Fostering critical thinking: features of powerful learning environments

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Abstract

Critical thinking is a recurrent educational ambition. At the same time, it is not self-evident how that ambition can be realized. This is partly due to the different perspectives from which Critical Thinking can be approached. A large group of authors have explored different meanings of CT and proposed different aspects. For most researchers in the domain of CT, CT entails both ability and attitudinal components. Research in the area of psychology on different types of cognitive processing has similarly pointed to the importance of both skills and attitudes. From an educational perspective, a tripartite notion of disposition was put forward, highlighting the importance of ability, inclination and sensitivity.

In line with the tripartite dispositional perspective, this contribution discusses an educational protocol. The educational protocol argues that CT can be fostered by implementing powerful learning environments that are aligned to the ambition for CT in terms of goals, conditions and interventions. More specifically four interventions are proposed: modelling, inducing, declaring and surveillance. The need for dedicated research on the educational protocol is stressed.

Keywords

Critical thinking

Powerful learning environments

Dispositions

Epistemic cognition

Educational protocol

1 INTRODUCTION

Critical thinking is widely acknowledged to be important, difficult and complex. Hence, powerful learning environments are required to support students to develop critical thinking skills and become critical thinkers. Such environments will only come about if systematically designed.

This article proposes features of learning environments for supporting the development of critical thinking. It revisits CRITHINKEDU, an education protocol developed in 2019 (Elen et al., 2019). Specifically, by conceiving critical thinking, in line with Perkins, as a tripartite disposition and as something that matters. The protocol presents elements to be considered in the design of powerful learning environments for critical thinking.

The article is structured as follows. First, we use a *backwards design* approach (Wiggins & McTighe, 2005), common in instructional design, to analyse critical thinking and how it matters for the difficulty and complexity of curricula. Next, the literature on fostering critical thinking is discussed by pointing at major approaches. As a third step, we discuss the assumptions on which our proposal about features of powerful learning environments builds. In a fourth and fifth section we describe and discuss the features of powerful learning environments.

2 CRITICAL THINKING

Critical thinking is recognised to be an important educational goal (e.g., Bećirović, Hodžić, & Čeljo, 2019; Facione, 1990; Halpern, 1998). A lot of authors refer to Dewey as one of the more important educational scholars who advocated for *reflective thinking* which—while not identical—at least underpins critical thinking (e.g., Thomas & Lok, 2015). Dewey advocated fostering reflective thinking; he was also aware about how difficult *reflective thinking* is.

> Reflective thinking is always more or less troublesome because it involves overcoming the inertia that inclines one to accept suggestions at their face value; it involves willingness to endure a condition of mental unrest and disturbance. Reflective thinking, in short, means judgement suspended during further inquiry; and suspense is likely to be somewhat painful. (Dewey, 1910, p. 13)

The importance of critical thinking as an educational goal is also apparent in higher education programmes. For instance, a curriculum analysis of 48 diverse bachelor programmes in Belgium demonstrated that *critical thinking* was a frequently stated learning goal (Verburgh et al., 2009).

In addition to its educational importance, some researchers have attempted to reveal the real-world significance of critical thinking. Butler looked for links between scores on the Halpern Critical Thinking Assessment (HCTA; Butler, 2012; Halpern, 2010)—a rather robust measurement of critical thinking—and an assessment of so-called real-world outcomes

(RWO). The RWO contains 40 very different real-world like activities, some more positive and some more negative (which the respondent can influence), such as getting fined for returning a library book too late or oversleeping and missing class (Butler, 2012). Butler reported that higher scores on the HCTA were associated with fewer reported negative life events (Butler, 2012).

