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Equipping Students for Wicked Problems

The Potential of Problem-based, Challenge-based and Transdisciplinary Learning to Encourage Contextual, Constructive, Collaborative and Self-regulated Learning

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Abstract

The world is facing many wicked problems, including climate change, political polarisation, scarcity of natural resources and inequal access to quality health care and education. Education has an important role to play by equipping students with the competencies needed to navigate an unpredictable future with these systemically interwoven challenges. Next to problem-based learning, challenge-based education and transdisciplinary learning are educational approaches increasingly being implemented to better prepare students. In this theoretical paper, we demonstrate how the design principles of contextual, constructive, collaborative and self-regulated learning (CCCS) inform the student-centered approaches of problem-based learning, challenge-based education and transdisciplinary learning and prepare students to better understand wicked problems. We refer to scientific evidence behind the CCCS

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principles and make a plea on how to bridge these with the three approaches to teaching. Nevertheless, we acknowledge that success of a particular approach in one context does not guarantee success elsewhere. What works best is dependent on many variables, including the intended outcomes, the particular target group of students, the assessment formats and teachers' experiences with these approaches.

Keywords: Problem-based learning; challenge-based learning; transdisciplinary learning

Introduction

The world is facing major challenges, including climate change, political polarisation, scarcity of natural resources and inequal access to quality health care and education (e.g. Tassone et al., 2018; UN DESA, 2024). These challenges could be identified as 'wicked problems', as they have a variety of characteristics; i.e. these problems are difficult to define and hard to solve because stakeholders have conflicting values on what the problem is and how it can solved, and because these problems are often interconnected with other problems (Rittel & Webber, 1973; Lönngren & van Poeck, 2020). The diversity of values of perspectives of actors involved, make wicked problems challenging to understand, make it difficult to find better solutions and to forecast outcomes.

Education is tasked with the responsibility of equipping students with the competencies needed to navigate their demanding role in an unpredictable future (Veltman et al., 2019; Head & Alford, 2015). Students should learn to embrace challenges and learn that uncertainties are inherent to wicked problems. Furthermore, they should be willing to learn from failures and to take responsibility. However, earlier studies focusing on the higher education setting have shown that not all teaching approaches, for instance lecture-based education, are suitable to develop such competencies among students (O'Neill & Short, 2023). Therefore, we need to critically reflect on the teaching approaches adopted by higher education institutions and assess their potential to equip students to better understand wicked problems (Bowman et al., 2024; Van Rijnsoever et al., 2023).

In this theoretical paper, we argue that student-centred approaches to teaching align with the social-constructivist paradigm (i.e. the idea that knowledge is constructed by and between people, gained through dialogue and interactions with others), as opposed to a positivist paradigm (i.e. where knowledge is

considered absolute, objective, and generalisable) (Jonassen, 1991; Tangney, 2014).

Problem-based learning is an example of a student-centred teaching approach fitting well within the social-constructivist paradigm in which knowledge is considered as being constructed by interactions with others. Problem-based learning is influenced by philosophers such as Dewey, cognitive psychologists, and scientific evidence, but also grounded in practice and inspired by what others tried when innovating education in the time and context in which it is situated (Servant-Miklos & Schmidt, 2016).

Problem-based learning has been implemented on a large scale for decades. While it has been implemented worldwide, its exact format has been adjusted to the needs and practicalities of particular contexts. Nowadays, we see many new approaches being implemented next to problem-based learning, such as challenge-based education and transdisciplinary learning. In this theoretical paper, we explain that all three approaches belong to a family of student-centred approaches that are characterized by four related underlying principles: contextual, constructive, collaborative and self-regulated learning (CCCS principles), theoretical principles fitting within the social-constructivist paradigm (Dolmans et al., 2005, Dolmans, 2019, Dolmans et al., 2021, Schmidt, 1993).

In this paper, we also refer to scientific evidence behind these principles and make a plea on how to bridge the four principles with practice and the three approaches to teaching. We aim at combining and bridging constructivism with pragmatism, given that we need to make decisions on what works in practice, preferably based on justifying why it might work. Explaining and justifying why an approach might work will contribute to a better understanding of how the approach might work in a local context, and how it might work in other contexts.

