Promoting Critical Thinking in European Higher Education Institutions:

Towards an educational protocol

Promoting Critical Thinking in European Higher Education Institutions: towards an educational protocol

TECHNICAL AND CATALOGING DATA

Cover layout
Background image designed by Harryarts / Freepik

Date of publication
April 2019

Recommended cataloging
PROMOTING CRITICAL THINKING IN EUROPEAN HIGHER EDUCATION INSTITUTIONS: TOWARDS AN EDUCATIONAL PROTOCOL
Promoting Critical Thinking in European Higher Education Institutions: towards an educational protocol / coord. CRITHINKEDU proj. Caroline Dominguez; coaut. Jan Elen… [*et al*.]. - Vila Real: UTAD, 2019

ISBN: 978-989-704-375-8

I. Elen, Jan, (coaut.)

1. Pensamento crítico--Competências--Formação pedagógica--Séc. 21--[Relatório técnico] / 2. Educação--Ensino superior--Formação pedagógica--[Relatório técnico]

CDU 378.025"20"(047.3)
165.19"20"(047.3)

Recommended citation
Elen, J., Jiang, L., Huyghe, S., Evers, M., Verburgh, A., … Palaigeorgiou, G. (2019). *Promoting Critical Thinking in European Higher Education Institutions: towards an educational protocol*. C. Dominguez & R. Payan-Carreira (Eds.). Vila Real: UTAD.

Funding
This work is part of the 'Critical Thinking Across the European Higher Education Curricula - CRITHINKEDU' project, with the reference number 2016-1-PT01-KA203-022808, funded by the European Commission/EACEA, through the ERASMUS+ Programme.

agência nacional erasmus educação e formação

Co-funded by the Erasmus+ Programme of the European Union

COORDINATORS

Catholic University of Leuven (KU Leuven), Belgium

LAI JIANG, PhD, Centre for Instructional Psychology and Educational Sciences

STEVEN HUYGHE, PhD, Advisor, Unit for Educational training and support

MARLEEN EVERS, MSc, Scientific Collaborator, Centre for Instructional Psychology and Educational Sciences

JAN ELEN, PhD, Full Professor, Centre for Instructional Psychology and Educational Sciences

University College Leuven-Limburg (UCLL), Belgium

AN VERBURGH, PhD, Educational Quality Assurance Officer and Educational Specialist

PARTNERS

Bucharest University of Economic Studies (ASE Bucuresti), Romania

DANIELA DUMITRU, PhD, Associate Professor, Department for Teacher Training

DRAGOS BIGU, PhD, Senior Lecturer, Department of Philosophy and Human Sciences

Modern Didactics Centre (MDC), Lithuania

ASTA RAILIENĖ, PhD, Trainer and Researcher of the MDC, Associate Professor at Mykolas Romeris University, Institute of Education and Social Work

DAIVA PENKAUSKIENĖ, PhD, Director of the MDC, Lecturer at Mykolas Romeris University, Institute of Education and Social Work

University College Dublin (UCD), Ireland

AOIFE AHERN, PhD, Associate Professor, School of Civil Engineering

CIARAN MCNALLY, PhD, Assistant Professor, School of Civil Engineering

JOHN O'SULLIVAN, PhD, Assistant Professor, School of Civil Engineering

University of Economics, Prague (VŠE), Czech Republic

EVA JAROŠOVÁ, PhD, Associate Professor, Department of Managerial Psychology and Sociology

HANA LORENCOVÁ, PhD, Assistant Professor, Department of Managerial Psychology and Sociology

University of Roma Tre (UNIROMA3), Italy

ANTONELLA POCE, PhD, Associate Professor, Department of Education

FRANCESCO AGRUSTI, PhD, Full-time Researcher, Department of Education

MARIA ROSARIA RE, Research Fellow, Department of Education

FRANCESCA AMENDUNI, MSc, Research Fellow, Department of Education

University of Santiago de Compostela (USC), Spain

BLANCA PUIG, PhD, Assistant Professor, Faculty of Education Sciences

PALOMA BLANCO, PhD, Assistant Professor, Faculty of Education Sciences

INÉS MOSQUERA, MSc, Research Fellow, Faculty of Education Sciences

BEATRIZ CRUJEIRAS-PÉREZ, PhD, Assistant Professor, Faculty of Education Sciences

MARÍA PILAR JIMÉNEZ-ALEIXANDRE, PhD, Full Professor, Faculty of Education Sciences

ISABEL GARCÍA-RODEJA GAYOSO, PhD, Full Professor, Faculty of Education Sciences

University of Thessaly (UTH), Greece

IOANNA V. PAPATHANASIOU, PhD, Assistant Professor, Nursing Department

KONSTANTINOS TSARAS, PhD, Assistant Professor, Nursing Department

EVANGELOS C. FRADELOS, PhD, Adjunct Professor, Nursing Department

University of Trás-os-Montes and Alto Douro (UTAD), Portugal

CAROLINE DOMINGUEZ, PhD, Assistant Professor, Engineering Department, LabCIDTFF - Centre of Didactics and Technology in Education of Trainers

GONÇALO CRUZ, MSc, Research Fellow, Engineering Department

HELENA SANTOS SILVA, PhD, Associate Professor, Department of Education and Psychology, CIEE - Centre for Research and Intervention in Education

MARIA DA FELICIDADE MORAIS, PhD, Assistant Professor, Department of Letters, Arts and Communication

MARIA M. NASCIMENTO, PhD, Assistant Professor, Mathematics Department, LabCIDTFF - Centre of Didactics and Technology in Education of Trainers

RITA PAYAN-CARREIRA, PhD, Assistant Professor with Habilitation, School of Agrarian and Veterinary Sciences

University of Western Macedonia (UOWM), Greece

CATHERINE DIMITRIADOU, PhD, Full Professor, Department of Primary Education, Faculty of Education

DIMITRIS PNEVMATIKOS, PhD, Full Professor, Department of Primary Education, Faculty of Education

SOFIA AVGITIDOU, PhD, Full Professor, Department of Early Childhood Education, Faculty of Education

GEORGE PALAIGEORGIOU, PhD, Assistant Professor, Department of Primary Education, Faculty of Education

Executive summary: the CRITHINKEDU educational protocol on developing critical thinking

Critical thinking is considered to be an important goal for European Higher Education Institutions. To support the achievement of this goal, an educational protocol is proposed, which builds on all the outputs developed in the CRITHINKEDU project. That means, it builds on the reviews of the literature, the experiences with new approaches and on ample discussions in the project team.

This report proposes the CRITHINKEDU educational protocol to develop critical thinking in European Higher Education Institutions.

Considerations with regard to the CRITHINKEDU educational protocol

As an introduction to the protocol a number of considerations are highlighted. These reveal the strength as well as the limitations of the current protocol.

a. The protocol is not static given; it is a *construction* made at a particular intersection of time and place. Any change in time and place may result in changes with respect to both its particular elements and its structure.

b. The protocol is the result of a European project in which a group of staff members of European Higher Education Institutions (HEIs) shared their scholarship.

c. The protocol is fundamental and general. It specifies a number of essentials that may guide and promote the development of critical thinking.

d. In assessing and using the protocol, the specific meaning given to critical thinking in this endeavour needs to be considered.

e. Any initiative to support critical thinking must be of high quality. This means that in the design of the initiative, the best possible 'evidence' is considered. Similarly, it is presumed that the development of critical thinking remains consistent with highly valued ethical principles.

An educational protocol to support the development of critical thinking

This educational protocol reflects a historically situated, operational understanding of the theoretical and empirical research on critical thinking on the one hand, and actual experiences with developing critical thinking on the other.

The educational protocol rests on two major claims:

1) students will develop their critical thinking by explicitly engaging in appropriate learning activities, and

2) becoming stronger in critical thinking requires repeated engagement in critical thinking processes.

The educational protocol has three parts: goals, conditions and supportive interventions.

Goals

In order to support the development of critical thinking, critical thinking has to be a goal of education. This is shown by:

- At the institutional level: A clear mission statement recognising critical thinking as an important goal and explaining how it can be accomplished.
- At the teaching program level: A clear description of critical thinking as an important goal of the teaching program, detailing how it can be reached.
- At the course level: A clear description of critical thinking as an important learning outcome, explaining how it can be realized.

In the above, '*clear'* means that an explicit clarification (by referring to the relevant literature) of the meaning of critical thinking is provided. In other words, the goals are explicit and transparent; they can be read and understood by all those involved.

In the above, '*important'* means that not reaching the goal would be considered a failure. At the institutional level, it means that the institution would not be accredited unless the goal was realized. At the teaching program level, it means that a student could not graduate unless the goal is realized. At the course level it means that a student could not progress unless evidence of critical thinking is provided. In other words, considering critical thinking as an important goal implies that it is part of assessment and evaluation.

Given substantial conceptual and methodological differences between the fields and the disciplines, it is to be expected that clear descriptions of critical thinking as an important goal at the teaching program and/ or course level will vary between the fields and between the disciplines.

Conditions

Critical thinking requires that at the institutional, the teaching program and course levels, critical thinking is *continuously* and *congruently* allowed and made possible.

'*Continuously*' implies that the development of critical thinking is not a one-shot operation. Critical thinking does not occur automatically or effortlessly. It needs continuous practice, reinforcement and support.

'*Congruently*' implies that all actions with respect to critical thinking are aligned to the goals.

Allowing critical thinking implies that critical thinking cannot have a negative consequence for the institute, its staff and its students. More specifically, it requires autonomy of the institution, the staff and the students who are enabled to think for themselves and with an authorial voice.

Making critical thinking possible implies that the resources needed for critical thinking are made available. It implies that students can flourish in an environment that is well-designed and offers them the time needed for development. It also implies that teaching programs can operate within a transparent and open structure, and institutions can work within clear legal frameworks.

Supportive interventions

Research suggests that with regard to the development of critical thinking (skills, dispositions or combinations of both), four categories of intervention (to model, to induce, to declare, to surveil) can be identified. For all supportive interventions the rule is that the support gradually withdraws.

- To model

Critical thinking development is supported when the institute (through its management structures), the teaching program (through its representatives) and the course (through its teachers) shows what it is to think critically. This can take various forms.

- To induce

Critical thinking development is supported by inducing critical thinking. This implies that open questions are raised, ill-structured tasks are provided, complex problems are discussed and/or authentic, real-world issues remain at the core. What '*inducing*' entails and how it can be done may vary for different fields and disciplines and may be done in different ways.

- To declare

Critical thinking development is supported by declaring or making explicit what is at stake, what strategies can be used and what criteria are to be met. Declaring can be either spoken or written, but in all the cases it is both explicit and specific. What '*declaring'* entails and how it can be done may also vary in different fields and disciplines.

- To surveil

Critical thinking development is difficult. To increase the probability that sustained action is taken, surveillance may help. Surveillance monitors the ongoing efforts and activities, provides feedback on those efforts and activities and helps to keep the efforts and activities oriented towards the (development of) critical thinking. While differing in its concrete content and form among fields and disciplines, surveillance will always entail monitoring, feedback and orientation.

Target audience and layout of report

The primary target audience of this report are staff members of higher education institutions with responsibility for the delivery of both undergraduate and postgraduate courses and teaching programs. Other professionals from different fields may also be interested in the report's content, as will the research community seeking insights on current thinking with regard to the development and promotion of critical thinking.

The report is targeted to university staff members responsible for the delivery of both undergraduate and postgraduate courses and teaching programs.

The structure of the report should allow one to get an in-depth understanding of the educational protocol as presented in Chapter 5. The nature of an educational protocol, the ambitions of the protocol as well as the steps in its development are outlined in Chapter 1. The protocol rests on a number of theoretical perspectives and assumptions. These are presented in Chapter 2. One of the assumptions is that critical thinking can be developed when the environment for those involved is well designed. What this entails is discussed in Chapter 3. Another assumption relates to the domain-specific nature of critical thinking. Different strategies and approaches to foster critical thinking skills and/or dispositions are presented in Chapter 4. The structure of the report is such that report sections and chapters are self-contained and readers can limit themselves to read those sections and chapters that are of greatest interest to them.

Table of contents

List of tables, figures and vignettes

Chapter 1. Problem statement

At the core of the project CRITHINKEDU is critical thinking, probably the most important educational goal of higher education as well as its most important responsibility (Paul, Elder, & Bartell, 1997; Verburgh, 2013). While the importance of the goal of Critical Thinking (CT) is quasi unanimously supported (at least in principle), there is far less consensus when it comes to three important aspects of the development of critical thinking: its definition, its assessment and approaches to foster its development (Tiruneh, Verburgh, & Elen, 2014). That absence of consensus reflects the multidimensionality, the complexity, the domain-specificity as well as the richness of critical thinking.

This report focuses on the development of critical thinking. The report is presented in the context of a specific position on critical thinking with respect to its definition, assessment and development (see Chapter 2: Theoretical perspectives and assumptions). That position rests on the results of previous activities in the CRITHINKEDU project (http://crithinkedu.utad.pt/en/crithinkedu/). Within the scope of the CRITHINKEDU project, this report targets those with responsibility for course development (e.g., university teachers), those responsible for teaching programs (e.g., Programme Boards), and those within the senior management structure of higher education institutions (e.g., (vice-)deans, (vice-)rectors). It might also be useful for all those in educational support roles (e.g., teaching assistants, members of educational support services). The report provides an overall understanding on how European Higher Education Institutions (EHEIs) foster or might foster critical thinking at different levels (course, teaching program, institution), considering both the current educational intervention studies reported in the literature, and educational practices.

This report aims at presenting recommendations for critical thinking promotion in (European) higher education institutions.

Given the importance of critical thinking on the one hand and its particularities in different fields and contexts on the other, this report outlines how EHEIs may foster (the development of) critical thinking. In other words, the current report aims at consolidating (part of) the field by presenting quality guidelines for critical thinking in (European) higher education. In so doing, the report will present an ‘educational protocol’. An ‘educational protocol’ presents an operational, agreed and formally acknowledged set of rules that defines the best possible approach to address a recognized educational challenge by considering conceptual and empirical evidence at a certain moment in time and within a specific context.

All elements in this description of an educational protocol are important:

- The protocol addresses an *educational challenge*. From different perspectives and by different stakeholders the issue is indeed recognized to be a challenge for education. In our case, the educational challenge pertains to the development of critical thinking, an issue that has been widely recognized conceptually as well as empirically.

- It is *operational*: as such it specifies a series of actions to be taken when confronted with the educational challenge. In our case, a series of actions is identified that is important with respect to the development of critical thinking.

- The protocol contains *a set of rules* that describe the relationship between actions on the one hand, and outcomes on the other. In this case, the rules describe positive relationships between actions at the course, program and institutional levels and critical thinking. As such, the protocol presents a pedagogy of critical thinking.

- The protocol is *agreed upon and formally acknowledged*. This implies that (a) it is the property of a community which aims at addressing the educational challenge and, (b) a decision is made in mutual agreement about a theoretical perspective, about a terminology and about appropriate actions. That agreement is formally established in order to make it visible, transparent and hence debatable and changeable. The implication is also that a community is presupposed. It may well be the case that multiple communities might exist (which may differ with respect to the theoretical stance they take) for one particular educational challenge. In our case, the protocol is discussed within the context of the CRITHINKEDU project and presented in a variety of scholarly communities and/or higher education institutions. It is important that in the longer term, the protocol is also acknowledged by important educational organisations and associations. We see the protocol as a 'living' document' and it is our wish that through wider discussions, inspired hopefully by the experiences of others who engage with the protocol, that the protocol will continue to evolve.

The protocol addresses challenges on critical thinking education. It is agreed among CRITHINKEDU's project members and formally acknowledged. It is operational, contextualized, and linked to research.

- It is clear that our understanding of fundamental processes continuously evolves and that it is contextualized. As such an educational protocol may be altered given new findings and/or new insights. It is not fixed. Given the

contextualized nature of our understanding, it might also be that the educational protocol is valid in context 'A' but not in context 'B'. The idea of an educational protocol invites consideration (the evidence) of the reasons for the lack of explicit cross-context validity. That in itself will help to further develop the protocol. In our case we put the European context at the core. It might be that some of the actions/interpretations will be deconstructed as highly contextualized.

- An educational protocol has a clear link with research and scholarship as it rests on conceptual and empirical evidence. The elaboration of a protocol is in itself an act of (critical thinking and) scholarship as it involves the consideration of multiple elements, the weighting of a variety of perspectives, the elaboration of meaning, the clarification of terminology and the specification of lines of action. In our case, the educational protocol is the outcome of the CRITHINKEDU project in which various steps towards the protocol were set.

In elaborating an educational protocol in the CRITHINKEDU project, the following was outlined:

- Actions in the protocol are presented at three levels: the institutional level (e.g., incorporate into existing review process systems that monitor how critical thinking is embedded in the programs), the teaching program level (e.g., provide different and progressively complex activities and opportunities to foster critical thinking throughout the curriculum, ensuring that students can transfer what is learnt in one part of the curriculum to other areas) and the course level (e.g., present to students, at the beginning of the course, explicit guidelines on how assessment of critical thinking will take place).