The importance of critical thinking in daily life was demonstrated in a recent study (Erlich et al., 2022). The study focused on the importance of critical thinking in Ukraine (Erlich et al., 2022). The study was conducted in 2019, after the annexation of the Crimean, but before the Ukraine war. It focused on *analytic thinking*, an aspect of critical thinking assessed by the widely used Cognitive Reflection Test (CRT; Frederick, 2005). The study investigated whether the ability to engage in analytic thinking is related to the ability to identify misinformation. A particular focus was on analysis of whether people were able to rate false stories as false, and true stories as true, and whether the ratings were associated with outcomes on the CRT assessment and outcomes on an *active open-minded thinking scale* (AOT; Haran et al., 2013; Stanovich & West, 1997). The researchers reported a strong positive and significant link between outcomes on the CRT and the ability to detect misinformation, the same (but not in all analyses) for the AOT.

In addition to revealing the importance of critical thinking, the literature also demonstrates the difficulty in attaining critical thinking. Higher education is expected to increase critical thinking skills; yet, the development of critical thinking appears to be far from self-evident. Evens and colleagues investigated the development of critical thinking among 1134 bachelor students in Belgium during their regular studies (Evens et al., 2014). This descriptive study followed a mixed longitudinal design, with student cohorts from different programmes and different years. Student critical thinking was measured using the Scipio, a test consisting of both constructed response items and forced choice items largely based on the HCTA. The analyses were split up by academic and professional bachelor students. Critical thinking skills of students in professional bachelor programmes did not seem to increase anymore after the first year. While academic bachelor students did not noticeably develop critical thinking skills in the first year, the development of these skills was observable in the second and third year. The results of academic bachelor students demonstrated a greater increase in the development of critical thinking skills compared to professional bachelor students.

In a recent study supported by the Organisation for Economic Co-operation and development (OECD; Van Damme & Zahner, 2022) a similar increase in skills is reported. In this study the College Learning Assessment (CLA+; Klein et al., 2007) was administered. It is a cognitive test that contains multiple critical thinking items. It is administered to students entering higher education, and again four years later, when graduating from higher education. Overall, a growth in proficiency was reported. While a growth was noticeable, descriptive data showed comparatively poor outcomes with more than 45% of the students at the lower levels of the scores on CLA+. Similarly, Arum and Roksa (2011) found that for 36% of participating students, there was no significant increase in critical thinking skills, after four years of higher education. Moreover, the authors of the OECD study rightly point out that

> The analysis cannot positively confirm that the learning gain is caused by the teaching and learning experience within university

> programmes. It is possible that, for example, selection effects (selective drop-out), general maturing of the student population or effects of learning outside university contribute to the average learning gain. (Van Damme & Zahner, 2022, p. 259)

Discussions about education for supporting the development of critical thinking skills reveal not only that critical thinking is important and difficult but also complex. The same notion may carry very different meanings. Barnett argues that the idea to *foster critical thinking* is part of a *critical thinking movement* and outlines the major streams in that movement (Barnett, 1997). Using the term *criticality*, Davies and Barnett identified three major ambitions: first, critical rationality or the ability to think critically; second, critical character, or the ability as well as the disposition to think critically; and third, critical action, or the use of one's abilities in the world (Davies & Barnett, 2015). In this view, the educational goal of critical thinking has only been reached when action is involved. Students who faced a line of tanks on Tiananmen Square in 1989, or pupils engaging in actions to support sustainability efforts in the 2020s, demonstrate critical thinking as critical action. This contribution reflects the educational goal of critical thinking not simply as the ability to engage critical thinking skills but also as the willingness to put such skills into action.

3 UNDERSTANDING CRITICAL THINKING

In view of determining the features of powerful learning environments for critical thinking, a more refined understanding of critical thinking is needed. Numerous conceptions have been elaborated from different perspectives (Rear, 2019). In the following, we describe three different perspectives; namely, (1) a perspective of critical thinking researchers, (2) a psychological perspective and (3) a perspective focused on how to teach critical thinking.

