* where arguments are gathered by students, structured by scaffolding questions and hints [48].

DeBono's hats: In a discussion, each student is assigned a perspective on the situation (a *thinking hat*): the white specializes on the *facts*, whether known or needed, the yellow explores *opportunities* and benefits, the black spots the *problems* and difficulties, the red analyses *feelings* and emotions, the green explores *possibilities* and alternatives, the blue controls and *manages* the other five [49, 50, 144].

Pro-Con Grids: In small groups, find three advantages and three disadvantages regarding a topic that you give to the class. Share and discuss at the level of the class. A simpler setup is the *Plus, Minus, Interesting* method where you have to find one advantage, one disadvantage and one interesting point regarding the issue at stake. Having to ponder both sides of a question, electing a temporary devil's advocate, walking the other side's shoes and allowing for dialectical inquiry can be fruitful [51, 52].

Consider All Factors: In small group and limited time, list all factors, available options that impact a situation. This can be done interactively with the *Other People's View* setup where students express their own position on a subject in private writing, then move around the classroom to hear about other people's views and expose theirs, taking notes of different points of view, trying to collect the most differing opinions [52, 53].

2x2 Matrix: : When considering two independent factors, laying out these criteria as axis and defining four blocks picturing crossing the options regarding these factors can help grasping the situation in a *Polarity Map*. In a systemic project, this can lead to a full-fledged *SWOT analysis* identifying Strengths, Weaknesses, Opportunities and Threats, or a *RAID analysis* studying the Risks, Assumptions, Issues and Dependencies associated to a given situation. Decomposing a problem in sub-parts is essential in mathematics but usual project management techniques might not apply so easily such as the *Hot Air Balloon* planning strategy, the basket being the essential people on the project, the burners the skills available, the left/right winds the opportunities and risks, the anchor the difficulties to lift up the balloon, built up of all the measures to take [48, 54].

Line-up: Also known as *Spectrum Debate*. Suitable for large groups in order to get the degree of agreement of the class. A certain matter is presented with two opposite viewpoints. One viewpoint is associated to an end of a wall, the other with the other end. After some discussion, each student has to take a position and line-up against the wall, between the two ends in a *gradient of agreement* that reflects his/her position regarding the matter at stake. The matter should be complex enough that some gradient and gray areas should arise, resolved by one-on-one discussion. This method can as well be used to situate collectively a numerical answer inside a given interval. A simpler line-up setup is the *Giant Step* technique where students whether step forward or backward indicating their simple approval or disapproval, or *Four Corners Debate* for a *2x2 matrix* format [55].

Fist to five: An agile formative five scales assessment technique, simpler to set-up than a Line-up yet more informative than a simple *Straw poll*. Each student takes a stand showing their hands and fingers, from five fingers full extended hand for a total agreement, to a total disagreement with a closed fist. A simpler message is given by *Thumbs up*, side-way or down, especially for self-assessment of mastery of the objectives. Engagement regarding agreement and disagreement is provided by in-

volving the body [56]. When there are several issues to assess, a *Dartboard evaluation* where students have to place a dot on a physical target with concentric circles serves the same purpose [9].

Quescussion: Participate in a discussion where answers can only take the form of questions, added to the board in a progressive questioning. Statements are not allowed, a participant can not speak again until two other persons have given an input. A follow-up could be to work deeper on a selection of the most important questions, the selection itself being an activity. This goes along with the *5 Whys* technique to determine the root cause of an issue, or the *5 hows* to help implementing a technique. Taking notes of a quescussion is better achieved in the form of a tree or a *Mindmap* [40, 57].

Index Card Pass: Each student writes a question about a subject at stake (the course, an assignment, organization…) and then swap cards, read it, swap again, making at least 4 passes. Then in small groups, everybody reads the card they have and the group elects one question to discuss [40].

1-Minute Papers/Reflections: At the end of an activity, as a *check-out technique*, ask for a short response to a short reflection question (concept that was not clear, lesson learned…). Begin the following class answering the most salient issues raised. You can focus the reflection on the *4L* questions: One thing I Liked, one thing I Learned, one thing I Lacked, one thing I Longed for. It is an elaboration of the *KWL perspective* where one has to answer what they Knew and was useful, what they Want to know and what they have Learned, as a progression card during the learning process or as a conclusion. A more radical way is to have students self-evaluate their *Return On Time Invested, ROTI* with a *Fist to five* [58, 59].

These methodologies are most effective when involving different instructional strategies and rely on some basic interaction principles regarding how students cooperate with the tutor and with one another, or even with themselves [8]:

Six Serving Men: Based on a poem by Rudyard Kipling [60]

I keep six honest serving men, they taught me all
I knew.
Their names are What and Why and When
and How and Where and Who.

Try to ask your six serving men before reaching out to others. In mathematics, *who* can be a number or the author of a theorem, *when* can be associated with conditions that makes things work. But this methodology can as well be used to assess projects, what needs to be done, who needs to do it and when it should be done…

Ask 3 before me: Is a general rule of interaction between students and tutors, where a tutor can address a question only if it has been already asked to at least three fellow students [61].

Stick Debate: In order to have students think before talking or asking, in talkative context, have them hand out a stick (out of 3 at the beginning) each time they raise an issue [9].

Numbered Heads: A random strategy to call on students in a more equitable fashion than answering the raised hands. The answer can be elaborated in groups, the team whether validates the individual answer or simply uses the individual as the messenger of the collective answer [62, 63].

Appreciation: Don't forget as a tutor or as a student to show respect to others and appreciate their efforts rather than focusing on the inadequacies [9].

5 seconds Rule: As a tutor, don't move on to another subject until 5 seconds of silence after asking a question such as "Are there any questions?" [64].