- Actions in the protocol pertain to fostering critical thinking in general but, wherever possible, guidelines also (at the course level) pertain to specific critical thinking skills and dispositions.

- Actions in the protocol are considered to apply to all fields but wherever possible, specifications on the outlook of the guidelines in different disciplines/ professional fields are made.

A systematic approach was adopted in the elaboration of the protocol. This approach was largely iterative, involved important stakeholders and repeatedly considered the most up-to-date findings as reported in educational literature. The approach consisted of the following steps:

a) At the start of the project, Facione's (1990) definition of critical thinking was selected as a conceptually suitable critical thinking framework for underpinning the project. The Facione (1990) model recognizes that there are several critical thinking skills and dispositions. By selecting the Facione construct of critical

thinking, the debatable terminological framework that underpinned the protocol was also defined.

b) Next, the definition of critical thinking was validated in different professional fields (retrieved from different focus groups). The validation entailed a systematic review of the meaning of critical thinking in different professional fields: STEM, biomedical sciences, social sciences and humanities (for the full report, see: Dominguez, 2018a http://bit.ly/2sEffTH. Starting from Facione's theoretical framework (Facione, 1990), the outcomes of the focus groups largely confirmed previous research (Jones, 2009; Jones, 2010; Grace & Orrock, 2015; Sin, Jones & Wang, 2015). The focus groups indicated that (a) critical thinking is widely understood and interpreted as a set of interdependent skills and dispositions; (b) critical thinking is unquestionably needed in today's graduates, and (c) with respect to the importance of critical thinking skills, slight differences in their practical application across professional fields can be detected. Across the fields considered, it is clear that that the most values and sought after employees are those who hold a well-educated way of thinking, fueled by the motivation and willingness to learn and improve, anchored on a set of interdependent cognitive aspects allowing them not only to anticipate and be ready for any situation, but also to regulate and monitor their own thinking and behaviour during the process. The outcomes of the focus groups suggest that well-developed critical thinking requires strong propensity elements (e.g., dispositions) and arises from experience, lifelong learning, effort and persistence, dealing with long-term goals and development. Additionally, critical thinking is frequently associated with problem-solving and decision-making, and its application depends not only on a stand-alone ability, but also in the convergence and interconnectedness of several other skills and dispositions out of the applied framework, such as proactivity, adaptability, creativity, emotional maturity, communication and teamwork. The review (Dominguez, 2018a) revealed that while the different fields may emphasize different skills and dispositions and while the instantiation of critical thinking skills and dispositions differs across fields, there is widespread agreement on the importance of the critical thinking skills and dispositions as stipulated in the Facione's definition.

A systematic approach was adopted in the elaboration of the protocol, involving important stakeholders and considering the most up-to-date findings.

c) A third step entailed the elaboration of general guidelines for stimulating critical thinking (for the full report including the guidelines, see: Dominguez, 2018b http://bit.ly/2Pwtic0). The project engaged in a mixed method study to reveal

current practices, strategies and considerations and to discuss their effectiveness. National and international research publications were reviewed and interviews were done with teachers from 9 different European countries from the four above mentioned professional fields: biomedical, STEM, social sciences and humanities. In line with previous reviews (Abrami et al., 2008; Behar-Horenstein & Niu, 2011; Tiruneh et al., 2014; Abrami et al., 2015), the following was concluded:

1. the interest in how teaching strategies may influence the development of critical thinking is increasing. However, the evidence on what teaching strategies and learning environments better support the development of students' critical thinking is scarce;

2. critical thinking intervention studies and educational practices mainly address the development of critical thinking skills in students and seem to ignore the value of critical thinking dispositions and the importance of considerable practice, effort and long-term interventions;

3. the reported studies and practices tend to be based mostly on practices adopting an immersive critical thinking approach (Ennis, 1997). This implies that critical thinking principles are not made explicit to students, as it is assumed that critical thinking skills are acquired as part of the apprehension of subject-matter. All this notwithstanding, the current academic literature on the subject identifies the need for a clear identification and definition of critical thinking skills to be developed;

4. given the outcomes of the studies reviewed, the following aspects are claimed to contribute to effectiveness: the use of active learning methodologies including use of real-world situations and/or workplace-based scenarios; teachers' training, and students' support;

5. still, the assessment of students' progression in critical thinking remains challenging irrespective of the use of qualitative assessment methods or formal critical thinking tests.

d) Next, the preliminary guidelines, elaborated based on the reviews, were tested. The testing of the guidelines entailed their validity, transparency as well as their feasibility. During a 5-day-long-workshop the guidelines were discussed by representatives of EHEIs and their implementation was tested by actually designing learning environments in line with the guidelines (for the full report, see: Dominguez, 2018c http://bit.ly/2I8J20V). The workshop included training sessions to discuss quality teaching on critical thinking, presentations of the use of effective pedagogical methods and approaches, learning tasks, supportive exercises as well as strategies and methods for the assessment of critical thinking. The interactions revealed the role of both the institutional and the teaching program context.

e) Finally, the protocol itself was actually elaborated by considering on the one hand the outcomes of a multinational review of the literature on interventions to promote the development of specific critical thinking skills and dispositions (rather than critical thinking in general), and on the other hand, an inventory and evaluation of teaching/learning experiences developed from actual implementations of the designed learning environments in the partners' institutions [see (d)]. Over several iterations, different versions of the educational protocol on critical thinking were discussed within the context of the CRITHINKEDU project with representatives of EHEIs.

This report will (see Chapter 2) adopt a position with respect to a number of issues that orient the educational protocol. Following this in Chapter 3, it will be argued that in view of promoting critical thinking, the following is needed: (a) an organisational context that fosters the development of critical thinking, (b) a teaching program level that contains a good structure and courses that consistently and coherently aim at developing critical thinking, and (c) actual learning environments that are systematically designed in line with design principles which are relevant for any type of learning environment.

In Chapter 4, the field-specific findings of the literature study on specific interventions for particular critical thinking skills and/or dispositions are presented. Each of the sections in this chapter are considered to be standalone and notwithstanding the authors attempts to minimise repetition, there exists, in a number of cases, overlap between some sections of the chapter. The actual educational protocol is presented and discussed in the final chapter of the report.

Chapter 2. Theoretical perspectives and assumptions

As previously mentioned, the field of developing critical thinking is characterized by a lack of consensus on three major and closely interrelated issues: the meaning of critical thinking, the assessment of critical thinking, and the methods to foster its development. This chapter presents an outline of our position with respect to these issues. Taking a position implies that choices were made, partially in view of advancing an educational protocol. These positions can and should be questioned and criticized based on conceptual and empirical arguments in view of strengthening the protocol.

A definition of critical thinking

Davies and Barnett (2015) have clearly argued that notwithstanding the importance of critical thinking, critical action or critical doing is even more important as it reveals the need for engaged relations with society, encompasses critical thinking and highlights an ethical position reflecting consistency in thinking and doing. Critical thinking is the focus of this project in the full understanding that extensions towards critical doing might be possible and desirable.

In line with its previous reports, the CRITHINKEDU project follows the Facione (1990) definition of critical thinking as being a set of (cognitive) skills and dispositions.

In line with the previous project reports, the CRITHINKEDU project follows the Facione (1990) definition of critical thinking as it represents a shared and sustained understanding of the concept. The definition is the outcome of a Delphi research study in which participants from different disciplines and professional fields participated. Facione (1990, p. 3) describes the consensus as follows:

> *"We understand critical thinking to be purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based. CT is essential as a tool of inquiry. As such, CT is a liberating force in education and a powerful resource in one's personal and civic life. While not synonymous with good thinking, CT is a pervasive and self-rectifying human phenomenon. The ideal critical thinker is habitually inquisitive, well-informed, trustful of reason, open-minded, flexible, fair-minded in evaluation, honest in facing personal biases, prudent in making judgments, willing to reconsider, clear about issues, orderly in complex matters, diligent in seeking relevant information, reasonable in the selection of criteria, focused in inquiry, and persistent in seeking results which are as precise as the subject and the circumstances of inquiry permit. Thus, educating good critical thinkers means working toward this ideal. It combines developing CT skills with nurturing those dispositions which consistently yield useful insights and which are the basis of a rational and democratic society."*

For this report therefore, critical thinking pertains to a set of (cognitive) skills and a set of dispositions. Hence, critical thinking is not a purely cognitive activity, it also implies for instance an engagement towards sincerity and truth. For an overview of critical thinking skills and dispositions, see Table 1.

Table 1. Critical thinking skills and dispositions (Facione, 1990)

Skill	**Description (Facione, 1990, pp. 13-19)**
Interpretation	To comprehend and express the meaning or significance of a wide variety of experiences, situations, data, events, judgments, conventions, beliefs, rules, procedures, or criteria.
Analysis	To identify the intended and actual inferential relationships among statements, questions, concepts, descriptions, or other forms of representation intended to express belief, judgment, experiences, reasons, information, or opinions.
Inference	To identify and secure elements needed to draw reasonable conclusions; to form conjectures and hypotheses; to consider relevant information and to reduce the consequences flowing from data, statements, principles, evidence, judgments, beliefs, opinions, concepts, descriptions, questions, or other forms of representation.
Evaluation	To assess the credibility of statements or other representations that are accounts or descriptions of a person's perception, experience, situation, judgment, belief, or opinion; and to assess the logical strength of the actual or intended inferential relationships among statements, descriptions, questions, or other forms of representation.
Explanation	To state and to justify that reasoning in terms of the evidential, conceptual, methodological, criteriological and contextual considerations upon which one's results were based; and to present one's reasoning in the form of cogent arguments.
Self-regulation	Self-consciously to monitor one's cognitive activities, the elements used in those activities, and the results educed, particularly by applying skills in analysis, and evaluation to one's own inferential judgments with a view toward questioning, confirming, validating, or correcting either one's reasoning or one's results.
Disposition	**Description (Facione, 1990, pp. 4-6)**
Truth-seeking	Being eager to seek the best knowledge in a given context, courageous about asking questions, and honest and objective about pursuing inquiry even if the findings do not support one's self-interests or one's preconceived opinions. The truth-seekers remain receptive to giving serious consideration to additional facts, reasons, or perspectives even if this should necessitate changing one's mind on some issue. The truth-seekers evaluate new information and evidence.
Open-mindedness	Tolerant of divergent views and sensitive to the possibility of one's own bias. Valuing tolerance and understanding of the beliefs and lifestyles of others.
Analyticity	Prizing the application of reasoning and the use of evidence to resolve problems, anticipating potential conceptual or practical difficulties, and consistently being alert to the need to intervene.
Systematicity	Being organized, orderly, focused, and diligent in inquiry. Organized approaches to problem-solving and decision-making are hallmarks of a thoughtful person regardless of the problem domain being addressed. The inclination to approach problems in an orderly and focused way.
Self-confidence	Trust the soundness of one's own reasoned judgments and inclination to lead others in the rational resolution of problems.
Inquisitiveness	One's intellectual curiosity and one's desire for learning even when the application of the knowledge is not readily apparent.
Cognitive maturity	Approach to problems, inquiry, and decision making with a sense that some are necessarily ill-structured, some situations admit of more than one plausible option, and many times judgments must be made based on standards, contexts and evidence which preclude certainty. Making complex decisions involving multiple stakeholders, such as policy-oriented and ethical decision-making, particularly in time-pressured environments.

Anyone engaged in critical thinking displays a variety of related skills and demonstrates the presence of an interrelated set of dispositions. At the core of critical thinking is the willingness and the ability to (a) distance oneself from the issue, problem, or phenomenon by considering different alternatives/perspectives, and (b) make a (quality, action, resolution, selection) judgement after carefully thinking through different alternatives.

That makes critical thinking different from other complex activities to which it is closely related such as problem solving, designing, or creative thinking. Essential in critical thinking is the interaction between and alignment of specific skills and dispositions in view of taking some distance and making a judgement. While some of the specific skills and /or dispositions may also play a role in problem solving, designing or creative thinking, the blends and the orientations of critical thinking are specific and unique.

Methods to assess and develop critical thinking

Among assessment approaches to critical thinking, we can distinguish those which are generally holistic and those which are generally analytical – being both suboptimal.

As critical thinking is a complex phenomenon with implied skills and dispositions, it is perhaps understandable that its assessment and development are not easy. In this respect, we can distinguish between approaches to critical thinking that are generally holistic and those that are generally analytical. Both are intrinsically suboptimal.

In the more holistic approaches, students get the task to engage in critical thinking (e.g., by reading a text and offering a critique) and a holistic and often very context-specific assessment (e.g., of the critique) is made. Such a holistic assessment often lacks precision and is heavily dependent on the assessor. As Kayapinar (2014) illustrated, grading of essays by different assessors reveals poor reliability of individual assessments. The same (being suboptimal) is true for a global approach in critical thinking development. While interesting and authentic tasks can be given, the support of students is holistic and directions by teachers lack specificity. At the same time, a global approach embeds students in a culture of thinking critically and invites them to get socialized in the dispositions and skills of critical thinking by adopting a contextually appropriate critical discourse.

Analytical approaches in both assessing and developing critical thinking decompose (and try to recompose) critical thinking into specific skills and dispositions. It assumes that critical thinking is the sum of related skills and dispositions. Although analytical approaches can sometimes obscure the integrated nature of critical thinking, they can also add significant precision both to the assessment and the support that can be given. Specific skills are identified and considering the extensive scientific literature,

specific and detailed assessments can be made. Similarly, specific dispositions can be identified and programs elaborated to stimulate the development of those dispositions.

Given the suboptimality of both approaches, we suggest that a combination of both approaches might be most appropriate. Such combined approaches are advocated by the proponents of integrative or infusion approaches (Ennis, 1989). An integrative/infusion approach starts with authentic tasks but pays - either by the use of rubrics (assessment) or the use of specific scaffolds (development) - explicit attention to facets of critical thinking. In an integrative approach, the total picture remains intact while the opportunity to zoom in on particular aspects is equally created. The idea is largely borrowed from the 'elaborative sequencing model' as proposed by Reigeluth and Stein (1983). While integrative or infusion approaches are attractive in many settings, their implementation is far from simplistic in that they require a continuous balance between the overall and the specific as well as the integration of the different particular aspects towards the overall.

With respect to assessment, the CRITHINKEDU project claims that an optimal assessment of critical thinking implies the use of authentic critical thinking tasks that can be assessed by using 'rubrics' which detail within the context of the entire task how from specific perspectives (skills/dispositions), critical thinking aspects can be scored. Such competence-based assessments afford opportunities to highlight the aspects to consider and the perspectives from which those aspects can be assessed (Baartman, Bastiaens, Kirschner & van der Vleuten, 2006).

For the development of critical thinking we take the position that critical thinking might be fostered by allowing and/or inducing students to think critically. This presupposes a climate that allows for critical thinking, tasks that are open and a continuous invitation to answer 'why' questions. An infusion approach offers tasks that are at the core of the discipline or field while also providing explicit instruction on critical thinking: what it entails and how it can be done. This could involve: making explicit what is expected as a result, what intermediate steps can be taken, and/or what prompts might instigate thinking.

The relationship between critical thinking and 'a' domain

An important debate in the literature on (stimulating) critical thinking pertains to the domain-specificity and domain-generality of critical thinking (Dwyer, 2017). In some cases, critical thinking is addressed in a specific topic, the focus of which is on a number of skills that are practiced with different types of content. This is the general approach. Conversely, there is the conviction that critical thinking is domain-specific and hence fostering critical thinking cannot but be part of domain-specific courses. This has been called the immersion approach. While in the case of the general approach, transfer to domain-specific tasks is a major issue, in the case of the

immersion approach, critical thinking does not get explicitly addressed as it gets totally embedded in teaching the subject matter. Given the outcomes of a lot of research, there seems to be some consensus that knowledge about the topic at hand is essential in view of critical thinking. Critical thinking implies the consideration of alternatives and hence knowing those alternatives. It also implies assessing evidence and hence knowing what in a domain is epistemologically considered to be evidence. In other words, having appropriate "mindware", which refers to a knowledge structure, including rules, subject-specific knowledge, procedures, and strategies that a person can retrieve from memory in order to aid decision making is a precondition for critical thinking (Stanovich, West, & Toplak, 2016).

In addition, research has shown that addressing specific skills by making them explicit and visible may contribute to the development of critical thinking. One may not assume that any learner will spontaneously consider alternatives, compare them in a systematic way and establish how they relate to a specific problem or issue. However, these skills can be learned by modelling them, making them explicit and practicing them. That is why in this report the infusion approach is argued for. In the infusion approach, subject-matter is at the core but specific dispositions and skills relevant for critical thinking are made visible and are explicitly discussed. Given the importance of the specific field/ discipline (and the knowledge in it), it is clear that critical thinking always handles different concepts, strategies, issues or problems in different fields and disciplines. The same is true for the object of critical thinking. Depending on the nature of the object, critical thinking may take a different form. The nature of critical thinking will be different depending on whether it pertains to a concept, a theory, a phenomenon, a practice, … This mixed position recognizes the importance of domain-specific knowledge and presumes that (within the context of domain-specific tasks) critical thinking skills can be exercised and critical thinking dispositions developed. By pointing to the importance of domain-specific knowledge, the position also tries to avoid an excessive disciplinary focus which would assume that disciplines can be easily identified as fields with 'unique' concepts, approaches or criteria for ascertaining the validity of truth claims.