3.1 Critical thinking researchers

A very diverse set of definitions of critical thinking has been proposed by a large and diverse group of critical thinking researchers. Ennis, for instance, stresses the element of judgement: "*Critical thinking is reasonable reflective thinking focused on deciding what to believe or do"* (Ennis, 2015, p. 32). Halpern (Halpern, 1998, 2010) has stressed that critical thinking refers to a disposition in addition to an ability, she points out that

> Critical thinking is the use of those cognitive skills or strategies that increase the probability of a desirable outcome […]. Critical thinking is purposeful, reasoned, and goal directed. It is the kind of thinking involved in solving problems, formulating inferences, calculating likelihoods, and making decisions. Critical thinkers use these skills appropriately, without prompting, and usually with conscious intent,

> in a variety of settings. That is, they are predisposed to think critically. (Halpern, 1998, p. 450–451)

Both of these definitions explicitly refer to critical thinkers and their thinking. In contrast, a definition that focuses more on activity defines critical thinking as "*skilled interpretation and evaluation of information and argumentation*" (Fisher & Scriven, 1997, p. 20). In a similar vein, Paul and Elder (2006) refer to critical thinking as an art that pertains to thinking itself, for them "*critical thinking is the art of analyzing and evaluating thinking with a view to improving it*" (Paul & Elder, 2006, p. 4). McPeck is another influential author who seems to stress activity but also assumes the presence of an actor with "*The skill and propensity to engage in an activity with reflective scepticism*" (McPeck, 1981 quoted in Nieto & Saiz, 2010, p. 20). McPeck emphasises that critical thinking is always about something and hence to a large extent is domain specific.

Confronted with all these different understandings of what critical thinking entails, attempts have been made to form consensus. A definition proposed by Facione, based on a study in which *Delphi technique* was used, has gained a lot of attention (Facione, 1990). In line with other definitions, it stresses the aspect of judgement as well as the importance of both skills and dispositions.

3.2 A cognitive psychological perspective

From a cognitive psychological perspective various researchers have tried to detect what components and what processes play a role in critical thinking. Evans and Stanovich distinguish between two types of processing that are relevant to critical thinking (Evans & Stanovich, 2013). In general, Type 1 processing is basically intuitive, it does not require working memory and happens autonomously. Type 2 processing on the other hand is reflective, requires working memory and involves both cognitive decoupling and mental simulation. Type 1 processing is regarded to be helpful in many settings and at many occasions. Type 2 processing is argued to be essential when things are not self-evident and high-stakes decisions are required; or, when Type 1 processing may result in errors, in faulty decisions, or in erroneous problem-solving. While the distinction is relevant and illuminating, the key question is: what triggers the shift from Type 1 to Type 2 processing, given that Type 1 processing is automatic and autonomous. Different mechanisms have been suggested. One mechanism would be that Type 2 processing gets triggered when two different possible outcomes are generated by Type 1 processing. In the context of a conflict between two or more automatically generated responses, a decision needs to be made that seemingly cannot be made automatically and hence Type 2 processing is called in. In addition to this mechanism, Stanovich et al. (Stanovich et al., 2016) has suggested an alternative one by presuming the existence of three types of *minds* that play a role. A first type is the *autonomous mind* which generates responses drawing on Type 1 processing. *Algorithmic mind* is the second type, it draws on Type 2 processing and involves decoupling and/or making simulations of different types of decisions, i.e. problem-solving approaches. As previously indicated, multiple responses generated by the *autonomous mind* may engender

Type 2 processing by the algorithmic mind. Stanovich et al. propose that the algorithmic mind may also be invoked by the third type, i.e. the *reflective mind* (Stanovich et al., 2016). The reflective mind watches out for when Type 1 processing is not enough, by building on a number of dispositions and attitudes associated with open-mindedness. When problems are encountered, the reflective mind may initiate simulations via decoupling in the algorithmic mind.

In line with the proposal of Stanovich, from a cognitive psychological perspective, reflective critical thinking seems to involve elements of ability as well as a series of dispositions (Stanovich et al., 2016).