PALPaR: A checklist to follow when interacting effectively with students in five verbs; Present, Ask, Listen, Pause and Reply.

Revolving Circle: Interaction between students is not random in the classroom but in two circles, an inner and an outer, that shift by one unit repeatedly [65, 66].

SCAMPER: Before reaching to others for an answer, go through unblocking strategies summarized in six verbs: *Substitute*, elaborate examples, find alternatives, what could be different? *Combine*, mingle together different pieces of knowledge, bring together elements, unite and try to see the big picture; *Adapt*, adjust the data to fit an easier situation, reshape, what if…? *Magnify, Modify, Minimize*, change the scales of the problem, tune up or down to see if it's easier, how a particular case could be characteristic of a more general scheme; *Put to other use*, repurpose some of your skills and knowledge to another setting, stretch the intended purpose of a tool; *Eliminate*, remove, omit, simplify, get rid of some assumptions or hypothesis, challenge assumptions to see how it affects the problem; *Rearrange*, reverse, change the obvious order or layout, turn around your sketch to see it from a new perspective. These exploration strategies can as well benefit to work in group [67].

Parking Lot: a place where to explicitly put items that have to be discussed at another point in time. Check-out time should review the course parking lot, and whether its issues should be addressed next time [68].

2.2 Tools

Active Teaching happens definitely on the pedagogical side and as such is not connected to any particular teaching tool, whether physical or digital: it is more about methods to teach. Nevertheless, especially in the COVID era of distance learning, Active Teaching might be eased by tools that allow for effective collaborative work and smooth assessment [69]. These distance learning tools allow you to go deeper in the *SAMR* model where technology not only enhances but transform pedagogy [70]: these tools

- Substitute face to face work with online collaboration, content sharing,
- Augment work in the classroom by keeping track of a semester long conversation with peers and tutors,
- Modify work with powerful tools, allowing to ask questions that require deeper investment,
- Redefine tasks which were not conceivable without the use of technology.

All universities nowadays have their own Learning Management Systems (LMS), such as *Moodle*, *Claroline*, *Canvas*, *Blackboard*, *Sakai*, *Google classroom*, *Open edX*, *Opale* or home made brews. Like large software suites such as *Google Suite*, *LibreOffice* or *Microsoft Office*, they all have their own tools that can be used to assess or collaborate, but varying your tools may be beneficial to some aspects.

Distance learning is based on some tele-conference tool (sometimes embedded in the LMS) such as *Microsoft Teams*, *Google Meet*, *Zoom*, *Cisco WebEx*, *StarLeaf*, *Adobe Connect*, *GoToMeeting*, *ClickMeeting* with a special mention to the open-source *BigBlueButton* and *Jitsi Meet* (BBB is advised by French ministry).

The assessments we are dealing with here, in Active Learning strategies, are mainly of the formative kind, in order to gauge the mastery of a content, it can be autonomous as auto-assessment, with peers, competitive or not, or under tutor's supervision, where fun plays an important motivation role. Organizing and reviewing material should be creative and feel like a game. Knowing where students stand in their acquisition of competencies is very important, both for the tutor, instantly during the classroom and throughout the semester till the final exam, and for the students themselves, to explicitly know what they know and what they still need to practice.

Critical thinking is at the heart of Active Learning methodologies, and content is better memorized when put into use through problem solving, nevertheless, some healthy daily routine of content review and active recall is as well important in foundational knowledge [15, 66, 71]. Gamification will not instantly turn boring rote drilling exercises into a playful experience without some work on tutor's part but some tools can turn self-assessment and formative assessment into a joyful challenge and help motivate students [13, 72].

Some of these tools make the assumption that we can make a positive use of students' own device in the classroom, but their introduction presents pedagogical risks as well, in particular because social media are very effective at attracting students' attention [73].

Jeopardy: Think about quality questions that may lead to a particular answer, $(a_{k+1} - a_k)f\left(\frac{a_k+a_{k+1}}{2}\right)$ could be the answer to "What is the area of a generic rectangle in the Riemann sum?". Constructing and answering cards, challenging fellow students, are both interesting [74]. The answers can be the basis of a *Memory*.

Memory game: Choose a subject, for example primitives and derivatives. Make sets of two or three elements, for example $f(x) = \tan(x)$, $f'(x) = 1 + \tan^2(x)$, $F(x) = k - \ln(\cos(x))$ written on different cards. Put all cards on hidden face and arrange them randomly in an array. A player flips two cards, if they are associated, she/he can have a try at a third one or pick them up. Wins the student with most cards [42].

Flash Card: Traditional linear set up of cards (whether physical or digital) with a question on one side, its answer on the other. They are placed in boxes (or split as pairs in a Memory game), cards learner knows are promoted to less frequent review box, cards that are forgotten are demoted for more frequent review. Simple single sided *Cue Cards* are designed for more complex constructs or lists of items [75].

Mindmap: Make a sketch of the situation, the different concepts and arguments associated with it and their relationships, the different ingredients needed in a theorem or a technique. A great way to summarize a course or an algorithm. A collective exhibition as in a *Gallery* can be a way to share and follow-up on this activity. Some structure can be imposed such as *Constructing Walls*, *Priority Pyramids*, linking factors from bottom to top, or *Fishbone strategy* with a head, a spine and concurring bones, a tree or a spiral. There are collaborative online tools for that (see below) [57].

Plickers: A *Multiple Choice Question* modality where students answer by holding an individualized square QR Code card recognized by the tutor's smartphone scanning the entire class. Each card can be turned in four different ways in order to give the correct A/B/C/D answer at the top. The tutor manages the display of the question with a

video projector where a report can be displayed and tallied in a scoresheet or kept on the smartphone [76, 139]. *QCM-Cam* is an alternative that can be used offline [142]. *VotAR* is based on anonymous colour codes [148]. *Auto-Multiple-Choice (amc)* produces MCQ in PDF that can be printed or annotated digitally, then scanned back and optically recognized in order to grade students [114].