This report supports the infusion approach for critical thinking development: subject-matter is at the core but specific dispositions and skills relevant for critical thinking are made visible and explicitly discussed.

Critical thinking as an organizational issue, a cultural factor

While the actual activities of students at the course level and interactions with teachers/ lecturers play a major role, those activities are inevitably executed in a context (institutional, disciplinary, cultural) that models, induces and structures those

activities; a context that affects the probability that these activities may occur. That context is layered and multi-dimensional.

The teaching program and organizational/ institutional level can be specifically distinguished. While the focus in this report is on the course level and most guidelines will pertain to that level, guidelines at the organizational/ institutional level and teaching program level are also referred to as they may facilitate/ inhibit and support the work at the course level. This position is illustrated in Figure 1.

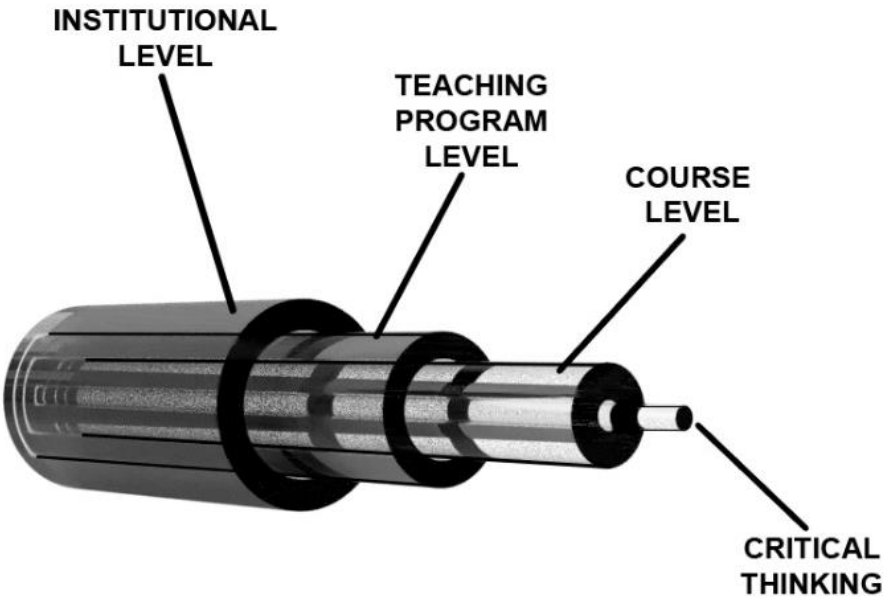

Figure 1. A layered context for critical thinking

At the core of Figure 1 is the course level, where critical thinking is done. Next is the teaching program level that (by building coherence over the courses) supports the development of critical thinking in the programmes. The institutional level is foundational as it enables and hampers particular activities (at the teaching program level as well as at the course level) - it sets the boundaries. More specifically, any higher education institution that aims at promoting critical thinking cannot but allow students to think critically (also about the institution and the principles it is built upon). At the core of our position is the idea that fostering critical thinking at the course level will require a teaching program that supports those initiatives and an institution that embodies critical thinking. In other words, critical thinking where taking a distance and making a judgement is at its

Fostering critical thinking at the course level will require not only a teaching program that supports it, but also an institution that embodies critical thinking.

core, presupposes a democratic environment. Critical thinking fosters and requires democracy.

This also clearly reveals that the context is multidimensional and that different dimensions may be different at different levels. Whereas at the course level, the nature of the learning tasks is of prime importance including their domain-specificity as well as the support provided (e.g., making relevant critical thinking skills and dispositions explicit), at the curriculum level a concern is the coherence across different courses as well as a learning path. At the teaching programme level, a sustained idea about the nature of critical thinking and its development will help to elaborate courses and their coherence. It seems equally valuable that the different courses (a) build on each other, and (b) ensure that as a whole, the courses address different aspects of critical thinking. The dimensions at the institutional level may pertain to human resource development (selection of staff that supports critical thinking), use of resources (make sure that sufficient resources are available for providing education that fosters critical thinking and uses authentic tasks), or its mission (clear ideas about role of HE institutions to deliver critical thinking graduates as a contribution to a democratic society).

Chapter 3. Designing for critical thinking

While promoting critical thinking amongst students is a mission of many institutions and individuals, it is also clear that given its complexity and layered nature, its prevalence or its development cannot be taken for granted. It needs deliberate attention at different levels. That deliberate attention pertains to the design for critical thinking, structuring the environment in such a way that critical thinking can flourish, making adequate curricular decisions and embedding interventions that both instigate and support learning.

Promoting critical thinking needs deliberate attention in designing and structuring the learning environment, making adequate curricular decisions and embedding interventions that instigate and support learning.

This section especially concerns the design for critical thinking. Previously, we indicated that this report pertains largely to the course level. That is why the largest part of this section is devoted to elements at the course level that may (in different disciplinary fields) help to foster the development of critical thinking. However, what happens at the course level is heavily context-bound. What can be done in a specific course is at least partially dependent on what is allowed by the teaching program and by the larger context of the institution (Tsui, 2000). That is why in the first part, factors at the institutional and the teaching program level that might promote or inhibit (the development of) critical thinking are presented.

As any attempt to foster the development of critical thinking implies the need for a learning environment that is powerful, in a second part, general aspects of powerful learning environments are presented.

Contextual factors that promote / inhibit critical thinking

At the institutional level, both intangible and tangible factors can be detected. Intangible factors relate to the ‘culture’ of the organizations. They pertain to the overall atmosphere and all kinds of activities that create the cultural context in which decision makers, teachers, administrators and students operate. Those intangible factors in the context are part of what is sometimes referred at as the hidden curriculum (Eisner, 1979). It is shown in the architecture of the institution, the overall layout, the decoration, the scheduling. Multiple higher education institutions for instance are characterized by a continuous interaction between two major groups of activities: research and learning. Some of these institutions separate these activities (with researchers in one part of the building(s) and teaching in other parts) whereas others try to integrate these activities in order to ensure that students are continuously confronted with research (and hence the continuous quest for new ideas, new solutions as well as the continuous need to rethink one’s options and reconstruct

knowledge) and researchers are continuously confronted with students (and hence the need to explain, highlight and reveal the importance of doing research and the skills and dispositions that are needed to do so). It may be clear that fostering critical thinking will be easier and more sustained when the institutional culture promotes critical thinking. Such a culture may be shown in a variety of concrete actions: regular organization of debates, argumentations for decisions are communicated openly, the presence of a student journal sponsored by the institution but with full control by the students, an openness for failure, position-taking and argumentation, the possibility for students and teachers to raise their voice about what works and what does not work during official events (opening / closure of the academic year, festivities).

In general, it can be assumed that the extent to which there is 'alignment' between the institutional context and the ambition to foster critical thinking will facilitate or hamper the fostering of critical thinking. In a context of a very hierarchical organizational culture with students and teachers being executors of what is decided at the top, with teachers regarded to be infallible experts, the ambition to foster critical thinking will be most probably an isolated 'academic' exercise by a small group of people who think they know what critical thinking is and how it is to be fostered.

The organizational context is important and pervasive, yet often difficult to grasp and rather intangible. A number of more tangible aspects however can also be mentioned. It seems that fostering critical thinking will be promoted when the following elements are in place:

- critical thinking is explicitly part of the mission (statement) of the institution. The mission statement articulates that real problems and issues are complex and need to be addressed from the different perspectives hold by different groups of participants and/or stakeholders, that what counts as a good solution may depend on the perspective taken and may evolve over time;
- critical thinking is considered to be an integral part of all activities of the institution: policy, social service, teaching, learning. Critical thinking is not only regarded as an educational objective for students but an intrinsic quality of all involved in the institution;
- the institution rewards critical thinking by a promotion system that recognises critical thinking rather than focusing on numbers and simple output. This could be done by asking teachers to document clear events of critical thinking in a portfolio;
- the institution promotes critical thinking by the implementation of a quality control system that continuously looks for factors that may obstruct critical thinking and foster pure obedience and narrow thinking. An important part of the quality system is a continuously ongoing review process that monitors how critical thinking is embedded in teaching programs;

- the institution fosters critical thinking by organizing professional development initiatives that facilitates discussion on critical thinking in the organization as well as in research, social service and teaching. Such professional development initiatives might for instance involve the establishment of communities of practice in which educators (teaching assistants and teaching support staff) are engaged in self- and peer-assessment, exchanging perspectives, perceptions and practices with respect to (fostering) critical thinking. Professional development might also take the form of sponsoring projects to foster critical thinking and/or providing institutional teams and resources to support teachers' engagement with critical thinking.

The teaching program level constitutes the level that brings together all those with a shared responsibility to support students in their efforts to acquire a degree. An important aspect of that degree is critical thinking. At the teaching program level, a number of initiatives can be taken to increase the probability that actions at the course level will indeed contribute to achieving the ultimate goal. In general, taking these initiations presupposes a willingness to interact, to collaborate and a continuous openness for critically analysing one's own and others instructional practices. This, is the case at the institutional level and can be promoted by providing targeted professional development (projects, communities of practice, expertise and resources that can be built upon).

Specifically, at the teaching program level, it is essential to outline and implement a curriculum that fosters critical thinking. The spider web curriculum model as introduced by van den Akker (2003) presents an interesting heuristic for discussing at the teaching program level the development of critical thinking (see Figure 2).

The spider web curriculum model presents an interesting heuristic for discussing the development of critical thinking at the teaching program level.

At the core of the web is the rationale: the agreement at the teaching program level about what critical thinking actually means for the teaching program and why it is regarded as being important. It might be for instance, that a clear link is made to research and/or the need for continuously elaborating new solutions for emerging problems. A basic agreement on this rationale seems essential as it ties the different curricular elements by grounding its argumentation.

The web representation clearly outlines that various curriculum elements need to be considered in full awareness that these elements are interlinked. Hence, decisions about one element affect other elements. For instance, specific decisions with respect to assessment affect the operational meaning of the aims and objectives and at least specifies the desirability of specific learning activities.

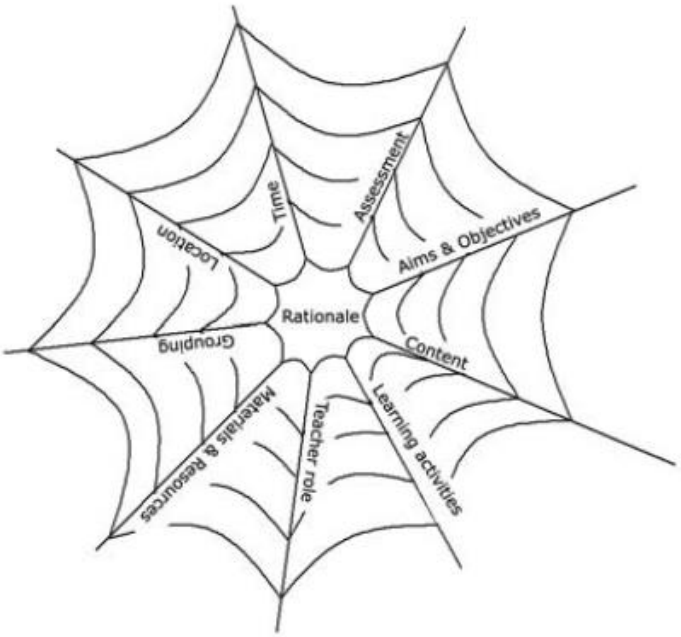

Figure 2. The spiderweb elaborated by van den Akker (2003)

The model of van den Akker (2003) suggests that in addition to discussing and agreeing the rationale of a curriculum (and hence critical thinking), the following elements need also to be considered:

- Learning activities: what activities in the different courses may promote the development of critical thinking and how can it be assured that students will (be able to) engage in those activities.
- Teacher role: given the ambition to foster critical thinking, what is the role of the teacher (see the paradox of forcing students to think critically) and might this role change over the course of the curriculum (e.g., more structured at the start, more open at the end).
- Materials and resources: what materials will be used or what resources will be made available. It might be that students get learner control over materials and resources or that this is an aspect for which control is shared. Again, in the run of the curriculum this may evolve.
- Grouping: how are students grouped (by discipline / level / age) and does this grouping promote exchange in which different perspectives may thrive.
- Location: decisions are taken on the location where learning activities take place. This might be related to the learning activities. It might be for instance that a flipped approach is adopted or that, given the characteristics of the learners who need more self-regulation support, all activities are carried out in

class. Some rooms allow for group activities whereas others induce a more frontal lecturing approach.

- Time: the development of critical thinking deserves careful build up. Hence one of the aspects relates to what happens, when, and in what course so that the different activities can mutually strengthen one another.
- Assessment: critical thinking is a complex phenomenon and, in the assessment, the particular interpretation at the teaching program level can be made. The assessment makes this very operational. That is why various authors (e.g., Biggs, 2003) have argued in favour of alignment between different curriculum elements in order to ensure for instance that in assessment, the essential aims and objectives are targeted. It might be that some elements of critical thinking are stressed more in some courses than in others. An analysis of assessment practices may help to monitor whether critical thinking is assessed as it is interpreted.
- Aims and objectives: while the rationale may highlight what critical thinking entails in the teaching program and why it is regarded as being important, the aims and objectives both at the teaching program level and the level of the specific courses specify how the ultimate aim gets achieved and how the different courses contribute to the ultimate goal.
- Content: critical thinking is not an abstract skill or empty attitude. It is about something and a major challenge relates to identify the context that will engender the intended learning activities in view of reaching the goal of critical thinking. Given that some context might be essential to understand content, agreements are needed at the teaching program level about what will be handled and when. Such discussions may also help to avoid unwanted overlap.

Critical thinking education requires the orchestration of the courses across the curriculum as to offer meaningful educational experience with transferable and long-lasting outcomes.

While the spider model presents an interesting heuristic for identifying what is to be discussed, some recommendations can also be made with respect to how a fruitful discussion at teaching program level can be maintained.

The development of critical thinking is a complex process. That complexity deserves to be recognized by acknowledging that critical thinking education is an endeavour that requires the orchestration of multiple courses as to offer a meaningful educational experience with transferable and long-lasting outcomes. That orchestration requires the collaboration of all relevant partners, especially those responsible for the specific

courses. The following recommendations may help to engage in a fruitful orchestration/ design process:

- Make sure all involved share an understanding of what critical thinking is all about.
- Make sure all involved share a vision of the outcomes of critical thinking education and what it requires.
- Engage in a systematic effort: a model that might help to structure the effort is the so-called Analyze-Design-Develop-Implement-Evaluate (ADDIE) model. It is a formal model that clearly outlines different steps: analysis, design, development, implementation and evaluation. The model at least suggests an iterative process as an evaluation may spark a new analysis phase and consequently new design, development, and implementation phases (Branch, 2009).
- Be aware that there might be a need for organizational development (to ensure that there is alignment between the organizational structure and culture on the one hand, and the ambition to teach for critical thinking on the other). Bartunek and Moch (1987) proposed a 3-order change for bringing and sustaining organizational changes through the change of cognitive schemata:
    - first-order change: the reinforcement of present understandings (e.g., what critical thinking all are about)
    - second-order change: the conscious modification of present schemata in a particular direction (e.g., a transaction to a new perspective: teacher do not merely implement teaching programs or apply critical thinking focused instructional practices, they interpret them through the filter of their own values and beliefs)
    - third-order change: be aware of present schemata (e.g., initially shared vision) and gain capacity to enrich/adapt them when it is necessary and meaningful (e.g., with practice, the understanding of critical thinking will be deepened, there will be systematic adaptation that is generated and promoted by the lecturer groups).
- Consider the establishment of teacher design teams (Binkhorst, Handelzalts, Poortman, & van Joolingen, 2015). Research has shown that the following elements may contribute to the success of teacher design teams:
    - Ensure fluent team interaction (open atmosphere, support, shared feeling of responsibility, interdependence)
    - Ensure that there are shared goals
    - Provide a team coach (and ensure recognition of different types of tasks)

Basic principles for designing learning environments

Learning always happens in a context, in a learning environment. Such a learning environment may take very different forms (e.g., auditorium, lab, computer simulation, desk at home). For a learning environment to be effective it needs to be adequate. A basic condition is that in that environment, learners can learn what they are supposed to learn. This is the case for any learning environment and hence also for learning environments that aim at fostering critical thinking.