3.3 Educational perspective

Studies have illustrated that education that fosters the development of critical thinking makes a difference in the development of *dispositions* (Perkins et al., 2006). Perkins and colleagues propose a tripartite model of dispositions in which central roles are accorded to *ability*, *inclination* and *sensitivity* (Perkins et al., 2000). *Ability* refers to the actual ability to follow through a particular behaviour, for instance to think critically. Ability does not solely refer to specific skills but also to the knowledge that is required in the execution of those skills. *Inclination* refers to the willingness to engage in that behaviour, for instance critical thinking. Persons with an inclination to critical thinking will feel a leaning toward critical thinking and hence, will be willing to invest in critical thinking when they identify the need to do so. *Sensitivity* finally, refers to the person's alertness to engage in critical thinking. For example, a person sensitive to the need for critical thinking will notice occasions where narrow thinking, prejudice or bias are likely, and criticality is appropriate. Various studies have demonstrated (Perkins et al., 1993, 2000) that each of these components is relevant and may explain why critical thinking is or is not engaged with.

Perkins and colleagues have invested a lot in finding ways to promote education that matters. Their notion of disposition reveals that such interventions will have to address multiple aspects. That is, education should in addition to developing knowledge and skills in critical thinking also support the development of inclination and sensitivity. In such efforts it should be recognised that this requires a long-term process involving more than individual interventions (Perkins et al., 2000).

4 FEATURES OF POWERFUL LEARNING ENVIRONMENTS FOR CRITICAL THINKING

Given that critical thinking matters and that it is difficult to attain, it is important to specify features of learning environments that foster the development of critical thinking. In the following, a proposal is developed. First, assumptions and claims upon which the proposal rests are outlined. They pertain to the nature of critical thinking as well as to what it implies to develop critical thinking. Second, components of three types of dispositions: (1) sensitivity, (2) inclination, and (3) ability are described in detail.

4.1 Features of environments that foster critical thinking

4.1.1 Assumptions and claims

Our proposal for features that characterise environments that foster critical thinking is based on three fundamental assumptions.

The first assumption aligns with Perkins (Perkins et al., 1993, 2000) in that critical thinking is understood to comprise of three types of dispositions, or that it is *tripartite*. This implies that in order to foster critical thinking, not only ability but also inclination and sensitivity are at stake. Consequently, approaches that focus on time limited interventions are comparatively weaker as they neglect the two other defining components or neglect development that requires time.

A second assumption specifies that domain specific knowledge is an essential component of critical thinking. In our tripartite model, *ability* does not simply pertain to broadly applicable general domain skills. Rather, ability has a strong knowledge component that affects the nature of the skill. While skills in analysing are an important critical thinking skill, which skills this entails more specifically, is largely dependent on the domain. What counts as valid arguments, standards, or evidence differs between disciplines (Bailin, 2002; Rapanta & Felton, 2022). Considering critical thinking as merely a general skill is problematic because such a definition lacks a normative domain-specific dimension of *good thinking* (Bailin, 2002). Analytical skills in economics requires different knowledge and strategies than analytical skills in biology because standards across the two disciplines are different. As a consequence, implicit approaches to foster critical thinking will probably be less effective than approaches that consider the domain, while at the same time making the critical thinking explicit. In other words, approaches in which students are explicitly trained to apply critical thinking skills as part of subject matter instruction—also called infusion approaches—are preferred (Tiruneh et al., 2014; 2016).

A final assumption pertains to learning. We conceive learning in line with a socio-constructivist perspective (Bransford et al., 1999). The central role of the learner in the learning process is recognised. Ultimately, what the learner does, determines what the learner will learn. Furthermore, the perspective highlights that the constructive activities of the learner are executed in a social context. That context affects what is, and can be, done. Meanwhile, that context is affected by the activities of the learner(s) themselves. Hence, the broader context is also to be considered even when it is the ambition to specify features of powerful learning environments at the level of specific courses. The probability of successfully powerful learning environments for critical thinking will decrease in a context that is not in line with the ambition to foster critical thinking—or even worse, is not open for allowing critical thinking to occur.