Kahoot: might be the best known quizz app where a QR-code or an easy short link is provided on the screen for the students to be able to answer the question [127]. It requires students to have their own device. There are many variants, while *Kahoot* builds on the competitive feeling, *Socrative* has break-out rooms [77, 146], *Mentimeter* embeds into slides presentations and has LaTeX support [129], *Slido* is simpler but integrates with *Google slides* and Videoconferencing [145], *iSpring* is a *PowerPoint* tool [126], *Poll Everywhere* integrates with *PowerPoint*, *Keynote* or *Google slides* [140], *Quizizz* [143], *DocEval* (with DGS answers!) [118] and *nearpod* [135] allow for asynchronous assignment, *Wooclap* can be answered by simple texting (SMS) [149]. [78, 79]

WIMS: is a very powerful exerciser, based on computer algebra system verification of answers to sophisticate randomly generated exercises [80].

GeoGebra: is the Swiss-army knife of interactive mathematics that allows to easily illustrate interactively most basic mathematical problems. These items can be embedded or assigned in many different e-Learning platforms. Now with *Geogebra Classroom*, students works can be easily browsed and surveyed, whether synchronously or asynchronously [81].

Miro: Collaborative online whiteboard with mind-mapping, video-chat, integration with many services such as file sharing, team management, bug tracking. A very complete collaborative tool [133]. Some other collaborative whiteboard software comprise *OpenBoard* which is multiplatform and can overlay on your desktop [136], *Google JamBoard* which is multi page [124], *Ziteboard* has text, audio and video chat [150], *Mural* which is more centered on team work [82, 134].

Coggle: A collaborative online Mind mapping tool [117], such as *MindMup* [132], *GroupMap* [125], *MindMeister* [131] or *MindManager* [130].

Padlet: A collaborative bulletin board tool with anonymous or identified pads, organized in columns. A pad can contain many things such as rich text, images, links, oral or video notes, scribbling, geolocation, documents... [137] *Coda* blends collaborative edition of documents and databases [116]. *Kialo* specializes on textual debate and critical thinking [128]. *ClassKick* is a full fledged collaborative learning system, with the teacher and her class, collaborating together [115]. *Etherpad* is an open-source simple collaborative real-time rich text editor [83, 123].

Prezi: A collaborative hierarchical presentation tool that can be used as a mind mapping tool. The *Prezi Video* app lets you embed your webcam feed within your presentation [84, 141].

edpuzzle: Let you transform any video into a course with MCQ, notes and open-ended questions along the way, giving assignments to students and tracking their progress [85, 120]. *Spiral* is a more general tool with questions, quiz and collaborative whiteboard where videos can be live commented by all students [147]. *PlayPosit* and *Educreations* are focused on video and along the same line of thought [121, 138].

2.3 Evidence

There is no definite clear cut evidence that adopting an Active Learning methodology *will* work in *your* setup, but a number of studies show more than promising results [7, 86, 87]. It is somewhat difficult to compare exactly what each study is showing and easily measured academic results are not the only indicators that have to be taken into consideration, but rather retention and engagement of students, yielding life-long learning skills such as problem solving, interpersonal and cooperative mindset.

2.3.1 Engagement

In order to be engaged, students need to be recognized in their prior knowledge, for the instruction to be in their *Zone of Proximal Development* [88, 89] where they are challenged but not overwhelmed by difficulties, where the new knowledge is anchored by multiple links to what they already master. Building teaching on students prior knowledge is difficult for several reasons. First the audience is heterogeneous and every student has his/her own specific learning gaps. These gaps are diverse and have to be identified and treated properly. That is to say the proposed activities have to create a cognitive dissonance that proves old conceptions to be unsuitable, but amendable, to solve the problem [89]. This dissonance, leading to mistakes, has to be accompanied and not hidden as a discouraging bad behavior. Preparing robust activities that don't require a bullet proof expertise from tutors both on subject matter, on professional context and on educational theories requires a lot of time and energy on the side of instructors. Otherwise cognitive dissonance, when disregarded,

shunned at, or simply not seen by tutors, may lead to a demotivating blow to morale of students. On the contrary, identifying and making explicit faulty conceptions gives an opportunity for the students to repair misunderstandings, possibly through remediation proposed by the tutor, and progress in meta-cognitive skills, being conscious of what has been learned [90–93].

2.3.2 Problem Solving Learning

Learning a fact is generally more fragile than learning how to do something. The first is called *declarative* or *conceptual knowledge* and the second *procedural knowledge* [94]. To envision knowledge as a tool to grasp and solve problems is the basis of Problem Based Learning (PBL) [99]. Indeed, transferring knowledge from an abstract context to an applied context is not transparent and learning directly a concept through its application as a tool can help better situate it epistemologically [95]. Notice that a problem can be of an abstract nature, it doesn't need to be related to realistic epistemic use in a professional situation, especially in mathematics [96], yielding *cognitive realism* instead of physical realism [97]. On the other hand, doing is not necessary linked to learning, some meta-cognition has to occur for a solution to a problem to become the basis of a stable procedural knowledge: exactly what have we achieved and how, and what does it mean? [98–100].

2.3.3 Collaboration

There are strong evidence that students learn better with others rather than alone [15, 101–104]. In comparison to competitive and individualistic learning, cooperative learning has strong effects on achievement, socialization, motivation and personal self-development [101].