The field of instructional design aims at identifying the features of adequate learning environments. More specifically, instructional design (ID) specifies the characteristics of a learning environment that increases the probability for specific target groups in specific contexts to achieve desired learning outcomes. The adequacy of instruction pertains to the match between learning goals, characteristics of learners and learning context on the one hand, and learning content and instructional approaches/methods on the other. For instance, "*what might be most effective for novice learners encountering a complex body of knowledge for the first time, would not be effective, or stimulating for a learner who is more familiar with the content*" (Ertmer & Newby, 2013, p. 60). Different types of learning outcomes also require different methods of instruction: e.g., promoting affective learning outcomes (attitudes, motivations) requires other approaches than those promoting more cognitive learning outcomes (cognitive skills). This congruence principle leads to a conclusion that effectiveness is a context-specific concept. Instructional designers need to ask "being effective for whom, for what type of learning outcomes (goals & performance) and from which perspective/value?" (Reigeluth, 1999, p. 21; Aronson & Briggs, 1983)

Each learning theory – behaviorism/empiricism, cognitivism/rationalism, and social constructivism – provides complementary approaches that are important to stimulate and foster the development of critical thinking.

Over the years, several authors have proposed different sets of principles on the design of effective learning environments. These principles stem from different theoretical backgrounds with respect to learning and teaching: behaviourism/empiricism, cognitivism/ rationalism, and/or social constructivism. Each theoretical perspective has its unique focuses and understanding of learning. Each of them adds to our understanding. The different theoretical backgrounds that ground the principles focus on different aspects of learning and teaching that are complementary rather than contradictory. Each background provides a unique focus on what might be important to stimulate learning and hence also to foster the development of critical thinking.

To introduce these principles (for an overview, Ertmer & Newby, 2013), first a brief description of each perspective is given to indicate the foundational learning theories where the principles were initially emphasized. The reason for providing such information is to indicate why certain instructional principles are likely to be beneficial for learning and on what basis such a claim was made. Each of the principles is recognized, deployed and emphasized by different existing instructional design (ID) models. They can be regarded to be basic principles to be considered when designing whatever learning environment (see Reigeluth, 1983 for a similar use of the notion of 'basic method'). Following the principles, possible corresponding ID implications or areas of application are discussed.

Behaviourism/Empiricism

Behaviourists recognize learning when appropriate behavior occurs in response to a given stimulus. In order to achieve behaviour change, reinforcement is essential. It ensures that observable associations are made (Greeno, Collins, & Resnick, 1996). To design effective learning environments, a number of ID principles were proposed with a particular emphasis on behavioural change/modification. Attention is mostly on selecting and designing learning content. In general, these principles are more suitable for mastery of standard rules, facts and the content of a profession (knowing what) or dealing with tasks that require a lower degree of processing (e.g., basic paired associations, discriminations, rote memorization) (Ertmer & Newby, 2013).

From a behaviourist perspective the following principles are proposed:

- Identify what students can do now (initial behaviour)
- Identify the desired behaviour and specify it in terms of observable and measurable outcomes in students
- Ensure mastery of early steps before progressing to more complex levels of performance, i.e. sequencing tasks from simple to complex and from easy to difficult
- Apply reinforcement strategies to impact performance amongst others by providing timely constructive feedback

Cognitivism/rationalism

Cognitive theories such as information processing theory including schema theory have provided great insights into characteristics of the brain and how it processes information to learn. At least two of them are relevant here. A first crucial insight pertains to the limited capacity of our working memory. As one of the consequences, we can only attend to a few things at once. Thus, directing attention to essential and

relevant information is a crucial necessary prerequisite for learner to mobilize and maintain cognitive processes for effective learning. A second insight is that learners' prior experience and knowledge largely affect the internalization of incoming information (Johnson-Laird, 1983). The information is organized in schemata by the individual learner. People may form different schemata, which influence people's knowledge construction. Hence, one of the central focuses of instruction is to activate learners: i.e. "*making knowledge meaningful and helping learners organize and relate new information to existing knowledge in memory*" (Ertmer & Newby, 2013, p. 54). To be effective, the ID principles derived from cognitivism hence take a learner-centered view and pay additional attention to facilitating information processing.

From a cognitive perspective the following principles are proposed:

- Ensure active involvement of the learner in the learning process by providing sufficient learner control and self-regulation
- Allow and encourage students to make connections with previously learned material by recalling of prerequisite skills and by using relevant past experience, examples, and analogies
- Develop and sustain learners' intrinsic motivation (i.e. natural tendency to learn and understand) to ensure engagement. Motivate learners by experiencing the feeling of being in control, improved self-efficacy, etc.
- In designing learning content, use hierarchical analyses to identify and illustrate prerequisite relationships
- Facilitate optimal processing by structuring, organizing, and sequencing information

Social-constructivism

Constructivism asserts that learning occurs when meaning is created from experience. Knowledge is no longer seen as being objective, existing outside the mind of a learner and easily fed into a learner. Instead, "*humans* create *meaning as opposed to* acquiring *it*" (Ertmer & Newby, 2013, p. 55). Social cognitive theory stresses the impact of reciprocal interactions among persons, behaviours, and environments on learning. "*Learning is largely an information processing activity in which information about the structure of behavior and about environmental events is transformed into symbolic representations that serve as guides for action*." (Bandura, 1986, p. 51).

Moreover, social cognitive theory suggested that people feel more motivated when 1) learning experience fulfils their goals and expectations, 2) perceiving control and higher self-efficacy, and 3) attributing success to internal reasons, such as ability and effort (see social cognitive theory and attribution theory).

To be effective, learning environments need to engage learners in actively constructing knowledge in a social environment. Social constructivism not only emphasizes the learner-centered principle, but also recognizes the importance of the learning context.

From a social-constructivist perspective the following principles are proposed (Wilson, 1996):

- Identify the context in which the skills will be learned and subsequently applied in view of anchoring learning in meaningful contexts by using authentic learning tasks
- Allow for learner control and build on the capability of the learner to manipulate information
- Motivate learners by creating communities where learning is valued and by supporting personal identity development
- Ensure variation by presenting information in a variety of different ways (revisiting content at different times, in rearranged contexts, for different purposes, and from different conceptual perspectives) and by multiple modes of representations
- Support the use of problem-solving skills that allow learners to go “beyond the information given” (e.g., developing pattern-recognition skills, presenting alternative ways of representing problems).
- Focused on transfer of knowledge and skills by presenting new problems and situations that differ from the conditions of the initial instruction
- Encourage self-awareness of knowledge construction process (know how we know) by explicitly encouraging students to engage in metacognitive and reflective activities.

Transfer of learning

Transfer of learning refers to knowledge being applied in new ways, in new situations, or in familiar situations with different content (Ertmer & Newby, 2013; Schunk, 2012). To judge the effectiveness of a learning environment, transfer of what has been learned is an important indicator. When stimulating critical thinking we do not want students to think critically in one specific setting or context but to do it whenever appropriate.

To enable learners to apply their knowledge and skills inside and outside of the formal learning environments, specifically to new cases/situations, in addition to the aforementioned principles, the following conditions were highlighted in the literature

Different conditions should be attended in order to enable students to apply critical thinking outside formal learning environments, especially in new situations.

(Seidel, Perencevich, & Kett, 2005; Schunk, 2012). First, transfer is easier when the learning settings contain similar elements as the ones in the transfer settings. The similarity can pertain to examples, physical stimuli, cognitive abstractions, and/or procedures (Druckman & Bjork, 1994). Strengthening analogical reasoning may also help learners to detect similarities (Gentner, Loewenstein, & Thompson, 2003). Second, developing automaticity may promote transfer, as it results in the reduction of cognitive load (Sweller, van Merriënboer, & Paas, 1998). Automaticity is a particular important condition for low-road transfer which was defined as the transfer of well-established skills in a spontaneous and perhaps automatic fashion (Salomon & Perkins, 1989). Third, transfer can be promoted by encouraging the abstraction of principles or rules beyond the immediate concrete context examples within a domain (also called high-road transfer). In order to abstract behavior and cognitions from a learning context, a learning environment needs to encourage learners to be proactive, i.e., actively self-monitor potential contexts and use of skills and knowledge (Salomon & Perkins, 1989; Griffin, 1995). Fourth, learners' awareness about transfer issues may promote transfer. Therefore, meta-cognitive skill development within a task-oriented learning environment is encouraged (Seidel, Perencevich, & Kett, 2005) for instance by using multiple tasks and making the similarities and differences in problem solving / learning in these tasks explicit (Borkowski, 1985). Fifth, transfer becomes more probable when learners have sufficient knowledge about potential transfer contexts (Salomon & Perkins, 1989). Sixth, there are motivational aspects to the transfer issue. The probability of transfer is higher when learners pursue mastery goals rather than performance goals, in other words when students want to 'master' the substance of a course the probability that they will be able to use what has been learned is larger than when students simply want to pass or to do well on the exam. Similarly, the probability of transfer is higher when students are interested in the essence of the learning content rather than in peripheral things (e.g., seductive details in text); and when they have higher self-efficacy and hold an explicit goal of achieving transfer (Pugh & Bergin, 2006).

Chapter 4. Designing for critical thinking: a perspective from different disciplines/fields

In the previous chapter, a number of more general principles on designing learning environments were discussed. In view of promoting critical thinking more specific information is needed. In "A European review on Critical Thinking educational practices in Higher Education Institutions" (Dominguez, 2018b), the CRITHINKEDU project has already discussed interventions that have been shown to be effective for critical thinking. That report has made clear that some general strategies do exist and also that discipline-specific variations can be retrieved as well. Based on the analyses, the report also presents a number of preliminary guidelines for fostering critical thinking. This chapter complements the previous study of the literature by identifying, for different fields, strategies that can foster critical thinking. This is done by looking at the literature on interventions that pertain to specific skills and dispositions that are part of critical thinking (in line with the definition of Facione, see Table 1). Combining the information in the previous report and this chapter may help propose principles, methods and approaches that may promote critical thinking.

This chapter complements the CRITHINKEDU preliminary guidelines by identifying strategies that can foster critical thinking for different fields.

For all fields the same methodology was adopted. Databases (Web of Science, ERIC) were screened with keywords that pertained to the different critical thinking skills and dispositions as identified by Facione (see Table 1 in Chapter 2). In order for a study to be retained for further analysis it had to (a) be published in English, (b) in a double-blind peer reviewed journal, (c) pertain to a skill or disposition as enumerated by Facione, and (d) present an explicit intervention study [this implied an explicit discussion of the intervention as well as the effects of the intervention (be it in quantitative or qualitative terms)]. A first screening was done by studying the abstracts. Finally, 83 papers were retained for further reading and analysis. Each of the selected publications was analysed (using the same analysis form) by two partners in the project in order to ensure reliability of the interpretations.

A first section presents research on specific critical thinking skills and dispositions covering multiple disciplines. The second and third section present research from respectively the biomedical and the STEM domain. In the fourth section research pertaining to humanities and social sciences are discussed. As far as possible, each section presents research on educational interventions and teaching methodologies that may foster critical thinking skills, dispositions and combinations of skills and dispositions. Each section concludes with a summary of the findings. Each section is written to be read as a text in its own right. Educators only interested in one specific field can read only the section pertaining to the field they are interested in. Given that

some disciplines can be said to belong to multiple fields, there is some overlap (redundancy) in the sections. For instance, biology can be said to belong to the fields of STEM as well as biomedical sciences. We decided to include the studies related to such disciplines in the sections of both fields. This on the one hand allows readers to be selective without losing information, on the other hand it induces overlap between the sections.

Throughout the CRITHINKEDU project partners have engaged in deliberate efforts to strengthen critical thinking in particular courses. Information on those attempts were systematically gathered. Descriptions of the interventions as well as perceptions of their effectiveness by teachers and their students are available. In order to enrich the information in the sections on the different fields, vignettes are inserted. These vignettes indicate what skills and/or dispositions were targeted by the intervention, the context of the intervention, the nature of the intervention as well as practical reflections made by teachers as well as students on the effectiveness of the interventions. The vignettes illustrate the recommendations that stem from research and offer an insight in the practicalities of fostering critical thinking at the course level. The vignettes also clearly show that critical thinking skills and dispositions are closely related. Rather than focusing on one skill or disposition, the interventions target combinations of skills, combinations of dispositions, and/or combinations of skills and dispositions.

Deliberate efforts to strengthen critical thinking in particular courses were developed by the CRITHINKEDU project partners. Those are presented in the form of vignettes throughout this report.

Designing for critical thinking: findings from studies covering multiple disciplines

In this section an overview is presented on methods and approaches to foster aspects of critical thinking that seem to apply for multiple disciplines. That does not imply that the methods or approaches are domain-general (and hence the discipline or professional field is of no importance). Rather it indicates that some methods (with domain-specific elements) seem to work in multiple fields. The information in this section is based on an analysis of 18 articles in which the impact of interventions on aspects of critical thinking was investigated. In this section, only the studies in which multiple disciplines were investigated are discussed.

Based on the analysis of the 18 publications, it is indicated as suggested by the authors of the different studies to make three preliminary remarks:

1) Given the widespread evidence about a tight connection between (disciplinary) knowledge and critical thinking, it seems indicated to *teach critical thinking as*

part of teaching discipline-specific courses[1]*.* This allows teachers to focus on and to make discipline-specific ways of reasoning explicit (Pithers & Soden, 2000).

2) The embedding of critical thinking in domain-specific courses requires teachers to have an in-depth understanding of the nature and purpose of critical thinking in their discipline/professional field. Although it might not be a guarantee, being active as a researcher in the field may at least help to develop that understanding. As Byrnes and Dunbar (2014) suggest, doing research or working with students on unresolved domain-specific issues might be a good approach to stimulate critical thinking and to motivate students to think critically. This implies that students work on unanswered questions, engage in appropriate methodologies, get the opportunity to be surprised by findings and to discuss or debate on how they interpret what was found. And most important, they start to value the necessity to follow a systematic and transparent approach (e.g., be explicit about the theories and assumptions underpinning the methodology and data analysis). They also start to recognize that a systematic and transparent approach is an adequate manner to withstand automatized heuristics and biases (Kahneman, 2011; Stanovich, Toplak & West, 2008; Stanovich, West, & Toplak, 2016). All this requires excellent teachers who are experts in their disciplinary field, in critical thinking and in supporting the learning of students.

3) Teaching for critical thinking is not easy for teachers or students. It requires leaving the solid path of providing information on what is already known. It requires teachers to question students. It implies allowing students to question teachers and their teaching, to come up with alternatives. Teaching for critical thinking will at least invite students to think for themselves, to come up with their own ideas and defend these with solid arguments. Teaching for critical thinking may make students who look for simple solutions and right answers uneasy.

Broadbear (2003) identified four essential elements of lessons designed to promote critical thinking, claiming that these elements should be repetitively present in lessons for a (discipline-specific) course that aims at critical thinking: (1) use of ill-structured problems; (2) clear criteria to assess thinking (e.g., based on Paul, 1995 and Paul & Elder, 2001: clarity, accuracy, precision, relevance, depth, breadth, logic, significance, and fairness); (3) student assessment of thinking (e.g., self-assessment, peer-assessment), and (4) improvement of thinking (opportunity to revise, make progress, show progress).

In general, research has not been very positive about the outcomes of learning environments that aim at promoting critical thinking. Niu, Behar-Horenstein, and

[1] See also blog by M. Neelen & P. Kirschner (with additional references to literature): https://bit.ly/2JU4JOI

Garvan (2013) concluded based on a meta-analysis that with a number of specific instruments aimed at measuring critical thinking in a structured way (WGCTA, CCTT, CCTST) only limited effects of interventions were found. The impact seems to be higher in social sciences than in health sciences. Interventions that last longer than 12 weeks seem to generate a larger impact. That interventions can be successful is demonstrated in a study of Dreifuerts (2012). Their intervention resulted in higher scores on the HSRT test already after one episode of the intervention (4 hours). This exceptional result may be explained by several methodological features of the study (the teaching approach was exceptionally innovative/effective; the control group and experimental group used different debriefers). It is to be noted that several authors have argued that the minimal effects may be partly due to the rather amateuristic way of the design of the learning environments and the short and/or isolated nature of the interventions.

Developing critical thinking and studying initiatives in this respect are clearly not easy (and hence a systematic design of the learning environments is indicated). The development of critical thinking (dispositions) takes time (and hence sufficient time is to be provided during the course as well as efforts at the teaching program level are needed). While evidence is scarce a number of methods have been argued to be useful to promote aspects of critical thinking in different disciplines. The following summarizes the relevant literature (covering multiple disciplines).

Skills

General

For critical thinking skills in general, Angeli and Valanides (2009) have demonstrated with undergraduates from different fields that lectures as such are not sufficient to develop critical thinking skills. There is a need for interaction with the students (as part of immersion or infusion approaches). In that interaction, open questions are raised that involve the students directly (what is your view; why have you done this, …) and ample feedback (by peers and/or the teacher) is provided. For understanding critical thinking, it was shown that there is no development without attention to it. The understanding grows more when the meaning and the different aspects of critical thinking are explicitly discussed (infusion). It seems that both guidance and feedback are essential.