5 TOWARDS A PROPOSAL

In line with the CRITHINKEDU educational protocol for critical thinking (Elen et al., 2019), features of powerful learning environments for critical thinking can be sorted by three categories: goals, conditions and supportive interventions.

5.1 Goals

A powerful learning environment that fosters critical thinking aims explicitly at critical thinking. This entails articulating in an explicit manner what is meant by critical thinking in a specific context; for example, for teaching a specific subject matter. This implies specifying what discipline-specific critical thinking entails in terms of ability, inclination and sensitivity. Considering critical thinking as something that matters also implies that it plays an important role in the assessment of students (Black & William, 2018).

5.2 Conditions

The assumptions described in the previous section highlight conditions that help to enact powerful learning environments for critical thinking. As a first condition, that critical thinking is allowed, and a context or learning environment is established that makes critical thinking possible. In other words, students get tasks that trigger their sensitivity for critical thinking, are encouraged to engage in critical thinking and receive support for engaging with critical thinking.

Spreading efforts to stimulate critical thinking over time is a second condition. Single shot opportunities to learn may not be sufficient to develop ability, inclination and sensitivity. Nieto and Saiz made an analogy between the development of critical thinking and sports (Nieto & Saiz, 2010). To stimulate a person new to a specific sport (or critical thinking) to start with it, one must talk about the benefits and joy of practicing the sport in return for the hard work and sacrifices. As a next step, small exercises can be carried out to experience the benefits and joy, after which that practice can be intensified. Meanwhile, the dispositions to do sports (or critical thinking) develop gradually over time.

5.3 Interventions

A number of research-based interventions increase the likelihood that critical thinking is developed. In line with the educational protocol (Elen et al., 2019) four types of interventions seem to be essential. A first one is *modeling*. Modeling implies demonstrating acts of critical thinking and at the same time explaining what and why things are done in a particular way. A second one is *inducing*. By inducing, learners are stimulated to act as critical thinkers by providing them tasks that encourage them to engage in critical thinking. *Declaring* is the third type of intervention. In line with the infusion approach, declaring pertains to making explicit what is aimed at, what criteria are to be met and what strategies can be used. And finally, because the development of critical thinking requires sustained action and practice, *surveillance* is a fourth type of intervention. Surveillance refers to interventions that monitor the activities of learners, provide feedback on these activities and help to orient further actions towards the intended goal of critical thinking. The next section elaborates on what these types of interventions imply for the different components of the tripartite disposition of critical thinking.

5.4 Sensitivity

Studies from very different contexts offer inspiration on how sensitivity (often along with inclination) can be fostered. Studies on this topic have been carried out, for example, in higher education curriculum research. Dekker asked 59 students from thirteen programmes in five

countries what aspects of their liberal arts and sciences programme made them think critically (Dekker, 2009). They offered a wide set of elements that have induced or at least fostered an inclination to think critically, or that made students more aware of differences and different perspectives, and hence more sensitive. The researchers distinguish between three factors, of which the first is a *multidisciplinary curriculum*. Multidisciplinary curricula induce students to look at a problem or phenomenon from different perspectives. Students reported that it stimulated them to develop an ability, an inclination as well as a sensitivity to look at problems and phenomena from different perspectives. Getting confronted with different subject matter areas seems to help students realise that a monodisciplinary view may be limited. A second factor is the use of *student-centred pedagogies* where students are continuously invited and encouraged to engage in deep processing of information. Also, that students are supported to develop a knowledge base on which they can draw for contributing to intensive discussions about meaning, implications, and assumptions. This approach underscores that the meaning of information should not be taken for granted and interpretations are continuously challenged in problem-solving activities, tutorials and seminars. A third factor is *community and culture*. Students indicated that an engaging academic culture that fosters debate inside and outside the classroom stimulated their critical thinking. A diverse student population with students having different backgrounds, orientations, and interests is said to promote discussion and encourages students to express themselves.