This theoretical paper is aimed at explaining the CCCS principles and illustrates how these principles fit with problem-based learning, challenge-based education and transdisciplinary learning and equip students for wicked problems. It starts with an explanation of the four CCCS principles underlying student-centred approaches and how they might support students in developing competencies needed to navigate wicked problems. We will then explain problem-based learning, challenge-based education and transdisciplinary learning as examples of student-centred approaches in higher education that fit well with the four CCCS principles. Finally, we will argue that the success of these approaches ultimately depends on how the four principles are implemented in practice, and that there is no one-size fits all solution, and

we will reflect on the limitations of the four CCCS principles and their implementation in practice.

The CCCS principles and how they could contribute to equipping students for wicked problems

How should higher education prepare students to better understand wicked problems? Bowman et al. (2024) argue that we should offer teaching approaches with room for discovery, experimentation, learning from mistakes, and students taking agency to understand different perspectives and adapt to changes. Instead of reducing complexities, uncertainties and value differences in higher education, we should embrace teaching approaches that prepare students for change by confronting them with open learning practices in which they address new, unknown challenges. These approaches prepare students to be creative, open-minded, curious, flexible, adaptive, and teach them to embrace uncertainties, which are important when dealing with wicked problems (Bowman et al., 2024). In the next paragraphs, we will explain the principles of contextual, constructive, collaborative and self-regulated (CCCS) learning and, how these principles may have the potential to prepare higher education students to better understand wicked problems.

Contextual learning

The principle of contextual learning emphasises the importance of organising learning around authentic, real-world problems, tasks or projects derived from professionally or societally relevant contexts. In traditional curricula, subjects tend to be delivered in separate strands or disciplines and detached from meaningful contexts. For example, knowledge is transferred in lectures, whereas skills are developed in separate skills training sessions. The risk of this compartmentalised approach is that there is limited transfer of what is learnt to practice. Contextual learning supports students in developing an integrated set of knowledge, skills and attitudes which is known to enhance transfer of learning to similar as well as new situations or contexts (Van Merriënboer & Kirschner, 2017). In other words, when designing education, teachers ideally start from a varied set of meaningful, authentic problems that are relevant for the future profession or society to enhance integration and transfer of what is learnt to practice and support students to transfer what they learn to an increasingly varied set of real-world problems or equip them for wicked problems (Van Merriënboer & Kester, 2008).

Constructive learning

The second principle, constructive learning, concerns the importance of encouraging students to actively construct and restructure their knowledge and mental models. This principle is known to stimulate students to gain a deep understanding of the subject they are studying (Dolmans et al., 2016, Gijbels et al., 2005, Hung et al, 2019). This can be done by stimulating students to activate their prior knowledge and encouraging them to generate meaningful relations between their prior knowledge and new knowledge. Constructive learning can also be enhanced by asking students to explain in their own words what they have learnt, by stimulating them to ask and answer critical questions, and by having them discuss cognitive disagreements to gain a deeper understanding about the why behind certain phenomena. Understanding the why is known to enhance transfer to novel problems which prepares students for future learning (Carbonell et al., 2014).

Collaborative learning

The third principle refers to students learning from, with and about each other, while discussing problems. Collaborative learning is beneficial when students build on each other's ideas through open dialogues around complex problems. Conditions for effective collaborative learning are that students are mutually dependent and that they have a common goal (Dillenbourg, 1999). Preferably, students engage, interact and exchange ideas with other students, teachers and researchers and other stakeholders from diverse backgrounds, such as societal partners or industries, and both within and outside academia. Learning with others can also have beneficial effects on the students' needs to feel related to others which is known to enhance students' autonomous motivation (Ryan & Deci, 2017).

Self- regulated learning

The final principle is about students learning to self-direct or self-regulate their learning. The emphasis in self-*directed* learning is on students' role in choosing learning tasks of their own interest that fit with their learning needs (Loyens et al, 2008). Self-*regulated* learning is about setting goals, planning and conducting learning activities, monitoring, reflecting on, and evaluating learning, from a meta-cognitive perspective (Zimmerman, 2002). As self-directed and self-regulated learning have many aspects in common, we use the term self-regulated learning in this paper. Stimulating students to self-regulate their learning will support them to take control and agency of their own learning. Students can be facilitated to become self-regulated learners by stimulating them to choose which learning activities fit their needs, for example, but also by encouraging them to set goals that need further study, to select relevant sources

to study, and to self-monitor and reflect on their performance and set new goals. This principle is complex as we need to find the right balance between stimulating students to self-regulate their learning and simultaneously offering students support to scaffold their learning. The amount of support needs to be adapted to the student's level of self-regulation. Not only cognitive self-regulation is important, but also the regulation of students' motivation. Making students feel autonomous, related and competent is known to enhance their autonomous motivation (Ryan & Deci, 2017).