To develop critical thinking skills, ample practice is required (see also Niu et al., 2013). This was shown by Dunbar (2014). In this study, addressing biases in thinking is the major goal. A game that allowed students to repeatedly check their ideas and confronted students with the effects of biased thinking is compared to a high-quality video that discusses and testifies about cognitive biases. The power of the game is demonstrated. It illustrates the importance of practice (incl. feedback) and the need for longer-duration interventions given better results with longer playing time.

Analysis

For analysis as a cognitive critical thinking skill the work of Kuhn is relevant. A number of studies illustrated how longer-term interventions (typically 8–10 weekly sessions) can alter the analytic strategies students use to acquire new knowledge about a causal system. Simple enhancement of their meta-strategic understanding of why these are the strategies that must be used and why others will not be sufficient to actually apply more appropriate strategies, requires sufficient time (Kuhn & Angelev, 1976; Kuhn & Ho, 1980; Kuhn, Ho, & Adams, 1979; Kuhn & Phelps, 1982; Kuhn, Amsel, & O'Loughlin, 1988; Kuhn, Garcia-Mila, Zohar, & Anderson, 1995; Kuhn, Schauble, Garcia-Mila, 1992).

Evaluation

Evaluation pertains to the use of knowledge-validation and consistency checking strategies. Richter and Schmid (2010) have demonstrated that epistemic beliefs [views on nature of knowledge (separated-connected)] do influence the use of such strategies. Moreover, it was shown that students from different disciplinary backgrounds also differ in the use of these strategies. Most probably this is related to the extent they are induced to use such strategies in their regular courses. In a similar vein, Kammerer, Amann and Gerjets (2015) revealed, with a diverse adult population, the role of epistemic beliefs with respect to search strategies on the internet. The conviction (belief) that the internet presents objective information results in less corroboration over different web pages and less time spent. These authors also demonstrated that an intervention in which explicit attention is devoted to these beliefs and strategies can be effective.

Self-regulation

Self-regulation is an important critical thinking skill. Positive effects of interventions based on Zimmerman's model have been found by Dörrenbacher and Perels (2016). The intervention is characterized by lectures and exercises (individual and in group): a combination of different teaching methods seems to be needed to reach a good result. Intervention is not equally effective for learners with different levels of self-regulation.

Cho and Cho (2013) have demonstrated that students can develop their metacognitive skills in general and more specifically their self-regulation skills when they are informed about the importance of self-regulation, what it entails, and when over the course of the semester they are repeatedly encouraged (partly through reflection prompts on social media) to reflect on and practice their self-regulation skills.

Dispositions

Using the California Critical Thinking Disposition Inventory (CCTDI), Akyuz and colleagues (2015) demonstrated that critical thinking dispositions can be developed by paying explicit attention to metacognitive processes during working on problems in group. They show that, problem solving by itself, does not develop critical thinking dispositions. There is a need for 'metacognitive coaching' through means of repeated self-regulation questions such as: what are you doing now, why are you doing this, will it help, what alternatives could you consider, why will they (not) work.

Cognitive maturity is an important critical thinking disposition. Also, here the work of Kuhn is interesting (e.g., Kuhn, 1999). Her research reveals that students evolve (see also the work of Perry, 1981) from "absolutists" to "multiplists". As multiplists they show an increasing understanding of the role of interpretation and context and come to understand that there is no way to discriminate between one viewpoint and another (all viewpoints are equally viable). With additional discussion and reflection students may develop an "evaluative" epistemology in which they respect the right of people to have their own opinion but use evaluative criteria regarding evidence and reasoning to decide whether one perspective is better than another (Kuhn, 1999). Again, the major lesson here is that the development of critical thinking requires time and is/cannot be a one-shot operation.

Combinations

An interesting cooperative learning method for stimulating the development of combinations of critical thinking skills and dispositions (in an integrated way) is the use of 'constructive controversy' (Johnson, Johnson, & Smith, 2000). Constructive controversy implies that different (groups of) students take different (selected or allocated) positions/stances toward an issue or problem. For each position/stance pertinent arguments are looked for as well as counter-arguments for alternative positions. By bringing together the arguments and counter-arguments for the different positions, a more balanced position/stance can be taken or a solution can be proposed that considers different perspectives.

Conclusion

In this chapter research and ideas are discussed that are field transcending. In general, it is to be observed that the empirical evidence is scarce and that only in a limited number of cases attempts are made to replicate findings in multiple fields. While the selection criteria of the articles was strong (e.g., need for explicit intervention), it remains the case that a lot of studies have methodological flaws (e.g., no measurement of prior knowledge or other control variables).

It is also to be noted that given our approach to select publications (specific critical thinking skills and/or dispositions rather than critical thinking as such) we have complemented the work done earlier in the project. As such important research by amongst others Diane Halpern (e.g., Halpern, 2014) is not discussed here.

Notwithstanding these observations, a few lines seem to be consistent. Interventions seem more powerful if they are designed starting from an in-depth understanding of the targeted skill/disposition. Effects are also greater when students get spread over time ample opportunities to practice (and to get feedback). Attention is to be paid to underlying notions about knowledge and attitudes towards information (use). The studies also suggest that (a) explicit attention for critical thinking is a must and (b) teaching for critical thinking implies that complexity is recognized, different (well-argued) opinions are valued and students are required to think for themselves. Given different practices (and goals) in different fields some fields might have fewer problems to stimulate critical thinking than others. A focus on 'right' procedures might be less inductive to promote critical thinking in comparison to a focus on dilemmas and complex problems.

Interventions seem more powerful if they have an explicit attention and understanding of critical thinking skills/dispositions, and if students are given ample opportunities to practice them over time.

Designing for critical thinking in the biomedical domain

In this section, an overview is presented on methods and approaches to foster aspects of critical thinking. It is based on an analysis of 22 papers stemming from the biomedical domain. Two of these papers are systematic reviews (Lee, Lee, Gong, Bae, & Choi, 2016; Yue, Zhang, Zhang, & Jin, 2017) covering 21 studies (with two overlapping studies, and one of them (Iranfar, Iranfar, & Mohammadi, 2012) was also included as a separate paper in this text, which means that in total 40 different studies are included.

Skills

General

In general, Lee et al. (2016) argue in their review that problem-based learning may not always improve critical thinking-skills of health care providers. They could not find significant effects in the studies reviewed.

Wass, Harland and Mercer (2011)[2] argue that participating in research activities and conversations with teachers might stimulate critical thinking. In this longitudinal study, undergraduate zoology students were followed over a three-year period. The researchers highlighted the following considerations when it comes to stimulating critical thinking:

- Learning through research could cause a shift in students' view of knowledge: from knowledge as something incontestable to epistemological uncertainty.
- Effective critical thinking teaching allows students to struggle and thus think for themselves.
- Teacher-student conversations (and thus improved access to teaching staff) are important as they induce students to explore their understanding at a deeper level.
- Teachers as role models.
- Diagnosis of student learning habits or schemes and needs is essential before taking appropriate and differentiated action (in contrast with first year: students as one large cohort).
- A collaborative environment might be beneficial for the development of critical thinking provided peers are willing to be supportive towards each other and take responsibility for peers' learning.

For a broad set of skills, working in groups to deconstruct papers is experienced by students (undergraduate biology and medicine majors) to be helpful in developing critical thinking skills such as interpretation, analysis, inference and evaluation (Abdullah, Parris, Lie, Guzdar, & Tour, 2015). Students go through a full cycle of paper deconstruction by explaining terminology and methods, by analysing experiments, by discussing data and presenting results, by discussing author's conclusions and finally by writing a follow up experiment. In this study, students were intensively coached through at least four papers during a longer period of about 10 weeks.

In a systematic review study, Yue, Zhang, Zhang, & Jin (2017) revealed that for healthcare providers (such as doctors, dentists, nurses, and students) concept mapping is an effective way to develop critical thinking skills. Yue et al (2017) combined three studies using CCTST as an effect measure and demonstrated a significant effect of the use of concept maps on critical thinking skill development compared to traditional education. This was also confirmed by combining 3 studies that used the CTS (Critical Thinking Scale (CTS), developed by Cheng, Wang, Wu and Hwang, 1996) as a measure for critical thinking skills. Concept mapping is easy to implement, students are asked to make nodes and links in a way to present

[2] Given that zoology can be categorised in multiple fields, this information is repeated in the section on STEM. This also applies to other studies in this section.

information and their relationships. Compared to traditional lectures, students are more challenged to explore on their own initiative (Yue et al., 2017). However, not all critical thinking-concept map studies come to the same conclusions. The study with nursing students of Bixler, Brown, Way, Ledford, & Mahan (2015), that was not included in the work of Yue et al. (2017) found no significant effect of the use of concept maps on the development of critical thinking. In contrast, Daley, Shaw, Balistrieri, Glasenapp, and Piacentine (1999) and Gerdeman, Lux and Jacko (2013) found significant effects. Gerdeman, Lux and Jacko (2013) report positive evaluations by nursing students of the use of concept maps to develop clinical judgement skills consisting in the following phases: noticing, interpreting, responding, and reflection. As evidenced in the concept maps, the students experience a progression from simply identifying a patient problem, to the actual use of data and assessment of information to determine priorities, interventions and successful outcomes for their patient.

During their undergraduate thesis writing, biology students learn to communicate to the broader scientific community. Researchers (Dowd, Thompson, Schiff, & Reynolds, 2018) found a significant difference in overall CCTST scores between those who were good at discussing implications of results and those who weren't. So, learning to discuss implications of research might help developing critical thinking.

A useful activity to enhance the development of critical thinking for food science students is the use of classroom discussions in small groups with student-led feedback afterwards by other groups (Hayes & Devitt, 2008). More significant effects were however seen in small class sizes of food science students [unfortunately Hayes and Devitt (2008) did not define small]. Probably in that case participation is higher because of a lack of anonymity (inherent to large classes).

Analysis

The use of counterintuitive exercises or examples help students use and question their prior knowledge and become deeper thinkers. Larsson and Tibell (2015) made biology students think by initiating cognitive conflict using a tangible model (demonstrating a self-assembly process of a virus).

Bravo et al. (2016) could measurably improve data analysis skills (like convert data to graphical representations, interpret graphical information, or draw conclusions based on the analysis of data) over one semester with interventions like linking rubrics to repeated classroom assignments and student self-reflection. Students could use the rubrics for self-assessment.

Vignette 1: UTAD, Portugal, Veterinary Medicine

In the theoretical classes (40% of total course) of a Master course on ‘’Animal Reproduction’ in the Veterinary Medicine program (attended by 72 students), a number of new strategies were implemented to target the following CT-skills: Interpretation, Analysis, Evaluation, and Explanation.

An interactive lecture-based approach was replaced by a flipped classroom approach supported by the institutional Moodle learning management system. Students got information about what topics would be addressed in each lesson as well as an explicit indication of the required knowledge for that lesson. In addition, supportive information for students’ self-study was provided. The theoretical classes started with about 5 questions about the topic of the lesson. After having presented the questions, the teacher asked students to justify their answers, to explain more controversial questions to their peers of the proposed strategies to act in standard situations. The assessment focused on the acquisition of interpretation, analysis and evaluation skills. During the exam for the theoretical classes about 80% of the questions required students to interpret and analyze real-word scenarios and to explain different phenomena.

The teacher has the impression that students’ clinical reasoning skills improved. For the future the teacher aims at preserving the analysis of practical situations as it triggers students to use their prior knowledge and to develop their interpretation and analysis skills. Important aspects are also the assessment approach (OSCE evaluation) and the required self-study by the students prior to the theoretical classes. It helps them to refresh or acquire the knowledge needed to actively participate. While a number of new strategies have already been implemented, in the future more attention could be paid to self-regulation and metacognition.

Changes attributed to the intervention are higher involvement and satisfaction of students, deeper discussion, better teamwork outputs (team presentation, outputs of teams during the seminar), better summary at the end of the class/activity, better results in the open-ended questions in the final test.

From the perspective of the students, the flipped classroom approach is much appreciated as it induces them to acquire the needed knowledge to participate during the classes and allows them to ask for clarifications and further explanations when needed. They also value weekly tasks as this helps them to structure their time and to study regularly (and not only for the exams). At the same time, students point to the amount of work, would prefer to have more time for the assignments as well as more traditional lectures.

Vignette 1 – UTAD, Portugal, Veterinary Medicine

Inference

Dowd et al. (2018) found a strong positive correlation between the inference (as a factor of the CCTST) and some of the dimensions they used to assess undergraduate theses of biology students. The dimensions focused on the scientific reasoning regarding the appropriateness for the audience, argumentation of the significance, articulation of the goals, interpretation of the results and discussion of implications. By using the inference skill, students focused on drawing conclusions from reasons and evidence. These results suggest that scientific writing tasks are related to the critical thinking-skill of inference as measured by the CCTST.

Evaluation

In a study by Anderson et al. (2001), students are asked to provide more arguments for their proposals, ideas (on health prevention) by encouraging them to raise questions about exercise proposals (first) and proposals of their peers (next). Ample discussion and modelling of that discussion by instructors as well as sufficient time seems to be essential for providing good arguments.

A well-designed journal club can be a platform for training critical appraisal of the literature in the medical discipline (Kellum, Rieker, Power, & Power, 2000). The journal club contained the following components:

- criteria for reporting specific research (like randomized trials)
- instructions to look for systematic bias;
- evaluation of the quality of statistical analysis;
- prepare a presentation;
- in-time feedback and required written reflection afterwards.

Explanation

Anderson et al. (2001) focused on developing the skill of evidence-based justification. The study showed that modelling the kind of thinking targeted and encouraging peer dialogue can help. Students (from a vocational qualification in social care and health care) made less unjustified statements and provided more justifications. These results were achieved via a series of activities: such as lecturer modelling of the rules and of the peer-based critique [asking why questions and providing justifications (anecdote based – research based)], having students write down preliminary ideas for a project, as well as present and justify these ideas in group discussions. The study also suggests that sufficient time is needed to develop this critical thinking skill.

Self-regulation

“Slow down when necessary” is one of the key functions of a critical mind. Self-regulation can be seen as the metacognitive control to enable one to be adaptive in switching mental modes (Louis & Sutton, 1991). In a study with expert surgeons, Moulton, Regehr, Lingard, Merritt and MacRae (2010) analysed the nature of the ‘slowing down’ phenomenon. Moulton et al. (2010) looked for initiators and influencing factors to slow down from a routine mode to an effortful mode. The interview analysis results revealed two sets of initiators for mindful surgeons to initiate the transition from ‘automatic’ to ‘effortful’ mind in professional practice. One set is the proactively planned ‘slowing down’ moments, which were anticipated preoperatively from operation-specific (tying superior thyroid vessels) or patient-specific (imaging abnormality) factors. Another set is the situationally responsive ‘slowing down’ moments to unexpected events (encountering an adherent tumour). The expert surgeons also described several influencing factors: internal factors (fatigue, endurance), personality factors (adaptability, confidence, willingness to learn, …), situational factors (time pressure, hierarchical pressure, …).

Being knowledgeable about the initiators can help a teacher to purposefully prepare students by letting them identify critical points of professional practice and having them use these critical points to proactively plan moments of slowing down. These anticipated moments can be originated from cues that are either procedural specific (occurring each time you perform that procedure) or context specific (occurring as a result of unique situations). Debriefing after the identification of the unplanned transitions from automatic to effortful mental mode can also be a useful teaching practice. Reflection on the necessary moments of slowing down can stimulate sensitivity, that is, to be alert to critical points. The debriefing framework for meaningful learning from Dreifuerst et al. (2012) can be used.

Vignette 2: University of Thessaly, Greece, Nursing

At the end of a 2nd year course, Medical Nursing Lab in the Nursing program, students (N=18) are expected to be able to evaluate and analyze the complex context of medical situations of patients and be able to organize and deliver appropriate and quality nursing care. Initially the course was more lectured oriented and students carried out literature research assignments about the learning topics in order to find evidence regarding effective nursing care.

The course was redesigned in order to be more interactive and stimulate critical thinking. More specifically the following critical thinking skills were developed: analysis, evaluation, explanation, and self-regulation. And the following critical thinking dispositions were aimed at: truth-seeking, analyticity, systematicity, self-confidence, and cognitive maturity.

By introducing simulation situations, case-based learning, role-play and problem-based learning, practice learning, practice sharing and collaborative activities students got opportunities to discuss their knowledge and demonstrate their medical-nursing skills mainly in simulation situations. Students' discussions were followed by discussions between students and teacher. By doing so students received feedback about hypothetical scenarios in a wide range of medical-nursing subjects.

By direct observation, the teacher experienced that students were highly engaged and trying to achieve the best results. Both the teacher and the students valued the authentic conditions of the simulations. The more interactive approach of the lessons gave students the opportunity to express their thoughts and ideas which fostered their learning.

Vignette 2 – University of Thessaly, Greece, Nursing

Dispositions

General

Dehkordi and Heydarnejad (2008) concluded that problem-based learning (PBL) was more effective in developing critical thinking dispositions for nursing students compared to lecturing. Their PBL-approach had the following features: group work on students' generated issues, guided by tutors, unlimited access to information and debating on different aspects of the problems. They found that solving problems without explicit guidance and prompts does not develop critical thinking dispositions.