By offering different perspectives and by encouraging to express different perspectives, sensitivity to the presence of different points of view as well as the inclination to value and discuss different perspectives seems to be encouraged. This seems also to be the case in mathematics. Studies on mathematics instruction demonstrated that in the formal context of schools, many children seem to solve word problems without actually considering the meaning of their solutions—they stop making sense. This is illustrated in research where students solve problematic and standard word problems. One of the most famous problematic items is the *captain problem* ("There are 26 sheep and 10 goats on a ship. How old is the captain?"). Verschaffel reported that only 17% of the answers to mathematics problems were realistic (Verschaffel et al., 1994). This means children provide a calculated answer to the mathematics problems without being aware of, or without pointing out, the non-sensical nature of the problem. To explain this disappointing result, different explanations have been brought forward. First, the outcome is not the result of a lack of ability. Otherwise, students would do equally poor on standard items which was not the case. Explanations underscored the contextual logic of the answers. Several authors have pointed to a *school logic* for explaining student behaviour. Prevailing socio-mathematical norms in schools do not stimulate critical thinking (see for example, Yackel & Cobb, 1996). Brousseau (Brousseau, 1998) even argued that there is a *didactical contract* which includes the idea that when a teacher offers a problem, the student can assume that the problem makes sense and can be resolved (hence there is no need for *sensitivity*). The contract also involves that students do not really have to think about the meaning of the words, they simply have to do the maths.

Fostering sensitivity and inclination for critical thinking requires a different type of contract, one that actually allows for critical thinking. In this respect, various attempts have been made also in the domain of mathematics instruction. Mason and Scrivani report about the positive effects of an intervention in two fifth-grade classrooms (Mason & Scrivani, 2004). They tried to implement different socio-mathematical norms and to establish a new classroom culture.

This included the active involvement of students while solving mathematical problems, stimulating students to engage in cognitive and metacognitive activities (*inducing*), and making students aware that many problems can be interpreted and solved in different ways (*modeling and declaring*).

It seems that the culture of the environment in which students operate has a strong influence on how they conceive problems and how they interpret discourses. Translating this to critical thinking, insensitivity to critical thinking can be induced by stressing unidimensional perspectives and by providing highly structured right-wrong experiences. Also, questioning assumptions is important for sensitivity to critical thinking. In this vein, sensitivity can be strengthened by making explicit that considering alternatives and context is a good thing to do (*modeling and declaring*), by providing ample opportunities to experience the need for sensitivity, and by creating occasions in which students can experience the positive effects of considering alternatives or contexts (*inducing*). It seems worthwhile to highlight from the start onwards that our discourse on phenomena, our descriptions of reality, as well as our wording of problems as such are constructs that deserve to be analysed and need to be considered from different perspectives. In other words, sensitivity can be strengthened by paying attention to epistemic cognition (Chinn et al., 2014; 2021)

5.5 Inclination

There seems to be a lack of research on how to stimulate the inclination for critical thinking. Nevertheless, inspiration can be found in literature on the stimulation of a mastery orientation as achievement goal orientation. This refers to students' reasons and purposes for engaging and persisting in learning activities and can influence cognitive, motivational and behavioural aspects of students' adaptive and maladaptive learning activities. Mastery orientation refers to an inclination to understand things, to achieve deep insights. It can be contrasted with performance orientation that is more focused on earning good grades and gaining recognition. Different interventions reveal the importance of modelling, inducing, declaring and surveillance.