While collaboration is valued in the workplace, education, at secondary level and in universities, rewards individual work mostly through *in fine* individual assessments: your academic path depends on your achievements [105]. From the point of view of a student, taking a personal advantage of the work of others seems only natural, keeping their own individual production to a minimum and getting the collective credit, a behaviour known as *free-riding* [106]. This shift towards collaboration has to be accompanied: preaching ethic is not enough [107]. Concrete steps have to be taken to promote collaboration and convince students in practice that it is indeed a better tool for learning from their own point of view, disregarding their own position in the learning ladder seen as a competitive ranking [108, 109]. Even in case of persisting uneven production, cooperative instructional methods allow students to feel included in the learning process and can motivate students [13].

Whereas *collaborative* work, for a common goal with mutual engagement, can be parasited by unethical behaviors taking advantage of others work, *cooperative* learning, where students take responsibility for a specific section of the work is easier to assess and helps negotiating this type of didactic contract [110, 111]. The common goal set by tutors has to be the result of group members working *together* in a positive interdependence where each one is accountable for a clearly identified contribution. And the coordination is done through positive interaction, support, encouragement, help, from the tutor but most of all from within the group, developing effective team work and interpersonal skills based on complementary division of the work: It is because they *need* each other, share resources, provide feedback, validate or challenge each other's conclusions, that students collaborate, and doing so tend to cooperate and grow a positive mindset towards their collective work. In fact, cooperative learning can be seen as the foundation for Active Learning [112].

2.4 Conclusion

In this consortium, *EduSCRUM* [122], coming from agile project management in software industry, has been widely used and its clear structure helps students adopt asymmetric roles and actively interact towards a common goal with clear objectives and ways to assess, by students or by tutor, what has been achieved, and what gets to be done, how and by whom. But other methodologies have been used to motivate students to learn and to develop their competencies and skills, in particular soft skills required by the present days Fourth Industrial Revolution.

Their findings are being published: the Polytechnic of Porto [1] from Portugal, the Slovak Technical University in Bratislava [2] from Slovakia, the Technical University Chemnitz [3] from Germany and Claude Bernard Lyon 1 from France.

Acknowledgement: With the support of the European Union Erasmus+ programme DRIVE MATH - Development of Innovative Mathematical Teaching Strategies in European Engineering Degrees, 2017-1-PT01-KA203-035866

References

[1] Carla M.A. Pinto, Jorge Mendonça, and Susana Nicola (2021). Drive-math project: Case study from the polytechnic of porto. In *Open Education Studies, accepted for publication*.

[2] Daniela Velichová, Jana Gabkova, and Peter Letavaj (2021). Drive-math project: Case study from the slovak technical university. In *Open Education Studies, accepted for publication*.

[3] Wolfram Hardt, Ariane Heller, and Uranchimeg Tudevdagva (2021). Drive-math project: Case study from the technical university chemnitz. In *Open Education Studies, accepted for publication*.

[4] Vikki Boliver (2011). Expansion, differentiation, and the persistence of social class inequalities in British higher education. *High Educ*, 61(3):229–242.

[5] Raymond Nickerson (1994). The Teaching of Thinking and Problem Solving. In *Thinking and Problem Solving*, pages 409–449.

[6] Rui M. Lima, Pernille Hammar Andersson, and Elisabeth Saalman (2017). Active learning in engineering education: A (re)introduction. *European Journal of Engineering Education*, 42(1):1–4.

[7] Michael Prince (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, 93(3):223–231.

[8] Mel Silberman (1996). *Active Learning: 101 Strategies To Teach Any Subject*. ERIC.

[9] Persida Himmele and William Himmele (2017). *Total participation techniques: Making every student an active learner*. ASCD.

[10] Charles C. Bonwell and James A. Eison (1991). *Active Learning: Creating Excitement in the Classroom*. Number 1, 1991 in ASHE-ERIC Higher Education Report. School of Education and Human Development, George Washington University, Washington, DC.

[11] S. Lord, M. Prince, C. Stefanou, J. Stolk, and John Chen (2012). The effect of different active learning environments on student outcomes related to lifelong learning. *International Journal of Engineering Education*, 28:606–620.

[12] Jorge Mendonça, Susana Nicola, and Carla Pinto (2018). ACTIVE LEARNING: SELF-MOTIVATION IN MATH COURSES. In *12th International Technology, Education and Development Conference*, pages 1870–1877, Valencia, Spain.

[13] Carla Pinto, Susana Nicola, Jorge Mendonça, and Daniela Velichová (2019). Best teaching practices in the first year of the pilot implementation of the project DrIVE-MATH. *Teaching Mathematics and its Applications: An International Journal of the IMA*, 38(3):154–166.

[14] Thomas A Angelo and K Patricia Cross (1993). Classroom assessment techniques: a guide for college teachers.

[15] Anastasia Sofroniou and Konstantinos Poutos (2016). Investigating the effectiveness of group work in mathematics. *Education Sciences*, 6.

[16] P. Dawson and S. Dawson (2018). Sharing successes and hiding failures: 'reporting bias' in learning and teaching research. *Studies in Higher Education*, 43:1405 – 1416.

[17] D. Allen, R. Donham, and S. Bernhardt (2011). Problem-based learning. *New Directions for Teaching and Learning*, 2011:21–29.

[18] C. Reading and Helen Doyle (2013). Teacher educators as learners: Enabling learning while developing innovative practice in ict-rich education. *Australian Educational Computing*, 27:109–116.

[19] Hulya Julie Yazici, Lisa A. Zidek, and Halcyon St. Hill (2020). A Study of Critical Thinking and Cross-Disciplinary Teamwork in Engineering Education. In Alice E. Smith, editor, *Women in Industrial and Systems Engineering: Key Advances and Perspectives on Emerging Topics*, Women in Engineering and Science, pages 185–196. Springer International Publishing, Cham.