In a systematic review (Yue et al., 2017) concept mapping is shown to be an effective way to develop critical thinking dispositions of healthcare providers (such as doctors, dentists, nurses, and students). Concept map users focused more on the important factors and the knowledge about interrelationships and hence it might be said to display critical thinking dispositions. In the seven studies that were reviewed (Yue et

al., 2017) significant effects were found using various approaches for open-mindedness, truth seeking, analyticity, systematicity, self-confidence, inquisitiveness and maturity. In each of these studies concept mapping was compared with traditional education methods. Another study (Tiwari et al., 2006 in Lee et al., 2016) revealed that significant results disappear after 2 years, which implies that working in a single course during one or two semesters might be insufficient. A joint force from different courses that lasts longer is needed to develop critical thinking dispositions.

One longer-term intervention was described by Zhang et al. (2017). They demonstrated that reflective training during internships can improve nursing students' critical thinking dispositions. To make such training successful, both nursing students and their mentors received a reflective skills training and professional portfolio user's guidance. During half of a year mentors were familiarized with the process of reflective practice by writing a portfolio that was revised under guidance. The students got a reflective skills training course in groups. This training emphasized the significance, patterns and procedures of reflective learning, with the goal to enable students to use the portfolio and to become reflective practitioners. During the 12-month internship students created and improved their portfolios based on mentors' feedback. There is no information on whether this process was pursued after the internship.

Vignette 3: UTAD, Portugal, Nursing

The learning goals of a 2nd year nursing course on management of chronic diseases are: to correctly interpret, analyze and evaluate different data from specific health/illness situations; to effectively explain and deliver efficient nursing care and to actively participate in their own knowledge construction process, by being intellectually curious, open minded and truth-seekers. Before the change, students (about 25) carried-out literature research assignments about the learning topics. All those assignments were presented, discussed and shared in the classroom for the teacher and colleagues. In the redesign the following critical thinking skills were aimed at: analysis, inference, evaluation, explanation, and self-regulation. Moreover, the following critical thinking dispositions were targeted: truth-seeking, open-mindedness and inquisitiveness.

To foster students' critical thinking the teacher introduced explicit support and systematization. Students' first task was the analysis of a research paper. The teacher explained the use and application of the FRISCO guidelines (Ennis, 1996). This assignment was made in groups of 4 students, and then shared and discussed in the large group of the classroom. During the large group discussion, teacher encouraged the active and reflexive participation from the students by introducing the 'Think-Pair-Share" method. Additionally, some difficulties in the use of the guidelines were presented by the students and clarified by the teacher. This first step was an overall basis to carry out the following assignment.

In a second and larger assignment, with randomly constituted groups, students had to reflect on and to define relevant questions that could potentially be included in the nursing interview protocols used with people living in difficult and/or socio-problematic situations due to chronic disease. After that, students identified, with complementary bibliographic searches and analyses, different nursing diagnosis and interventions that could possibly be implemented in those situations. The outcomes from each group were presented and debated in class.

Both assignments were evaluated. Additionally, students realized an individual final assessment which compiled all the previous acquired knowledge and skills. The teacher directly observed students' high motivation to engage with the proposed assignments, by seeking to achieve the best results. Students were more aware of the importance of developing critical thinking skills and dispositions in nursing, as an essential component of the professional responsibility and quality performance. The teacher experienced the promotion of cooperative learning using the 'Think-Pair-Share" method and the provision of opportunities to for questioning and/or CT questioning activities as key elements.

Vignette 3 – UTAD, Portugal, Nursing

Truth seeking

Make reasoning explicit for students is helpful to stimulate the disposition of truth seeking. A well-designed technique describing steps to take, helps students in analysing different possibilities and expressing their reasoning and uncertainties, as was shown with medical students using a mnemonic (SNAPPS – Summarize, Narrow, Analyze, Probe, Plan and Select; Wolpaw, Papp, & Bordage, 2009) for case presentations on patients.

Self-confidence and inquisitiveness

The use of reflective journals seems to be a good way to foster self-confidence, self-esteem and self-reflection (Sedlak, Doheny, Panthofer, & Anaya, 2003). Sedlak and colleagues asked students to work with reflective journals during their service-learning training and to weekly discuss their insights, directed by the instructors. The students focused on decision-making situations, how decisions were made, the thoughts during the making of the decisions, questions raised, … whereas the instructors gave feedback. These were regarded to be indicators of self-confidence and inquisitiveness.

Using qualitative analyses, Iranfar et al. (2012) concluded that an organized discussion for 45 minutes between nursing students on a collaborative task had a positive influence on their inquisitiveness. The first 30 minutes students had to discuss the questions within their groups to reach a consensus on the answers. Afterwards, a solution sheet was distributed and participants discussed their answers within groups for another 15 minutes.

Cognitive maturity

In a study comparing epistemological beliefs and versatility within changing situations (Roex, Degryse, & Clarebout, 2011), it was found that more sophisticated beliefs on the justification for knowing do not lead to a greater ability to respond to changing situational demands. The authors suggest that maybe appropriate knowledge (especially the way their knowledge base is organized) is necessary to demonstrate high levels of cognitive flexibility.

Combinations of skills and dispositions

In their review, Lee et al. (2016) compared two studies using CCTST (measuring critical thinking skills) and two studies using CCTDI (measuring critical thinking dispositions) and found a significant effect of concept mapping on critical thinking development of nursing students.

The effect of reflective writing interventions for nursing students was discussed by Naber and Wyatt (2014). Students had to report six times on what they had learned during a learning activity (class readings, clinical rotations or group activities). Students had to think of data and observations, inferences and interpretations, application of concepts learned, about their pre-existing assumptions, consequences for themselves and the others and on their point of view. Following the intervention, no differences were found in total CCTST and CCTDI scores (as well for control as experimental group). However, a positive significant difference was found on the subscale for the disposition of truth seeking.

Use of counterintuitive exercises or examples help students to use and question their prior knowledge and to become deeper thinkers. Larsson and Tibell (2015) made biology students think by initiating cognitive conflict using a tangible model (demonstrating a self-assembly process of a virus). This helped to make better inferences and also stimulated open-mindedness and analyticity.

Vignette 4: UTAD, Portugal, Sport Science, Rehabilitation

A 'Motor learning' course of a second year Sports Science degree with 165 students is divided into a practical and theoretical component. The practical component consists of interactive methodologies and group work tasks. Changes were made in the theoretical lessons in order to focus on the development of critical thinking. In the redesign the following critical thinking skills were aimed at: analysis, evaluation, and self-regulation. Moreover, the following critical thinking dispositions were targeted: truth-seeking, open-mindedness and cognitive maturity.

The changes entailed the introduction of topics using videos, news and authentic situations and/or real-life examples of athletes. The presented situations were analyzed in group discussions properly guided by the teacher. However, whenever necessary, a systematization of knowledge was carried out through a brief theoretical exposition. The jigsaw method was used were students discuss a topic in a small group and the groups discuss different topics. After this first round, participants from different groups come together in new groups to exchange (as experts) what they have learned from the first group.

The teacher observed that students' retention and learning related to the topic was much higher. Implementation of the jigsaw during the initial classes was crucial because it triggered a more critical behavior in students during the following learning activities/topics. Students asked more questions during the teaching, and they connected the learning topics with practical situations related to their past and future experiences within the sports context. The different debate situations have also contributed to support argumentation, making connections and analysis.

Students were evaluated through a variety of activities, including a written test, a portfolio and an infographic. The students had to make a portfolio, in which they summarized the information regarding each theoretical and practical class, in the form of a concept map. Through the creation of an infographic, students had to look for research on a learning topic, and summarize it in a graphic. In that way students selected the most pertinent information within a topic, and it allowed them to relate it in a more critical way. All these aspects of the course were highlighted by students as elements to be kept in the future.

Vignette 4 – UTAD, Portugal, Sport Science, Rehabilitation

Conclusion

In this chapter research on interventions in the field of biomedical sciences were discussed. In general, empirical evidence is rather scarce. However, for particular interventions (e.g., concept maps) more than one study was found (Lee et al., 2016; Yue et al., 2017). Although the selection of the studies was rigorous, it remains the

case that a lot of studies have methodological flaws (e.g., no measurement of prior knowledge or other control variables).

Even considering methodological flaws, the following might be concluded:

- Concept maps seem to be a useful tool to stimulate critical thinking skills and dispositions in the domain of biomedical sciences: overall, effects were rather positive for both critical thinking skills and dispositions. Most studies indicated that concept maps can make a difference in CT by stimulating students to discover relationships (Daley et al., 1999; Gerdeman et al., 2013; Tiwari et al. 2006 in Lee et al., 2016; Yue et al., 2017; Zhang et al., 2017).

- Problem-based learning (Dehkordi & Heydarnejad, 2008; Lee et al., 2016) is not powerful enough to systematically enhance critical thinking skills. On the other hand, PBL can make a difference for all the critical thinking dispositions provided it is combined with metacognitive strategies that help students to reflect on their own learning approach and process. Furthermore, discussing implications of results or engaging in classroom discussions within a group or between groups might positively impact on the development of all critical thinking skills (Dowd et al. 2018; Hayes & Devitt, 2008).

In biomedical sciences, concept maps, problem-based learning with metacognitive strategies, scientific writing, why-questions, and well-designed/explicit tasks seem to be useful tools to stimulate critical thinking.

- Scientific writing, deconstructing research, questioning given information by asking why-questions or by searching justifications and/or argumentations are good ways to develop certain critical thinking skills (evaluation, analysis, inference and explanation) or critical thinking-dispositions (open mindedness and analyticity) (Abdullah et al., 2015; Anderson et al., 2001; Dowd et al., 2018; Kellum et al., 2000; Larsson & Tibell, 2015; Wass et al., 2011).

- Well-designed tasks in which students' learning is scaffolded by explicitly described steps (Dreifuerst et al., 2012; Wolpaw et al., 2009) or embedding reflection moments in the learning process (Moulton et al., 2010; Naber & Wyatt, 2014; Sedlak et al., 2003; Zhang et al., 2017) are beneficial for the development of self-regulation, truth seeking, self-confidence and inquisitiveness.

Designing for critical thinking in the STEM domain

In this section an overview is presented on methods, approaches to foster aspects of critical thinking based on an analysis of 20 papers studying aspects of critical thinking in the STEM domain. The papers have mixed profiles: 7 papers relate to education into STEM-discipline[3], 5 to biology related disciplines, 3 to chemistry, 3 to mathematics or statistics and 2 to technology.

Skills

General

Wass et al. (2011)[4] argue that participating in research activities and conversations with teachers might stimulate critical thinking. In this longitudinal study, undergraduate zoology students were studied over a three-year period. The researchers highlight the following considerations when it comes to stimulating critical thinking:

- Learning through research can cause a shift in students' view of knowledge: from knowledge as something incontestable to epistemological uncertainty.
- Effective critical thinking teaching allows students to struggle and thus think for themselves.
- Teacher conversations (and thus improved access to teaching staff) are important to foster critical thinking as they induce students to explore their understanding at a deeper level.
- Teachers have to serve as role models.
- Teachers must have the skill to diagnose student learning and needs before taking appropriate and differentiated action (in contrast with first year: students as one large cohort).
- Peer interaction seems to be limited in impact: limited to affirmation and simple compromise instead of a robust challenge of ideas.
- A shift from 'self' to a more collaborative environment is needed; also, an investment from the student into the learning process of the group/peers is needed (willingness to take responsibility).

For a broad set of skills, working in groups to deconstruct papers is experienced by students (undergraduate biology and medicine majors) to be helpful in developing critical thinking-skills such as interpretation, analysis, inference and evaluation

[3] This may result in some overlap between the sections in this chapter as the relationship between disciplines and fields is not unilateral.
[4] Given that zoology can be categorised in multiple fields, this information is repeated in the section on the biomedical domain. This also applies to other studies in this section.

(Abdullah et al., 2015). Students go through a full cycle of paper deconstruction by explaining terminology and methods, by analysing experiments, by discussion of data and presenting results, by discussion author's conclusions. Finally, they write a follow up experiment. In this study, students were intensively coached through at least four papers during a longer period of about 10 weeks.

Analysis

Neilens, Handley and Newstead (2009) demonstrated that training analytic strategies (reasoning rules) increased students' analytic responses on reasoning problems (in statistics) and eliminated bias. This kind of training helps to evaluate a problem. They make students aware of how beliefs guide their responses and of the importance of learning in suppressing irrelevant or wrong beliefs when making judgements. The emphasis was on the importance for students to explicitly reflect on their evaluation of arguments and not to formulate a rapid judgement as merely rating the credibility of an argument. Offering students everyday problems where the conclusion is inconsistent with their beliefs/goals activated the use of analytic strategies. On the other hand, realistic content made analysing and evaluating the credibility of an argument difficult. In this case the responses depended on pre-activated knowledge structures.

Use of counterintuitive exercises or examples helps students to use and question their prior knowledge and to become deeper thinkers. Larsson and Tibell (2015) made biology students think by initiating cognitive conflict using a tangible model (demonstrating a self-assembly process of a virus).

Bravo et al. (2016) could improve data analysis skills (like convert data to graphical representations, interpret graphical information, or draw conclusions based on the analysis of data) over one semester with interventions like providing assessment rubrics for several classroom assignments and for student self-reflection.

Inference

Dowd et al. (2018) found a strong positive correlation between the inference (as a factor of the CCTST) and some of the dimensions they used to assess undergraduate theses of biology students. The dimensions focused on the scientific reasoning regarding the appropriateness for the audience, argumentation of the significance, articulation of the goals, interpretation of the results and discussion of implications. By using the inference skill, students focus on drawing conclusions from reasons and evidence. These results suggest that scientific writing tasks may help to develop and demonstrate the critical thinking-skill of inference.

Vignette 5: UTAD, Portugal, Mechanical Engineering

In the first-year course on Industrial Management, students (about 30) not only acquired knowledge but were challenged to develop critical and creative thinking. More specifically all critical thinking skills were addressed, namely analysis, inference, evaluation, explanation, and self-regulation, as well as the following critical thinking dispositions: open-mindedness, inquisitiveness and self-confidence.

In the first sessions, the teacher presented through dialogue and discussion what critical thinking is. Students, in groups, prepared answers (in a public presentation) to thematic questions through research assignments and resources' analysis with the use of FRISCO guidelines (Ennis, 1996). This work resulted in a personal concept map.

A newly introduced component was a group assignment on the theme of 'industrial waste'. As a member of a cooperative group (4-6 students), each student had to explore a research sub question about one particular sector of industry (i.e., aero spatial, textile, automobile). Students were supported by sessions moderated by the teacher and a library technician, making explicit the critical thinking, questioning and digital literacy skills using the FRISCO guidelines. Students engaged in a cooperative learning method known as "jigsaw", resulting in "expert" groups (i.e., all the students who had analyzed textile sector) in which students had the opportunity to interact with all the "expert" students of the other groups, finding through questioning and discussion an answer to the research question. Next to the group work students were asked to analyze weekly a recent newspaper article (using the FRISCO guidelines) about industrial management. Students were randomly assigned at the beginning of each lesson to present their readings and analysis on this task.

The teacher identified through the evaluation of the concept maps improvement in students' interpretation, analysis and evaluation of the consulted information. The jigsaw approach contributed to the improvement of students' questioning skills; it helped them to be more curious and motivated them to search for more information towards a deeper knowledge to better answer their questions. The students appreciated the interactivity of the lessons, the cooperative approach (jigsaw and group assignment) because the debate and discussion motivated them and promoted their critical thinking.

Vignette 5 – UTAD, Portugal, Mechanical Engineering

Evaluation

Using explicit models integrated into an electronic tool helps to make better decisions (Kert, Uz, & Gecü, 2014). Teachers need to be explicit about the strategies or principles used to make decisions and to refer to the theoretical origins of the principles used.

Self-regulation

Talanquer (2017) showed that promoting metacognitive awareness helped chemistry and engineering students to boost their performance in (multiple choice) knowledge tests. This was achieved by a prompt that asked students to predict the wrong answers that would be most commonly selected by unreflective students (filling in the same test). Reflecting about possible wrong answers activated self-regulation and analytical reasoning because the students experienced metacognitive conflict and were alerted to heuristic reasoning biases. Students performed better when they ranked their confidence level on each answer and then invested time reflecting on and revising those responses on which they had low confidence. Students who received the prompt and engaged in prediction were found to perform statistically better than the control group. It is hypothesized that the prompts results in more deliberate reflections.

Pilegard and Mayer (2015) presented slides (on how solar cells work) in teaching. Afterwards, students were asked to self-report their understanding of the slides (from very poor to very good) in response to the question "*Please reflect on your understanding of the slides you just viewed. How well do you understand [topic]?*" or "*Please reflect on your memory of the slides you just viewed. How well do you remember [topic]?*" (Pilegard & Mayer, 2015, p. 65). The correlation between the self-report and the performance was higher when students were prompted to judge their own understanding rather than judging their retention (memory) (Pilegard & Mayer, 2015). Adding to the study material prompts that focus on the highest level of learning seems to be a good way to induce specific types of (metacognitive) processing and these might help students to perform better on tests.