Gardner found that explicit attention to different goal orientations has a positive effect on mastery orientation (Gardner, 2006). In this study a control group and an experimental group were presented an increasingly difficult clinical problem each week over the course of one semester (Gardner, 2006). All students in the intervention engaged in group activities to solve the problem, and in question and-answer periods (*inducing*). Training for students in the experimental group was supplemented with didactic instruction contrasting the effects of mastery versus performance orientation, positive reinforcement and encouragement of problem-solving efforts, and teaching handouts that encouraged group members to be persistent and make additional effort to solve the case study (*declaring and surveillance*). Interestingly, the experimental group with explicit instruction contrasting the effects of mastery versus performance orientation got higher mastery orientations after the intervention than did the control group with no specific interventions on mastery orientation.

Research also points to particular classroom dimensions that positively affect a mastery orientation. Ames identified these dimensions as *task*, *authority*, *recognition*, *grouping*,

evaluation and *time* (*TARGET*; Ames, 1992). The different dimensions are closely related and have specific meanings. For instance, the task dimension concerns the design of classwork and homework. Appropriate tasks include a focus on learning, moderate challenges, curiosity and active involvement. The evaluation dimension focuses on methods that assess progress and improvement while avoiding the establishment of a competitive environment. Students experience that it is normal to make mistakes and that these are allowed in the classroom. Lüftenegger et al. (2014) demonstrated that a positive perception by students of the different dimensions of the TARGET framework is associated with higher scores on mastery orientation and with a higher chance to increase mastery orientation.

While far less evident and scarcer, research suggests that inclination can be promoted in learning environments with interventions for each of the four types of mastery orientation. Inclination can be promoted by explicit instructional efforts and by creating a culture or atmosphere that is conducive to the inclination. In all this, it is important that students acknowledge the relevance of the tasks and are enabled to work on tasks in a meaningful manner.

5.6 Ability

Most research on fostering critical thinking are studies in which (aspects of) critical thinking ability are examined. Ability is not restricted to cognitive skills, it also encompasses domain-specific knowledge on which skills operate. Several studies have been carried out ond the development of critical thinking outside and within specific domain-related courses to find out how optimal instruction for critical thinking ability looks like. Roughly three approaches can be distinguished (Tiruneh et al., 2014). First, there are stand-alone approaches or general approaches, in which students learn a critical thinking skill that is applicable in diverse contexts. Typically, the skill is learned outside a specific context, e.g. in a general module on critical thinking. Examples include critical thinking courses in which specific reasoning skills are trained and in which students are pointed to potential biases in reasoning. Second, are immersion approaches. Here students learn critical thinking skills within a domain. Students are assumed to be able to use those skills in the domain. Typically, there is no explicit focus or practice on transfer. Finally, there are infusion approaches, in which students learn critical thinking skills within a domain, with specific attention to the fact that the skills can be used in other contexts too.

Stand-alone or general approaches can be effective but the long-term differential effects are limited. Similarly, it is not evident to assume that general abilities will be automatically applied to domain-specific tasks or realities. For instance, a study on the effect of four approaches—approaches with (1) erroneous examples, (2) correct examples, (3) contrasting examples and (4) practice problems— was carried out by Van Peppen et al. (Van Peppen et al., 2021). The aim of the study was to stimulate in higher education students the development and transfer of critical thinking skills for *avoiding biased reasoning*. The results indicate that during practice students who studied with contrasting examples and correct examples performed best. However, in the transfer post-tests, there were no systematic differences between the four approaches. These results are roughly in line with most studies on general or stand-alone approaches.