[20] Joni K. Adkins (2018). Active learning and formative assessment in a user-centered design course. *Information Systems Education Journal*, 16:34.

[21] L. Allal (2020). Assessment and the co-regulation of learning in the classroom. *Assessment in Education: Principles, Policy & Practice*, 27:332 – 349.

[22] Rodney Carr, Stuart R. Palmer, and P. Hagel (2015). Active learning: The importance of developing a comprehensive measure. *Active Learning in Higher Education*, 16:173 – 186.

[23] Benjamin V. C. Collins (2019). Flipping the precalculus classroom. *International Journal of Mathematical Education in Science and Technology*, 50(5):728–746.

[24] Autar Kaw, Mary Besterfield-Sacre, and Renee M. Clark (2016). Comparing the effectiveness of blended, semi-flipped, and flipped formats in an engineering numerical methods course. *Advances in Engineering Education*, 5(3).

[25] Joseph Petrillo (2016). On flipping first-semester calculus: A case study. *International Journal of Mathematical Education in Science and Technology*, 47(4):573–582.

[26] Héctor Turra, Valeria Carrasco, Ciro González, Vicente Sandoval, and Soledad Yáñez (2019). Flipped classroom experiences and their impact on engineering students' attitudes towards university-level mathematics. *Higher Education Pedagogies*, 4(1):136–155.

[27] D. Velichová and J. Gabková (2019). Eduscrum method in teaching mathematics for engineers. In Nagy B.V., Murphy M., Jarvinen H.-M., and Kalman A., editors, *SEFI Annu. Conf.: Var. Delect.... Complex. New Norm., Proc.*, pages 1962–1971. European Society for Engineering Education (SEFI).

[28] J. Gabková and M. Omachelová (2020). Eduscrum in basic of statistical analysis course at FME STU in bratislava. In *Conf. Appl. Math., APLIMAT Proc.*, pages 487–494. Slovak University of Technology in Bratislava.

[29] J. Gabková (2020). Eduscrum – the innovative active learning and teaching method into basic mathematics II course. In *Conf. Appl. Math., APLIMAT Proc.*, pages 479–486. Slovak University of Technology in Bratislava.

[30] K. Ruhl, C. Hughes, and P. Schloss (1987). Using the pause procedure to enhance lecture recall. *Teacher Education and Special Education*, 10:14 – 18.

[31] T. Gok (2018). The evaluation of conceptual learning and epistemological beliefs on physics learning by think-pair-share. volume 4, pages 69–80.

[32] Maria Kalamas Hedden, Roneisha Worthy, Edwin Akins, Vanessa Slinger-Friedman, and RC Paul (2017). Teaching sustainability using an active learning constructivist approach: Discipline-specific case studies in higher education. *Sustainability*, 9(8):1320.

[33] Dwi Sulisworo (2012). Designing the online collaborative learning using the wikispaces. *International Journal of Emerg-*

ing Technologies in Learning (iJET), 7(1):58–61.

[34] JR Dhage, MS Patil, and AB Pawar (2017). Implementation and feedback analysis of jigsaw active learning method. *Journal of Engineering Education Transformations*, 30(3):192–199.

[35] Raoul A Mulder, Jon M Pearce, and Chi Baik (2014). Peer review in higher education: Student perceptions before and after participation. *Active Learning in Higher Education*, 15(2):157–171.

[36] Richard C Weisenberg (1997). Appropriate technology for the classroom–using" post-it notes" as an active learning tool. *Journal of College Science Teaching*, 26(5):339.

[37] Jaser Khalaf Mahasneh and Walid Thabet (2016). Developing a normative soft skills taxonomy for construction education. *J Civil Eng Architect Res*, 3:1468–86.

[38] Andrea Atzeni, Cesare Cameroni, Shamal Faily, John Lyle, and Ivan Fléchais (2011). Here's johnny: a methodology for developing attacker personas. In *2011 Sixth International Conference on Availability, Reliability and Security*, pages 722–727. IEEE.

[39] Heinz-Juergen Boeddrich (2004). Ideas in the workplace: a new approach towards organizing the fuzzy front end of the innovation process. *Creativity and innovation management*, 13(4):274–285.

[40] Vidzeme University of Applied Sciences and Sarma Cakula (2021). Active Learning Methods for Sustainable Education Development. In *14th International Scientific Conference "Rural Environment. Education. Personality. (REEP)"*, pages 59–65.

[41] Clever Ndebele and Cosmas Maphosa (2013). Promoting active learning in large class university teaching: Prospects and challenges. *Journal of Social Sciences*, 35(3):251–262.

[42] Nienke Vos, Henny Van Der Meijden, and Eddie Denessen (2011). Effects of constructing versus playing an educational game on student motivation and deep learning strategy use. *Computers & Education*, 56(1):127–137.

[43] Ganapathy Natarajan PhD PEM (2020). Round table technical presentation format: Lessons learned and application to active learning pedagogies. In *Proceedings of the International Annual Conference of the American Society for Engineering Management.*, pages 1–7. American Society for Engineering Management (ASEM).

[44] Sri Lestari Handayani, Sarwi Sarwi, and Putut Marwoto (2016). The implementation of three-stage fishbowl decision to improve students conceptual understanding and learning activity. *Jurnal Inovasi Pendidikan Dasar*, 2(1):1–8.

[45] Jeffrey A Greene, Victor M Deekens, Dana Z Copeland, and Seung Yu (2018). Capturing and modeling self-regulated learning using think-aloud protocols.

[46] Omolola Eniola-Adefeso (2010). Bringing outreach into the engineering classroom–a mass and heat transfer course project. *Chemical Engineering Education*, 44(4):280–286.