Introducing metacognitive strategies in combination with discussing and reflecting on students' work seem very positive to stimulate creativity (Hargrove, 2013). Students (from architecture and design disciplines) attended seminars introducing creative thinking strategies and metacognitive strategies to build a creative knowledge base. Attention was paid to knowledge as well as to the use of strategies. The framework used contained: preparing and planning, selecting and using strategies, monitoring strategy use, orchestrating various strategies, evaluating strategy use. There was direct instruction as well as paired problem solving, journal keeping, studying of case studies and designing through models. On top of that students were encouraged to use and follow blogs where they discussed and reflected on their work as well. For teachers it seems important to identify (considering the educational literature) what strategies will be most effective, to be explicit about their expectations and the strategies to use. It seems important that students are allowed to exercise on these by creating a learning environment over a longer period of time.

In a similar way, Bielaczyck, Pirolli and Brown (1995) introduced successfully two self-regulation strategies: monitoring comprehension and clarifying and addressing comprehension failures. Their approach increased the use of self-regulation strategies by students (with at least one semester of college-level calculus). The strategies were made explicit and closely connected to concrete tasks. Teachers modelled what was expected and gradual faded their feedback. Lin, Wen, Jou and Wu (2014) had teachers develop a web application to facilitate reflective learning activities after school in a product design course. Students working with the web application displayed higher learning motivation and reflection performance.

Vignette 6: University of Thessaly, Greece, Wood and Furniture Design and Technology

In the third bachelor of the program 'Wood and furniture design and technology', the course (20 students) 'Quality Control of Furniture' was revised in view of developing the following CT skills: analysis, inference, evaluation and explanation, and the CT dispositions: open-mindedness, analyticity, systematicity and self-confidence.

In the course, the quality control of wood-based panels is discussed. This implies the meaning of quality control, the context (European, world-wide) in which it happens, as well as different approaches and techniques. In the revision the content has remained identical. The changes pertain to the focus on the activities of the students who now have to use information that is provided to retrieve the main problems in defective materials. The approach is characterized by ample examples of quality products and defected products on the one hand and intensive activity by the students on the other.

The teacher perceives increased participation by the students as a major change. They started to discuss between them on the questions and the problems they had to solve. The teacher would like to further invest in more analytical descriptions, increased awareness about the need for doing tests and – in order to increase understanding – more easy examples from nature. The teacher recognizes the need for sufficient discussion time amongst students.

Students value the more active and energetic approach. They want to be involved and share their ideas. It helps them to think more deeply and better understand the relevance of particular approaches to control the quality.

Vignette 6 – University of Thessaly, Greece, Wood and Furniture Design and Technology

Dispositions

General

Inquiry-based learning had no significant different effect on the development of critical thinking dispositions compared to teaching methods that focused more on explaining, questioning and discussion (Arsal, 2017).

Solving problems in itself does not develop critical thinking dispositions. The development of critical thinking dispositions can be promoted when teachers combine problem solving with metacognitive coaching by asking students (from a computer and educational teaching department) questions that refer to understanding, finding relations, and making strategic or reflection questions (Akyuz et al., 2015). Also asking self-regulation questions like: "What are you doing now?", "Why?", "Will this way work?", "Could another way be used?" may help to develop all critical thinking dispositions.

In the context of information technology and mechanical engineering, Ding (2016) found that a problem-based learning approach could make a difference in the development of all critical thinking dispositions. The instructional approach used did not only include problem definition, hypothesis proposition, independent inquiry, but also included group negotiation, and self-reflection. It is assumed that adding those strategic and reflective steps might have a positive effect. In another study (Eren & Akinoglu, 2013) using a more traditional approach of problem-based learning (introduction of a problem situation, obtaining and exchanging information, making a report on the solution) only the development of the critical thinking dispositions of inquisitiveness and systematicity were positively affected.

Didem (2017) investigated the development of critical thinking dispositions of students in online communities (pre-service teachers in science and mathematics) during their internships. Students shared diaries and as evidenced by the qualitative analyses, exchanging their views fostered self-confidence and open-mindedness. However, these open interactive communities did not foster the development of analyticity, truth-seeking, inquisitiveness, and systematicity.

Vignette 7: KULeuven, Belgium, Engineering Technology

In a course "Mass and heat transfer (incl. balances)" in a bachelor program (~ 50 students), a number of new strategies were implemented with the intention to develop the following CT-skills: interpretation, inference, explanation and self-regulation, and promote these CT-dispositions: analyticity, self-confidence and inquisitiveness.

The overall approach of the course is explanation of theory with link to applications (for some chapters theory is introduced by the application), followed by practice with exercises. For these exercises the approach would be typically as follows: example followed by exercises by students; for the latter the teacher would give some time to think, then explain the strategy on the blackboard.

The "lecturer's demonstration on the blackboard for each exercise" was guided by an "cognitive modeling" method by paying specific attention to the following aspects: (a) students worked on 'interpretation' of the problem by drawing schemes and by focusing on visualization of the problem before starting to calculate; (b) the lecturer gave 'wrong' solutions and had students find the mistakes; (c) students teacher – students pairs were made; the lecturer gave the solution to the student teachers and they had to explain this to their fellow student (reciprocal peer teaching); (d) the lecturer encouraged students to compare different solutions to the same problem; (e) the out the problem solving thinking process for some examples, including also the looking forward (what could the answer be approximately) and looking back (is this answer correct, why do I think so), and (f) theory lessons started with applications requiring ample knowledge provided during the session (revealing knowledge gap).

The lecturer had the impression that some students liked this new approach and were very active. Some other students felt uncomfortable. A lack of self-confidence and inquisitiveness became clear. After a while, focus on visualization of a problem gave some students verbally expressed to lecturer that they felt more self-confidence for the more difficult questions. Lecturer asked more questions on the exam that required more independent thinking, but with the exam results, it seemed that one course was not enough to really make a difference (hence the exam was perceived as being quite difficult by the students). Even more attention is needed to show critical thinking in examples.

Students appreciated examples with critical reflection on the results, the discussions among students and between students and the teacher, and sufficient time to think. At the same time, they require more guidance in exercises (dealing with confusion of different solutions) and asking effective way to make the reciprocal peer teaching more effective (e.g., some of the 'student-teachers' could not answer to the questions of the other student).

Vignette 7 – KULeuven, Belgium, Engineering Technology

Combinations of skills and dispositions

Nussbaum, Sinatra and Poliquin (2008) demonstrated that argumentation can be taught by creating a learning environment that provides an opportunity for students to engage in dialogic discourse around a scientific phenomenon. What makes a difference is giving students both written information about constructing an effective scientific argument and argumentation criteria (with an example case to demonstrate how these criteria can be used to judge arguments). This approach facilitates students' consideration of evidence and alternative(s) or even opposing points of view, which in turn create greater opportunities for conceptual development. Suggestions were: "relate two variables", "describe a causal mechanism", "make claims that are

supported by 'facts'", "account for all facts", "search for counterexamples", and "consider alternative theories". It is important to enhance students' willingness to be critical of scientific theories as well as their awareness of inconsistencies in their own thinking. Instruction in argumentation (e.g., reading an instructional text) and the development of students' epistemic beliefs might help students become more critical and interactive. Students with the most developed epistemic beliefs (truth depends on the evaluation of evidence) outperformed the other students.

Vignette 8: University of Western Macedonia, Greece, Science Education

In the third bachelor of the teacher education program the course (45 students) on Pedagogical content knowledge in science education was traditionally an expository course with ample explanations and demonstrations, leaving the PCK concept largely implicit. In order to stimulate the development of CT in general, the new course explicitly teaches the three components of PCK (pedagogy, content, and context). An innovative interdisciplinary science content, Nanotechnology, is used to provoke students' interest. In the content of nanotechnological experiments and its everyday applications, primary student-teachers were invited to recognize the fire-up questions that support critical thinking development. In addition, they were asked to design a task, namely several science experiments including the fire-up questions for each activity and the related critical thinking skills and dispositions. For the evaluation primary teacher education students present during a university day on CT, their science experiments to their fellows explaining the fire-up questions, and what kind of skills and dispositions would like to develop through their experiments. Students have understood the importance of the fire-up questions and have been wondering about their importance.

The teacher indicates that a reflective introduction of the notion of CT as well as the discussion of the notion in the context of innovative scientific content are important features. The use of concrete experiments is certainly worthwhile. More examples of fire-up questions could be given in order to reveal the difference between common questions and fire-up questions. A further development might be the introduction of inquiry teaching methods.

Students also like the examples of fire-up questions, the innovative content, the experiments and the explicit focus on CT. They ask for even better communication, more examples and more elaborate discussion of CT skills and dispositions.

It is recognized that the impact on CT would be greater when more courses, over a longer period of time would pay explicit attention to CT.

Vignette 8 – University of Western Macedonia, Greece, Science Education

Conclusion

In this section, interventions are discussed in the field of STEM. In general, it was observed that the empirical evidence is rather scarce. For particular instructional methods or particular critical thinking skills or dispositions more than one study were found. While articles for this section were selected rigorously, it is obvious that there are methodological flaws in multiple studies (e.g., no measurement of prior knowledge or other control variables).

Nevertheless, taking everything together and with due caution, the following can be concluded:

- Involving students in research activities or discussing research with students is a worthwhile effort as the process facilitates the development of critical thinking skills (Abdullah et al., 2015; Dowd et al., 2018; Wass et al., 2011).

- Being explicit to students about the learning goals seems to be essential (Bravo et al., 2016; Kert et al., 2014; Neilens et al., 2009; Nussbaum et al., 2008). It can be operationalized by organizing specific trainings to emphasize particular analytic approaches, by giving students the assessment criteria or by modelling the cognitive thinking processes expected from students. All these could help develop critical thinking skills such as analysis, inference and evaluation.

- To develop self-regulation, it seems to be important that teachers foster metacognitive activities (Bielaczyck et al., 1995; Hargrove et al., 2013; Lin et al., 2014; Talanquer, 2017). Teachers can identify what skills students need (planning, monitoring comprehension, predicting wrong answers, orienting, self-judging, clarifying, …) and be explicit about their expectations and the strategies they want their students to use. Allowing students to exercise these strategies by embedding their training in a well-designed learning environment and by letting students exercise over a longer period of time (semester or year) with appropriate tasks, while modelling expected behavior and fading support seem to be beneficial for critical thinking development.

In STEM, research, metacognitive activities and explicitness of the learning goals can be essential to develop critical thinking.

- Problem-based learning on its own does not seem powerful enough to enhance critical thinking dispositions. It can be combined with metacognitive strategies that help students to reflect on their own problem-solving approach and learning processes (Akyuz et al., 2015; Ding et al., 2016; Eren & Akinoglu, 2013).

Designing for critical thinking in social sciences and humanities

In this section an overview is presented on methods, approaches to foster aspects of critical thinking based on an analysis of 30 papers studying aspects of critical thinking in the domains of social sciences and humanities. Given that only three empirical intervention studies on (elements of) critical thinking were found in the field of humanities, that field was integrated with the field of social sciences.

Skills

General

Irrespective of the specific cognitive skill, the following strategies seem to work in developing critical thinking skills in the domains of social sciences and humanities.

Guided writing tasks, with specific focus on critical thinking skills, provide opportunities for the development of critical thinking skills. Vardi (2012) gave students a critical writing task along with a description of requirements for the paper (breadth and depth of coverage; critical thinking (analysis and evaluation), and language conventions) and examples of excellent papers. During a one-hour workshop students deconstructed the examples in relation to the evaluation criteria. This helped them to fully understand the criteria. Students scored higher on the post-test measuring analysis, interpretation and evaluation in comparison to the pre-test.

Argumentation skills can be developed when students receive specific instruction on argumentation models (such as the Toulmin model, the three phases of Björk and Räisänen) and learn to apply them in realistic problem situations (Cho & Jonassen, 2002; Heijltjes, van Gog, Leppink, & Paas, 2015; Marttunen & Laurinen, 2001; Villarroel, Felton, & Garcia-Mila, 2016). The learning environment as well as the task characteristics affect the kind of learning. Cho and Jonassen (2002) showed that argumentation skills are positively influenced by ill-structured problem-solving tasks supported by an argumentation scaffold. The argumentation scaffold used in their study is a constraint-based tool, Belvedere, that supports students to structure their discussions and make use of the Toulmin model. Groups working with ill-structured problems produced more arguments than groups working with a well-structured problem and the groups working with an argumentation scaffold tool produced more problem-oriented comments than groups working with a mere note-supporting tool. In a similar vein, Villarroel et al. (2016) showed that an argumentation task directed towards consensus better mitigates the effects of argumentation bias than a similar task directed to persuasion. Students in the consensus condition could better read disconfirming information than students in a condition where they had to persuade another person. Students in the consensus condition made better use of graphs, referred more to their own and partner's positions and to statements in the dialogues. Marttunen and Laurinen (2001) also studied an argumentation course. Their course included argumentation exercises, either entirely face-to-face, either by email accompanied by two face to face lectures (one at the beginning of the course and one in the middle) about argumentation models and argumentation analysis. These exercises had a positive influence on students' argumentation skills. The learning environments affected the precise argumentation skills: face-to-face discussions seemed to support the skill to provide counterarguments, while the email group learned more in terms of identifying and selecting relevant arguments. Heijltjes and her colleagues (2015) made their first-year students read a text on critical thinking and made them also practice specific skills in the experimental condition. In the control condition where students did not practice the specific reasoning skills, they had to underline and encircle relevant parts, with a maximum number of selected words. This underline-exercise had similar effects on critical thinking as the practice. This seems to indicate that time-on-task is also an important factor for critical thinking.

In general, it seems that critical thinking skills can be developed by combining explanations about critical thinking and exercises on critical thinking. The 'explanation about thinking' can take different forms, e.g., thinking hats of De Bono (1987) (Belluigi & Cundill, 2017), the 4-question technique developed by Dietz-Uhler and Lanter (2009) (Alexander, Commander, Greenberg, & Ward, 2010), or by an infusion/immersion/general approach (Angeli & Valanides, 2009). Belluigi and Cundill (2017) developed inquiry learning environments where students received instruction about the thinking hats and practiced thinking using a socratic method with positive effects. Alexander and her colleagues (2010) used guided online discussions with their students. Prior to the online discussion, students had to read a case study about applying educational psychology and to complete the four-question technique: (1) analyse what was learned from the case study, (2) reflect on the concepts and theories addressed in the case study, (3) relate the concepts to one's life, work, study, and (4) generate questions that arose from reading the case study. They found that students improved their critical thinking skills (measured by the Washington State University Critical and Integrative Thinking Scale, WSUCITS, 2006). In the study of Angeli and Valanides (2009) students worked in dyad and discussed about a specific topic: the influence of mass media on American culture. They were divided according to four conditions. In the general condition students followed a lecture about critical thinking, discussed the topic and had to prepare an outline for a paper on that issue. In the infusion condition, students started with a discussion and a reflection on their thinking, followed by a short lecture about critical thinking and a dialogue with the lecturer. Next, students could complete the outline of their paper. In the immersion approach students started with a discussion and drafting an outline of their paper, followed by a reflection on their thinking (i.e. similar to the infusion approach). Students then engaged in a socratic questioning session with the lecturer after which they completed the outline. In the control group, students simply prepared an outline of their paper. Students in the control and general condition scored lower on critical thinking skills performance than students in the infusion and immersion conditions. The understanding of critical thinking was the lowest in the control condition and highest in the infusion condition. Furthermore, Ghabanchi and Behrooznia (2014) argue that brainstorming might have a positive effect on critical thinking skills and Zambrano, Quevedo, and Portilla (2012) argue the same for socratic discussion.

Vignette 9: USC, Spain, Teacher Education

In the third year of the primary pre-service teacher education program a course (18 students) on socio-scientific issues was redesigned in view of supporting the development of interpretation and analysis as CT skills and truth-seeking, open-mindedness, analyticity and self-confidence as CT dispositions.

A rather theoretical course was re-focused by putting issues at the core. For each issue the theoretical knowledge was analyzed from different perspectives with ample involvement of students. For example, in the lesson about nutrition students were engaged in discussions about the use of different products such as glutamate or palm oil in processed food, and in searching information to investigate why there is a controversy about these products and why they are considered harmful to our health.

The teacher assesses that students have become more motivated as was shown in greater involvement in the task, more questions and discussions as well as a deeper analysis of the information in view of better arguments. In order to be successful, students need sufficient time to study the information. Sufficient time is also needed for the discussions of the topics. Students may have more ownership if topics for discussion can be self-selected as soon as sufficient self-confidence has been developed. A further strengthening might involve paying even more explicit attention to CT and what it implies.

Students understand well that analyzing information that stems from different sources is essential to deeply understand an issue. By engaging in the analysis and interpretation of relevant information they become more aware about the controversial nature of some socio-scientific issues. Students would like even more structured discussions and sufficient time to process the scientific information. Students have a preference for issues dealing with environmental problems.