When the four CCCS principles are all integrated in teaching approaches, this could support higher education institutions in delivering graduates that are equipped to understand wicked problems. By organising curricula around complex real-life tasks, students' ability to learn to deal creatively with the wickedness of today's challenges is benefited (Bowman et al., 2024). In other words, this may contribute to 'helping foster an education for society' (Tassone et al., 2018, p.344) and to developing students' 'sensibilities to manage challenges and the unknown wickedness' (Bowman et al., 2024, p. 1374). Learning around real-world problems prepares students to become familiar with and learn how to approach new, unpredictable wicked problems (Veltman et al., 2025). Teachers have an important role to play when it comes to students' engagement in student-centered teaching approaches, they need content expertise, but also to know how to deal with this expertise, i.e. by asking questions, and they should know how to facilitate the students' learning, i.e. by asking students to give arguments (Dolmans et al., 2002). Collaborative learning, and especially when students are encouraged to collaborate within an interdisciplinary team and with various external stakeholders within and beyond academia, ensures that students learn how to cross boundaries between the potentially varying values, interests and perspectives of parties that are involved in today's and tomorrow's major challenges (Bowman et al., 2024; Penttilä & Kairisto-Mertanen, 2013). Finally, self-regulated learning, achieved by ensuring that students have autonomy in determining their own learning goals to address problems, and teachers stimulating students to take the lead themselves, contributes to a desirable sense of agency and autonomous motivation in students (Ryan & Deci, 2017; Zhu et al., 2025). In sum, the four principles of contextual, constructive, collaborative and self-regulated (CCCS) learning have the potential to prepare higher education students to better understand wicked problems.

Implementing these principles in practice is not easy. Education is complex in nature given that many different variables are at play and interact with one another: student characteristics, teacher characteristics, the content and format of learning materials, the way in which students are assessed, the intended learning outcomes etc. Cianciolo and Regehr (2019) emphasise the importance

of making a distinction between principles and techniques when analysing learning environments. Principles, such as the CCCS principles explained above, could be considered as theories about how pedagogical and didactical choices in complex contexts affect students' learning and development. Principles offer explanations about how learning environments might enhance student learning. Principles can be used to generalise or transfer findings from one context to another. However, Cianciolo and Regehr (2019) acknowledged that the way in which principles are implemented in practice can vary significantly. They captured this idea with the term technique, which refers to the way in which education is eventually shaped and looks like in daily practice. Large groups of students might hinder students to deeply interact with each other, students who are used to lecture-based education might also face difficulties when being confronted with student-centered teaching, and the same holds for teachers; i.e. their prior experiences and beliefs might hinder them to adapt to student-centered approaches.

The CCCS principles have been described in the literature as important principles underlying problem-based learning (Dolmans et al., 2005, Dolmans, 2019, Dolmans et al., 2021, Schmidt, 1993). We would like to argue that the CCCS principles also fit well with more recently introduced types of student-centred approaches, including challenge-based education and transdisciplinary learning in which wicked problems are used as the starting point of learning. The three approaches have many similarities but also unique characteristics. In the following section, we will describe these approaches in more detail. We will give examples of what each approach could look like in practice.

Three student-centred approaches in higher education

Problem-based learning

In problem-based learning (PBL), a problem or case – typically a description of a set of phenomena that need to be explained – serves as starting point and provides a meaningful context for learning. This can be a written case, a simulated case or a real case. Students meet in groups of 10-12 students to discuss the problem, facilitated by a teacher. Students typically activate their prior knowledge and discuss their knowledge gaps and what to further explore during self-study. In a next meeting they report to each other what they have learnt, raise questions and discuss disagreements. One of the students leads the team discussions. The teacher stimulates the students' thinking by asking critical questions and provides support to guide the process and the group dynamics. The primary aim of this approach is to help students to learn to better understand the problem and to learn how to apply knowledge in practice,

rather than to encourage the development of problem-solving skills (Neville et al., 2019). Although PBL might look slightly different across contexts, in essence all students will work on problems in small groups of students, facilitated by a teacher.