[47] Rizhaly B Maandig, Laila S Lomibao, and Charita A Luna (2017). Structured content reading instruction vs. direct instruction: Their implication on students' achievement, reading comprehension and critical thinking in mathematics. *American Journal of Educational Research*, 5(5):574–578.

[48] Bill Lucas and Janet Hanson (2016). Thinking like an engineer: Using engineering habits of mind and signature pedagogies to redesign engineering education.

[49] Edward De Bono (2017). *Six thinking hats*. Penguin uk.

[50] Ekaterina Lysenko and Liudmila Nazarova (2019). Developing technical thinking in engineering students. In *1st International Scientific Practical Conference" The Individual and Society in the Modern Geopolitical Environment"(ISMGE 2019)*, pages 430–435. Atlantis Press.

[51] Eric Forcael, Gonzalo Garcés, and Francisco Orozco (2021). Relationship between professional competencies required by engineering students according to abet and cdio and teaching-learning techniques. *IEEE Transactions on Education*.

[52] Edward De Bono (2017). *Teach your child how to think*. Penguin UK.

[53] Viktor Dörfler, Zoltán Baracskai, and Jolán Velencei (2010). Understanding creativity. *Transactions on Advanced Research*, 6(2):18–26.

[54] Monica F Cox, Carlotta A Berry, and Karl A Smith (2009). Development of a leadership, policy, and change course for science, technology, engineering, and mathematics graduate students. *Journal of STEM Education: Innovations and Research*, 10(2).

[55] Judit Mihalik (2019). Agile approach in higher education-a collaborative research project report. *Opus et Educatio*, 6(4).

[56] M. Bolger, M. Kobiela, P. Weinberg, and R. Lehrer (2010). Embodied experiences within an engineering curriculum. In *Learn. Discip.: ICLS Conf. Proc. - Int. Conf. Learn. Sci.*, volume 1, pages 706–713, Chicago, IL.

[57] Joseph D. Novak, D. Bob Gowin, and Jane Butler Kahle (1984). *Learning How to Learn*. Cambridge University Press, first edition.

[58] VLN Sastry, K Srinivasa Rao, Nekkanti Venkata Rao, Paul Clee, and G Reena Kumari (2016). Effective and active learning in classroom teaching through various methods. In *2016 IEEE 4th International Conference on MOOCs, Innovation and Technology in Education (MITE)*, pages 105–110. IEEE.

[59] David R Stead (2005). A review of the one-minute paper. *Active learning in higher education*, 6(2):118–131.

[60] Rudyard Kipling (2019). *Just So Stories: The Original 1902 Edition With Illustrations by Rudyard Kipling*. Suzeteo Enterprises.

[61] Credence Baker, James Gentry, and William Larmer (2016). A model for online support in classroom management: Perceptions of beginning teachers. *Administrative Issues Journal: Connecting Education, Practice, and Research*, 6(1):22–37.

[62] Spencer Kagan and Mary McGroarty (1993). Principles of cooperative learning for language and content gains. *Cooperative learning: A response to linguistic and cultural diversity*, pages 47–66.

[63] F Fanolong, Riki Bugis, Azwan Azwan, Hanapi Hanapi, and Nanik Handayani (2016). The students' reading ability improvement through numbered head together (nht) technique. *Jurnal Jupiter*, 14(2):67–78.

[64] John W Schuster and Ann K Griffen (1990). Using time delay with task analyses. *Teaching Exceptional Children*, 22(4):49–53.

[65] Shehzeen Alamir (2018). Exploring how secondary teachers promote critical thinking. *Journal of Teaching and Education*, 08(02):193–214

[66] Ravi Ramanujam (2011). Active learning to promote critical thinking skills. *Strathclyde University, Glasgow in Scotland, 1*, 41.

[67] Olivier Serrat (2017). The scamper technique. In *Knowledge Solutions*, pages 311–314. Springer.

[68] Kimberly Bernadine Catton, Abril Galang, and Alexander T Bulk (2016). Disruption in large classes during active learning ses-

sions. In *2016 ASEE Annual Conference & Exposition*.

[69] Jason Macleod, Harrison Hao Yang, and Yinghui Shi (2019). Systematic review of technology enabled active learning classrooms in higher education. In *2019 International Symposium on Educational Technology (ISET)*, pages 175–179.

[70] Jason T. Hilton (2016). A case study of the application of samr and tpack for reflection on technology integration into two social studies classrooms. *The Social Studies*, 107:68 – 73.

[71] Abeera P. Rehmat and Kendall Hartley (2020). Building engineering awareness: Problem based learning approach for STEM integration. *Interdisciplinary Journal of Problem-Based Learning*, 14(1).

[72] Bradley E Wiggins (2016). An overview and study on the use of games, simulations, and gamification in higher education. *International Journal of Game-Based Learning (IJGBL)*, 6(1):18–29.

[73] Iwan Gurjanow and Matthias Ludwig (2017). Gamifiying math trails with the mathcitymap app: Impact of points and leaderboard on intrinsic motivation. In *Proceedings of the 13th International Conference on Technology in Mathematics Teaching (ICTMT 13)*, pages 105–112.

[74] Joan Benek-Rivera and Vinitia E. Mathews (2004). Active Learning with Jeopardy: Students Ask the Questions———. *Journal of Management Education*, 28(1):104–118.

[75] Allyson Fiona Hadwin and Philip H. Winne (2012). Promoting Learning Skills in Undergraduate Students. In John R. Kirby and Michael J. Lawson, editors, *Enhancing the Quality of Learning*, pages 201–227. Cambridge University Press, Cambridge.

[76] C. Chanialidis (2019). Enabling active learning in large classes through the use of Plickers.