Much more is expected from immersion and especially infusion approaches (see for example, Tiruneh et al., 2016). Chemistry, geology and physics students followed a (compulsory) course on electro-magnetism. In the control condition no specific attention was given to critical thinking. Here, the course followed the approach of the previous years. In the immersion and infusion groups, different critical thinking skills such as reasoning skills, argument analysis skills, hypothesis testing skills as well as likelihood and uncertainty related thinking skills, were targeted. The course was systematically redesigned using a well-established instructional design model (more specifically, the first principles model of Merrill, 2002). The extent to which the skills were made explicit to students was however different, in the immersion group the tasks as well as the modelling by the instructor related to the targeted skills. The same was done in the infusion group but now targeted skills were explicitly introduced and repeated. Moreover, explicit references to the targeted skills were made in the tasks as well as in the modelling by the instructor. First, results indicate that the students participating in the two experimental conditions outperformed the control group during the exam. This illustrates that attention to critical thinking had a positive effect on the acquisition of learning outcomes. Furthermore, participants in the immersion and infusion groups outperformed participants in the control group on a domain-specific test of critical thinking (more specifically the Critical Thinking in Electromagnetism, CTEM-test; Tiruneh et al. 2017). Finally, the HCTA (Halpern, 2010) was administered as a general critical thinking domain test, to test the transfer of critical thinking. Results on the HCTA revealed no transfer effects as there were no significant differences between the experimental groups. The study reveals how difficult it is to achieve transferable results.

Studies aiming at fostering critical thinking differ in multiple, sometimes related, respects. Some score high on internal validity, others on external validity; some are qualitative, others quantitative or mixed. There are purely experimental or quasi-experimental studies and studies that follow a design-based tradition. In some general studies, domain-transcending critical skills are targeted, some studies are more domain-specific. The diversity is daunting and the conclusions to be drawn are not always very clear. What seems the case, though, is that the probability that students will acquire the ability to think critically increases with the quality of the learning environment. The probability of success seems to increase when in the interventions the four types of interventions (modelling, inducing, declaring and surveillance) are recognisably present.

6 DISCUSSION AND CONCLUSION

Given the importance of critical thinking, it is essential to design and implement learning environments that can foster student critical thinking. Identifying features of such learning environments is challenging for various reasons. First, while from an instructional design perspective a good understanding of the goal of the learning environment is essential, in the case of critical thinking this is complex. There are different definitions of critical thinking, this has consequences for specifying what to pay attention to and what kind of interventions are favoured.

In this this article, critical thinking has been conceived of as a tripartite disposition following the work of Perkins and colleagues (Perkins et al., 1993, 2000). Hence, in our proposal,

sensitivity, inclination as well as ability are targeted. Following a socio-constructivist perspective, we specify that this tripartite disposition can be fostered using four types of interventions: interventions that serve: (1) to model, (2) to induce, (3) to declare, and (4) surveillance purposes. The proposal further specifies that any learning environment always operates in a context. For critical thinking to develop, a context that supports, allows for, and stimulates critical thinking is essential. While this may seem self-evident, ample research has shown that formal school contexts are often characterised by singular perspectives, by the provision of information as given, and by a contract that encourages the learner to accept rather than to question.

Fostering critical thinking is challenging. The following three elements seem beneficial. First and foremost, fostering critical thinking requires that critical thinking is explicitly valued as an important educational goal. Second, it is crucial that the learning environment allows for critical thinking and enables the learners to engage in critical thinking (to become sensitive, inclined and able). This seems to require specific types of interventions at the level of the course, the programme but also a larger context that supports the ambition for critical thinking. A third essential element is that the environment stimulates epistemic cognition (Chinn et al., 2014). Engaging in critical thinking requires accepting the idea that in our thinking we use concepts and reasonings that are not given but constructed and hence debatable. It also presumes the acceptance that not all reasonings are equally valid. The challenge in developing critical thinking in education relates to the difficult task of balancing between two important dimensions. On the one hand, schools introduce learners to a new domain or discipline and stress that a full understanding of findings, concepts, and approaches in the domain is needed to be able to participate in the domain or discipline. At the same time, however, and to stimulate critical thinking, schools may also have to stress that each of these highly valued findings, concepts and approaches are also constructions and therefore open for critical thinking.

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