PBL was introduced in the field of health professions education and has been implemented on a large scale for decades. When this teaching approach was introduced over fifty years ago it was largely based on assumptions about what type of learning environment supports student learning best. Years of extensive research have taught us that the CCCS principles discussed earlier can be beneficial to student learning. Dependent on how these principles are implemented in a certain setting, PBL can result in a high level of student satisfaction and deep learning in students (Dolmans et al., 2016, Gijbels et al., 2005, Hung et al, 2019). In addition, it has been shown that PBL can enhance acquisition of generic competencies, such as effective communication and dealing with uncertainties (Hmelo-Silver, 2004; Gijbels et al., 2005, Dolmans et al., 2016).

Problem-based learning in practice – Example

> In groups of 10 and facilitated by a teacher, students work on a professionally relevant, complex problem. In this case, they are expected to learn about elderly living in their own home and the various cognitive, physical and social challenges they are facing in their daily life. This problem is studied from multiple perspectives or disciplines (psychology, nursing, geriatrics, social work). Students meet several times to discuss this problem. During the first meeting they analyse the problem, activate their prior knowledge and formulate issues in need of further self-study. After self-study they meet again to discuss their findings and synthesize what they learnt. Next to these meetings, additional learning activities in relation to this problem are offered, such as expert meetings or a skills training session. This hypothetical example is inspired by Claeys et al. (2022).

Challenge-based education

In challenge-based education (CBE), interdisciplinary student teams learn around real-world, open-ended problems for which solutions are not readily available. Within CBE, students learn through collaboration with other students and stakeholders outside academia (Gallagher & Savage, 2020). The unique characteristics of this approach are its focus on including external stakeholders who are often the problem owners. Students, teachers and external stakeholders or problem owners collaborate in finding solutions for the challenge that is mostly provided by the external stakeholder. There is a strong focus on helping

students to connect knowledge and theories available within universities with real world practices. Student teams are encouraged to find innovative solutions for challenges faced in practice by stakeholders outside academia. Students are assumed to take the lead in their own learning, to acquire and apply knowledge relevant to the challenge, and to transfer this knowledge to practice (Helker et al., 2024). CBE is primarily implemented in higher education institutions that focus on STEM education (i.e. science, technology, engineering and math) (Gallagher & Savage, 2020).

Challenge-based learning in practice – Example

> Students work on a challenge that is provided by a company that develops robots and other technological solutions that could potentially address elderly people who face loneliness. This company is an external stakeholder and the so-called problem owner. The group is expected to develop an innovative technological solution to the problem. Students work together during multiple sessions over a period of several weeks to develop an innovative prototype. They are offered various activities to guide their work, for instance design-thinking activities. The students in the group come from different disciplines and collaborate closely with entrepreneurs of the company and a teacher from the university. The external partner can be consulted for advice, while the teacher's role is to coach the students. This hypothetical example is inspired by Claeys et al. (2022).

Transdisciplinary learning

Transdisciplinary learning (TDL) encourages students to learn from addressing complex, open-ended real-world challenges while collaborating with stakeholders from both within and beyond academia. The unique characteristics of this approach is its focus on co-learning. In transdisciplinary learning, the learning of all stakeholders is key. All stakeholders should feel responsible and learn from and with each other to establish an environment in which co-learning between students and external partners takes place (Gulikers et al, 2025). Besides academic knowledge, experiential knowledge is considered highly relevant. Integration and co-construction of scientific and experiential knowledge is core, with the aim of creating impact on society (Bernstein, 2015; Visscher et al., 2022; Visscher, 2024). Transdisciplinary learning fosters a process in which learning not only happens in students, but in all stakeholders (Visscher, 2024). In participatory transdisciplinary learning, all participants are learners in co-creation processes (Gulikers et al., 2025). This journey requires coaching and a supportive learning environment, that is open to experimentation, ambiguity and uncertainty (Veltman et al., 2021). Students in transdisciplinary settings are offered opportunities to discover what their

personal values and motivations are and learn to deal with major challenges (Gulikers & Oonk, 2019).