[77] José David Badia Valiente, Françoise Olmo Cazevieille, and José Manuel Navarro Jover (2016). On-line quizzes to evaluate comprehension and integration skills. *Journal of Technology and Science Education*, 6(2):75.

[78] Sherlock A. Licorish, Helen E. Owen, Ben Daniel, and Jade Li George (2018). Students' perception of Kahoot!'s influence on teaching and learning. *Research and Practice in Technology Enhanced Learning*, 13(1):9.

[79] Brianna Donahoe, Derrian Rickard, Hunter Holden, Kerra Blackwell, and Nancy Caukin (2019). Using Edtech to Enhance Learning. *International Journal of the Whole Child*, 4(2):57–63.

[80] M. Kobylanski (2019). Wims: Innovative pedagogy with 21 year old interactive exercise software. In International Conference on Technology in Mathematics Teaching, Gilles Aldon, and Jana Trgalová, editors, *Technology in Mathematics Teaching: Selected Papers of the 13th ICTMT Conference*, pages 123–144.

[81] Robert Weinhandl, Zsolt Lavicza, Markus Hohenwarter, and Stefanie Schallert (2020). Enhancing Flipped Mathematics Education by Utilising GeoGebra. *International Journal of Education in Mathematics, Science and Technology*, 8(1):1.

[82] Nabeel Al-Qirim (2011). Determinants of interactive white board success in teaching in higher education institutions. *Computers & Education*, 56(3):827–838.

[83] Henrik Skaug Sætra (2021). Using Padlet to Enable Online Collaborative Mediation and Scaffolding in a Statistics Course. *Education Sciences*, 11(5):219.

[84] Mary Caton-Rosser (2014). Discovering Interdisciplinary Uses of Online Technologies in Higher Education. *SYSTEMICS, CYBERNETICS AND INFORMATICS*, 12(3):17–21.

[85] Celal Karaca and Mehmet Akif Ocak (2017). Effect of Flipped Learning on Cognitive Load: A Higher Education Research. *Journal of Learning and Teaching in Digital Age*, 2(1):20–27.

[86] Joel Michael (2006). Where's the evidence that active learning works? *Advances in Physiology Education*, 30(4):159–167.

[87] Cindy Cogswell, Scott Pauls, Adrienne Gauthier, and Erin DeSilva (2019). Agile and active: Sustaining pedagogical change in a large-enrollment calculus course. *Journal of Effective Teaching in Higher Education*, 2(2):1–22.

[88] Arlene Mae C. Valderama, Joel B. Mangaba, Roel C. Traballo, Paulino H (2018). Gatpandan, Mary Ann B. Taduyo, Daniel D. Dasig, Mengvi P. Gatpandan, Rudolph Val F. Guarin, and Albert A. Vinluan. Efficacy of Learning Scaffolds and Learner-User Experience (UX) in the Zone of Proximal Development. In *2018 IEEE 10th International Conference on Humanoid, Nanotechnology, Information Technology,Communication and Control, Environment and Management (HNICEM)*, pages 1–8, Baguio City, Philippines, IEEE.

[89] Lorayne Robertson (2018). Toward an Epistemology of Active Learning in Higher Education and Its Promise. In Anastasia Misseyanni, Miltiadis D. Lytras, Paraskevi Papadopoulou, and Christina Marouli, editors, *Active Learning Strategies in Higher Education*, pages 17–44. Emerald Publishing Limited.

[90] Dorothy Gabel and National Science Teachers Association, editors (1994). *Handbook of Research on Science Teaching and Learning*. Macmillan ; Maxwell Macmillan Canada ; Maxwell Macmillan International, New York : Toronto : New York.

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

[92] Margarita Limón, Lucia Mason, and Inc ebrary (2002). *Reconsidering Conceptual Change Issues in Theory and Practice*. Kluwer Academic, Dordrecht; Boston.

[93] Martene L. Stanberry (2018). Active learning: A case study of student engagement in college calculus. *International Journal of Mathematical Education in Science and Technology*, 49(6):959–969.

[94] Bethany Rittle-Johnson and Michael Schneider (2014). *Developing Conceptual and Procedural Knowledge of Mathematics*, volume 1. Oxford University Press.

[95] Mona Lisa Dahms, Claus Monrad Spliid, and Jens Frederik Dalsgaard Nielsen (2017). Teacher in a problem-based learning environment – jack of all trades? *European Journal of Engineering Education*, 42(6):1196–1219.

[96] Bettina Dahl (2018). What is the problem in problem-based learning in higher education mathematics. *European Journal of Engineering Education*, 43(1):112–125.

[97] Kate Roach, Emanuela Tilley, and John Mitchell (2018). How authentic does authentic learning have to be? *Higher Education Pedagogies*, 3(1):495–509.

[98] Cindy E. Hmelo-Silver, Ravit Golan Duncan, and Clark A. Chinn (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to kirschner, sweller, and clark (2006). *Educational Psychologist*, 42(2):99–107.

[99] César Rodríguez González and José Fernández Batanero (2016). A review of Problem-Based Learning applied to Engineering. *International Journal on Advances in Education Research*, 3:1–6.

[100] Fridolin Sze Thou Ting, Wai Hung Lam, and Ronnie Homi Shroff (2019). Active learning via problem-based collaborative games in a large mathematics university course in hong kong. *Education Sciences*, 9(3):172.

[101] Robyn Gillies (2016). Cooperative learning: Review of research and practice. *Australian Journal of Teacher Education*, 41(3):39–54.

[102] Anuradha A. Gokhale (1995). Collaborative learning enhances critical thinking. *Journal of Technology Education*, 7(1).

[103] D. W. Johnson and R. T. Johnson (2013). The impact of cooperative, competitive, and individualistic learning environments on achievement. In J. Hattie and E. Anderman, editors, *International Handbook of Student Achievement*, pages 372–374. Routledge.