Transdisciplinary learning (TDL) in practice – Example

> Students from different disciplines, for instance nursing, occupational therapy, social work and dietetics, work together on a complex challenge faced by elderly. They meet several times with elderly people who are living at home, as well as with their caregivers, to gain a better understanding of the needs of the elderly. They discuss the needs of the elderly and together search for solutions. Students collaborate closely with the network of the elderly to make a positive impact on their lives, for instance by supporting them to strengthen their social relations or health management. As not only the learning needs of the students are addressed but also the needs of the patients, co-learning or mutual learning is assumed to take place. A teacher or coach facilitates the student learning. This process usually takes multiple sessions over a period of weeks. This example is adjusted from Claeys et al. (2022).

Reflection and conclusion

The world is facing wicked problems. Instead of reducing complexities, higher education should emphasise uncertainties and differences in values to equip students with the competencies needed to navigate their demanding role in an unpredictable future (Gulikers & Oonk, 2019; Van Rijnsoever et al., 2023). In this paper, we explained the CCCS principles and illustrated how these principles fit with problem-based learning, challenge-based education and transdisciplinary learning and equip students for wicked problems. These approaches have many elements in common but also have unique characteristics. In PBL, problems derived from real life are discussed that should be studied by students from multiple perspectives or disciplines. In challenge-based education, the focus lies on challenges owned by external stakeholders that need innovative solutions. And finally, in transdisciplinary learning, making societal impact takes centre stage by emphasizing the importance of co-learning among students, teachers and societal partners. Although, the examples might suggest that challenge-based education is typically applied in technical education and transdisciplinary learning in a social context, this is not the case. Challenge-based education and transdisciplinary learning can be applied in social or technology settings.

Despite the potential of these approaches in equipping students to better understand wicked problems, we also emphasise that the approaches described

above are continuously on the move and in practice have many different shades. Which approach might work best, depends on the intended learning outcomes, and on how they are implemented in practice. In particular, it is important that the learning activities, intended learning outcomes and the assessment are well aligned (Biggs, 1996). For instance, although problem-based learning is often associated with active and deep learning, this might not happen when students perceive a high workload or when they perceive that their assessment is not rewarding deep learning. The students' and teachers' prior learning experiences as well as their beliefs about problem-based learning also shape their behaviours to adopt a student- or teacher centered approach to teaching in problem-based learning.

We would like to draw attention to a few final aspects in relation to this theoretical paper.

First, it is important to consider the authors' backgrounds, as these might have influenced their thinking. All three authors work in a context in which problem-based learning has been implemented for many years. The authors have investigated problem-based learning for many years, not only in Maastricht but also in other countries, such as Indonesia, and they all have experience with teaching in problem-based learning in practice.

Second, we acknowledge that the principles and approaches described in this manuscript are not exhaustive, and that they have evolved over time and will further evolve, based on philosophical views or paradigms, scientific evidence, and experiences in diverse contexts. All approaches to teaching are continuously being reinvented, based on our ideas about knowledge, scientific evidence, experiences in practice, what we value and societal changes.

The CCCS principles allow for a fluid, flexible and variable implementation, for instance problem-based learning and challenge-based education can be offered in a multi-, inter- or transdisciplinary manner. There are many approaches that might work and more principles that matter, but within this theoretical paper we explain why and how these four CCCS principles fit well with three contemporary approaches to teaching.

Third, success of a particular approach in one context does not guarantee success elsewhere; there is no one-size fits all approach that works in any given context (Dolmans et al, 2021). The success of teaching approaches depends on factors such the intended learning outcomes, didactical and pedagogical expertise of teachers, and potential constraints, such as the assessment format,

the experience and beliefs of the student and the teacher, that might limit implementing an approach in a particular context. It would be suboptimal, for

example, to administer individual knowledge tests when the intended learning outcome is to make societal impact or to find an innovative better solution for a challenge faced by an external stakeholder.

Finally, the four principles and three approaches, problem-based learning, challenge-based education and transdisciplinary learning, might prepare students for their future contribution in a complex society with wicked problems in which they have to better understand complex problems and have to learn to deal with uncertainties, but further research is needed on how to optimize the design of these approaches to enhance student learning.

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