[104] Wilbert James McKeachie, Marilla D. Svinicki, and Barbara K. Hofer (2006). *McKeachie's Teaching Tips: Strategies, Research, and Theory for College and University Teachers*. College Teaching Series. Houghton Mifflin, Boston, 12th ed edition.

[105] Laura Tubino, Andrew Cain, Jean-Guy Schneider, Dhananjay Thiruvady, and Niroshinie Fernando (2020). Authentic individual assessment for team-based software engineering projects. In *2020 IEEE/ACM 42nd International Conference on Software Engineering: Software Engineering Education and Training (ICSE-SEET)*, pages 71–81.

[106] Saroj Bala Gaur and Tripti Gupta (2013). Is group assessment a bane or boon in higher education? A students–teacher perspective. *International Journal of Fashion Design, Technology and Education*, 6(3):141–148.

[107] Elizabeth Pfaff and Patricia Huddleston (2003). Does It Matter if I Hate Teamwork? What Impacts Student Attitudes toward Teamwork. *Journal of Marketing Education*, 25(1):37–45.

[108] Irem Sanal (2018). A review on student-centred higher education in civil engineering: Evaluation of student perceptions. *International Journal of Continuing Engineering Education and Life Long Learning*, 28(2):205–217.

[109] John Mason (2009). From Assenting to Asserting. In Ole Skovsmose, Paola Valero, and Ole Ravn Christensen, editors, *University Science and Mathematics Education in Transition*, pages 17–40. Springer US, Boston, MA.

[110] Guy Brousseau, Bernard Sarrazy, and Jarmila Novotná (2020). Didactic Contract in Mathematics Education. In Stephen Lerman, editor, *Encyclopedia of Mathematics Education*, pages 197–202. Springer International Publishing, Cham.

[111] Yves Chevallard and Marianna Bosch (2020). Didactic Transposition in Mathematics Education. In Stephen Lerman, editor, *Encyclopedia of Mathematics Education*, pages 214–218. Springer International Publishing, Cham.

[112] D. W. Johnson and R. T. Johnson (2019). Cooperative learning: The foundation for active learning. In Sílvio Manuel Brito, editor, *Active Learning - Beyond the Future*. IntechOpen.

[113] Heather Witten. Flipped learning network. https://flippedlearning.org/ Last accessed 15 February 2021.

[114] AutoMultipleChoice. https://www.auto-multiple-choice.net/ Last accessed 15 February 2021.

[115] Classkick. http://app.classkick.com Last accessed 15 February 2021.

[116] Coda | A new doc for teams. https://coda.io/signup Last accessed 15 February 2021.

[117] Coggle. https://coggle.it/ Last accessed 15 February 2021.

[118] Doceval. https://doctools.dgpad.net/ Last accessed 15 February 2021.

[119] Dotmocracy – dot voting tips and resources. Last accessed 15 February 2021.

[120] Edpuzzle. https://edpuzzle.com/ Last accessed 15 February 2021.

[121] Educreations. https://www.educreations.com/ Last accessed 15 February 2021.

[122] eduScrum homepage. https://www.eduscrum.nl/ Last accessed 15 February 2021.

[123] Etherpad. https://etherpad.org/ Last accessed 15 February 2021.

[124] Google jamboard. https://jamboard.google.com/ Last accessed 15 February 2021.

[125] GroupMap. https://www.groupmap.com/ Last accessed 15 February 2021.

[126] iSpring. https://www.ispringsolutions.com/ Last accessed 15 February 2021.

[127] Kahoot! | learning games | make learning awesome! https://kahoot.com/ Last accessed 15 February 2021.

[128] Kialo edu. https://www.kialo-edu.com/ Last accessed 15 February 2021.

[129] Mentimeter. https://www.mentimeter.com/ Last accessed 15 February 2021.

[130] MindManager. https://www.mindmanager.com/ Last accessed 15 February 2021.

[131] MindMeister: Online Mind Mapping and Brainstorming. MeisterLabs. https://www.mindmeister.com/

[132] MindMup. https://www.mindmup.com/ Last accessed 15 February 2021.

[133] Miro. https://miro.com/ Last accessed 15 February 2021.

[134] MURAL is a digital workspace for visual collaboration. https://www.mural.co/ Last accessed 15 February 2021.

[135] Nearpod. http://nearpod.com Last accessed 15 February 2021.

[136] OpenBoard. http://openboard.ch/ Last accessed 15 February 2021.

[137] Padlet. https://padlet.com/ Last accessed 15 February 2021.

[138] PlayPosit | Interactive Video Platform. https://go.playposit.com Last accessed 15 February 2021.

[139] Plickers. https://get.plickers.com/ Last accessed 15 February 2021.

[140] Poll everywhere. https://www.polleverywhere.com Last accessed 15 February 2021.

[141] Prezi. https://prezi.com/ Last accessed 15 February 2021.

[142] QCMCam. https://qcmcam.net/ Last accessed 15 February 2021.

[143] Quizizz. https://quizizz.com/ Last accessed 15 February 2021.

[144] Six thinking hats – de bono group.

[145] Slido - audience interaction made easy. https://www.sli.do Last accessed 15 February 2021.

[146] Socrative. https://www.socrative.com/ Last accessed 15 February 2021.

[147] Spiral, the Social Learning Network Ltd. https://spiral.ac

[148] VotAR. https://votar.libre-innovation.org/ Last accessed 15 February 2021.

[149] Wooclap, an interactive platform that makes learning awesome. https://www.wooclap.com/ Last accessed 15 February 2021.

[150] Ziteboard. https://app.ziteboard.com/ Last accessed 15 February 2021.