Vignette 9 – USC, Spain, Teacher Education

Analysis

The use of writing and rewriting assignments is helpful to develop analysis and evaluation skills of students, especially when students can use a scoring rubric to improve their writing (Schamber & Mahoney, 2006; Sin, Jones & Petocz, 2007). The students in Schamber and Mahoney's (2006) study were involved in group writing. This rewriting resulted in significantly higher scores on group critical thinking skills.

A series of well-designed writing tasks accompanied with good preparation and feedback helped to improve students' analysis skills (Sin, Jones & Petocz, 2007). Sin and her colleagues did a one semester course for first year students in accountancy. Throughout the semester students had three accounting-based assignments of 1 page with increasing complexity. Every assignment started with an explanation on the criteria for that assignment during a lecture. The students then had to do some writing exercises in order to prepare them for the assignment. The extent of the support of the scaffolds was reduced over the three assignments. Before handing in, the students had to self-assess their assignment using the received criteria. Students improved across the three assignments. The results of the second and third assignment were positively correlated with the final knowledge-based exam. Students gradually made better self-assessments: the overrating diminished over time. In general, using scoring rubrics or giving information on evaluation criteria helps students to improve their work (Brown, Afflerbach, & Croninger, 2014). Similarly, the breadth and depth of task analysis can be improved with practice accompanied with clear instructions about the expectations e.g., explanation of the expected steps, diagram action or concept map (Adems, Rogers, & Fisk, 2013).

Inference

Information problem-solving where inference and evaluation are needed, can be developed when students learn about the model with different steps in the problem-solving process with additional support on applying the different steps (Frerejean, van Stien, Kirschner, & Brand-Gruwel, 2016). Given findings in the research on media comparisons, the specific approaches to deliver additional support are of minor importance.

To stimulate inference, the use of explicit strategy instruction seems to be helpful compared to simply asking students to read text for comprehension (Horiba, 2000; Nahatame, 2014). In a study of Nahatame (2014), predictive inference is investigated during second language reading with a focus on explicit strategy instructions, compared to a more general instruction to read the text for comprehension. More particularly, students in the experimental group were given the instruction to anticipate the outcome of the events described in the text. The results show that inferences were generated during reading only when explicit instruction was given, without impairing the comprehension of the text, although in both conditions the text contained a possible inference. The same conclusion was drawn from other research (Horiba, 2000) in which students who were given the instruction to read for coherence generated more (backward and forward) inferences than those in the read-freely condition. Finally, in the theoretical framework of both studies a description is made of other factors influencing the development of inference making, like the readers' working memory, the degree to which the text that is being used allows for inference making, as well as the questions being asked to the students.

Evaluation

Realistic cases where students have to take ethical decisions supported by an online tool that prompts reflection, seems to be beneficial for the quality of ethical decisions (Kert et al., 2014). The online tool appears to be an important feature in the learning environment because the students who were able to use the prompting tool outperformed the students who could not use the tool, even though students received similar teaching and practice opportunities.

Self-regulation

Explicit training with regular feedback on metacognition and self-regulation helps to develop self-regulation skills (Cho & Cho, 2013). Students who got no training in self-regulation performed less self-regulation activities than students who received the training and, in contrast to the experimental group, they did not show a growth in self-perceived metacognitive skills. Asking regularly a simple question such as 'what are

you thinking to complete your project' is a good way to activate self-regulation in students.

Training on self-regulation in an authentic learning environment helps to develop self-regulation (Masui & De Corte, 1999). In an ecologically valid intervention, students worked on cause attribution and reflection over the course of four sessions. The intervention was based on the general principles of powerful learning environments. Students were asked to reflect and discuss their reflection with peers during assignments. After the sessions, students showed more reflective behaviour, made more constructive attributions and their study results improved, in comparison to a control group in which students did not receive similar training.

Vignette 10: Mykolas Romeris University, Lithuania, Career Management

Students (N=18) in the first master year of the 'Management of Education Technologies, Career Management' program follow a course on 'Methodology of Education Research'. The course focuses on interpretation, analysis, inference, evaluation as CT skills and on open-mindedness, analyticity, systematicity, and cognitive maturity as CT dispositions.

Classically the course discusses epistemological, ethical, juridical and methodological principles of social sciences research. Furthermore, the conception of educational research, as well as different types of research and the variety of research objects are presented. The research cycle for both quantitative and qualitative approaches including data analysis, structure of research projects, and presentation requirements are dealt with. In view of strengthening the support of CT a new topic 'interpretation of data' was introduced. Theory was interrelated with students' practical tasks. Master students developed and completed a pilot study, interpreted and presented their findings. They also made inferences and formulated suggestions for further research. The presentations of the different studies were discussed with the entire group of students.

The teacher has noticed a more attentive attitude towards master thesis development, more efforts to understand the essentials of doing research and an alignment of individual tasks and thesis research topic. The teacher will continue to focus on CT development. The alignment between tasks and thesis research topics helps as it makes the course more personally and professionally relevant. The presentation and discussion of the pilot studies are an interesting method to foster CT development. Further strengthening the link between tasks and master research, more cases and examples to clarify the difference between quantitative and qualitative research and a more critical evaluation of data may help to increase the impact on CT of the course. Given the characteristics of the student group, the course will be moved to the second year.

Students especially liked the discussions and analyses of the research papers of other students. They would like to get less theory and would prefer a stronger alignment between tasks and work for the master thesis.

Vignette 10 – Mykolas Romeris University, Lithuania, Career Management

Dispositions

General

Investing in the development of critical thinking-disposition is valuable, not only because critical thinking-dispositions are highly valued personal characteristics but they also have effects on other aspects of learning and studying. Critical thinking dispositions are positively related to grade point average (Stupnisky, Renaud, Daniels, Hayens, & Perry, 2018). Inquisitiveness in combination with cognitive aptitude also has an impact on student learning (Fry, 1972). While students with high aptitude and a high level of inquisitiveness learn most under a high level of student control, it is not the case for students with a lower aptitude or lower levels of inquisitiveness. Open-

mindedness is a positive predictor of students' reasoning skills (Heijltjes, van Gog, Leppink, & Paas, 2014; Heijltjes et al., 2015).

Stupnisky et al. (2008) argue that in general a learning environment that allows or stimulates academic control might stimulate critical thinking dispositions. Ding (2016) illustrated that problem-based learning settings might provide that type of learning environment. He found a positive effect of a problem-based learning setting on the development of critical thinking dispositions, as measured with an adapted version of the CCTDI. Eren and Akinoglu (2013) found that PBL had a positive effect on inquisitiveness and systematicity but not on analyticity, open mindedness, self-confidence and truth seeking. Temel (2014) used the same instrument (CCTDI) as Ding but could not retrieve – for development of critical thinking dispositions - a major difference between traditional and PBL environments.

Problems solving in combination with metacognitive coaching seems supportive for the growth in critical thinking dispositions (Akyüz et al., 2015). Student who received metacognitive support from their teacher while working on a problem in groups developed their critical thinking disposition significantly. The control group, where the teacher did not intervene with the group discussion, did not develop their critical thinking dispositions during the interventions. The questions the teacher asked were Understanding Questions, Relation Questions, Strategic Questions, and Reflection Questions, based on the IMPROVE method (see: Mevarech & Kramarski, 1997).

Cross cultural learning tasks can be supportive for the development of critical thinking dispositions (Harrigan & Vincenti, 2004). Previous involvement in a course on diversity was found to be a positive predictor of student overall critical thinking dispositions and specifically on student self-confidence (Laird, 2005).

An inquiry-oriented learning experience can be helpful to develop critical thinking dispositions. Zeki (2017) compared the impact of two different environments on students' development of critical thinking dispositions. In the inquiry learning condition students had to follow five main phases: (1) orienting and asking questions, (2) hypothesis generation, (3) integration, (4) analysis and interpretation and (5) conclusion and evaluation. In the control condition students didn't conduct inquiry learning. Although the experimental group significantly increased their critical thinking dispositions, they did not outperform the control group. Developing dispositions via inquiry learning may need to consider the target group's scientific ability. Teaching specific skills (e.g., science inquiry skills) to a target group who have low ability on the target skills may not automatically improve their critical thinking dispositions.

Another way to stimulate critical thinking dispositions seems to be repeated interpersonal controversies using moral dilemmas. Especially cognitive perspective-taking (open-mindedness) and information-seeking behavior (curiosity) were found to be affected (Tjosvold & Johnson, 1978).

Vignette 11: University Colleges Leuven-Limburg, Belgium, Office management

As part of a course on project management first year students in office management had to learn using a specific software tool for project management. Because the tool was not often used in practice, the lessons were adapted. In four newly developed lessons students could trial different software tools for project management. The lessons aimed at developing several critical thinking skills and dispositions (interpretation, analysis, self-regulation, open-mindedness, analyticity, systematicity and inquisitiveness), with the intention that students would be able to explore different tools and decide which tool they would use for a specific purpose.

Each lesson focused on a specific aspect of project management (time management, concept pitch, planning, events). Different teaching methods were used such as think- pair-share, speed-dating, self-regulation prompts, guided independent work (look for examples, look at a tutorial, answer question and use the tool for a short assignment) and feedback on the assignment.

The newly developed lessons were appreciated by the teacher and the students. The next time the teacher gives these lessons she will adapt these so as to further stimulate critical thinking. She will discuss her expectations on critical thinking in the first lesson, instead of during the feedback at the end of the lessons. This will be accompanied with the rubric she will use to score the assignments and with hint-questions in order to deepen the analysis students make. In addition, she will stipulate that students use the tools in the remainder of the course (and beyond), in order to make students realise the value of the tools for their future careers and for organising their work as a student (e.g., time management).

Vignette 11 - University Colleges Leuven-Limburg, Belgium, Office management

Truth-seeking

Vardi (2012) demonstrated that a focus on intellectual engagement is more beneficial for the development of truth-seeking than a focus on academic integrity is. A context that allows students to take a critical position and talk with an authorial voice is supportive for developing the disposition on truth-seeking.

Blended learning is helpful for the development of critical thinking dispositions, especially open-mindedness and truth seeking (Korkmaz & Karakus, 2009). In the experimental condition different methods were used: website, visuals, animations, online learning, bidirectional communication. Students in the control group had classroom activities with course supervision without class application.

Open-mindedness

Open-mindedness can be supported by sharing reflective diaries in an online community of practice, as illustrated by Didem (2017). In a pre-test / post-test quasi-experimental study, pre-service students were divided in two conditions. In both conditions, students had to prepare reflective diaries about their internship. In the experimental condition students shared their diaries with the fellow students in an online community of practices. The students in the control condition did not accommodate peer interaction, only student-teacher interaction. Students in the experimental condition improved more on open-mindedness and self-confidence in comparison to the control condition group. In both conditions there was no growth for analyticity, truth-seeking, inquisitiveness, and systematicity.

Tjosvold and Johnson (1978) have shown that open-mindedness (and curiosity) can also be stimulated by interpersonal controversies (later called as constructive controversy) using moral dilemmas. In their study, Tjosvold and Johnson (1978) operationalized open-mindedness as being able to and being accurate in taking the partner's cognitive perspective, listening with an open mind to the partner's arguments and being willing to make concessions to the position of the other person and arguments during a discussion. Curiosity in this same study meant the degree to which a student feels informed by the arguments given by the confederate, the subjective (un)certainty of one's own initial position, and the number of questions asked concerning the given arguments. Interestingly, this study shows that, if open-mindedness is pursued, the controversy should take place within a cooperative context and not in a competitive context. At the same time, it was found that a controversy in a competitive context resulted in more questions asked, more information-seeking behavior, as well as more accuracy in taking the cognitive perspective of the opponent compared to the cooperative context. However, as previously mentioned, these findings do not mean that controversy in a competitive context is always more effective than in a cooperative context. When controversy is held within a competitive context a closed-mind orientation is created, expressed by students who are unwilling to take the perspective of the opponent, and unwilling to make concessions (both based on self-reports of the participants). This means increased accuracy of perspective-taking does not necessarily results in an attitude of open-mindedness.

Systematicity

Realistic cases where students have to take ethical decisions supported by an online tool seem to be beneficial for the quality of ethical decision-making (Kert et al., 2014). The online tool that prompted reflection, appeared to be an important feature in the learning environment because the students with access to the tool outperformed the students who could not use the tools, even though students received similar teaching and practice opportunities.

Cognitive maturity

In the field of social science, no study was retrieved that solely focused on cognitive maturity. One study investigated the effect of open-mindedness and cognitive maturity on the development of reasoning skills and if that effect differed according to the instructional approach (Heijltjes et al., 2014). Results indicate that open-mindedness and cognitive maturity predicted reasoning skills at pre-test but they did not interact with instructions on post-tests performances. So, the effect on the disposition open-mindedness and cognitive maturity was similar with the different instructional approaches. The instructional approaches that combined critical thinking instruction

with practice of the reasoning skills had the largest effect on reasoning skills performance. Critical thinking instruction without practice did not result in improvement of reasoning skills. Activation prompts or self-explanation prompts in addition to critical thinking instruction did not result in better immediate performance but self-explanation prompts seemed to have a positive effect on not-practiced tasks in a delayed post-test. This last aspect is considered to be an indicator of cognitive maturity.

Vignette 12: University of Economics in Prague, Czech Republic, Management and Leadership

In an obligatory Master course on 'Leadership' in the management program (lectures attended by 244 students, seminars by 32 students), the importance of CT as a meta-competence was discussed as important for successful leadership and employability. The intervention targeted several critical thinking skills: Interpretation, Analysis, Inference, Evaluation, Explanation, Self-regulation, and dispositions: Truth-seeking, Open-mindedness, Analyticity, Systematicity, Self-confidence, Inquisitiveness, Cognitive maturity.

The course consists of 1,5 hours lecture and 1,5 hours seminar/week. Seminars are interactive, based on solving case studies, teamwork, role playing, reflection, self-reflection in oral and written form, student presentations and pro and con-discussions between students and between students and the teacher. As part of the intervention attention was focused on existing activities towards the development of CT. Emphasis was placed on development especially CT skills in the labour market.

Changes attributed to the intervention are higher involvement and satisfaction of students, deeper discussion, better teamwork outputs (team presentation, outputs of teams during the seminar), better summary at the end of the class/activity, better results in the open-ended questions in the final test.

The teacher experienced an impact on the development of critical thinking skills and dispositions. Given this perceived impact, in future runs of the course group work (solving case studies), discussions, and reflection and self-reflection will be certainly kept. More attention will be paid to encouraging students to better prepare at home in view of more effective discussions and group work. Further work seems also be needed with respect to further clarifying the assessment criteria for some activities.

Students (N=32) value the interesting and diverse activities, the dynamics and the energy during the seminars as well as the continuous efforts to link theory and practice. Rather than lengthy presentations by students they would prefer even more activities, guest speakers and more intensive sharing of experiences.

Vignette 12 - University of Economics in Prague, Czech Republic, Management and Leadership

Conclusion

In this section interventions are discussed in the fields of social sciences and humanities. In general, and similar to what was found for the other fields, empirical evidence is limited. Particular instructional methods, critical thinking skills or dispositions are seldom addressed by multiple studies. Replication studies seems to be non-existent and although a rigorous selection of papers was conducted, basic methodological criteria are not met by the majority (no measurement of prior knowledge or other control variables). In addition to the need for more systematic

In social sciences and humanities, interventions with well-designed and explicit information, writing tasks, ill-structured problem-solving, and argumentation tasks seem to be powerful to develop critical thinking.

research, this shows how difficult research on critical thinking in ecologically valid settings actually is.

Research within the domain of social sciences suggests that critical thinking skills in general can be developed by the following interventions:

- Well-designed and guided writing tasks with specific focus on critical thinking skills, with explicit and specific instruction on the expected critical thinking strategies that have to be applied and with explicit attention given to the evaluation criteria (for example Vardi, 2012).
- Argumentation tasks that are directed towards consensus (Villarroel et al., 2016). Such tasks may involve brainstorming (Ghabanchi & Behrooznia, 2014).
- Ill-structured problem-solving tasks supported by an argumentation scaffold (Cho & Jonassen, 2002).
- Specific instruction on argumentation models (such as the Toulmin model) and on how to use them in realistic problem situations (Cho & Jonassen, 2002; Heijltjes et al., 2015; Marttunen & Laurinen, 2001; Villarroel et al., 2016), the four-question technique developed by Dietz-Uhler and Lanter (2009) (Alexander et al., 2010) or an infusion or immersion approach (Angeli & Valanides, 2009).
- Explicit information on critical thinking with ample practice opportunities (Belluigi & Cundill, 2017).
- Writing tasks with rubrics that make the expectations explicit and provide clear instructions (Adems, Rogers & Fisk, 2013; Kert et al., 2014; Schamber & Mahoney, 2006; Sin et al., 2007).

The number of studies in the domain of social sciences focusing on the development of critical thinking dispositions appears to be rather low and almost all combine at least two different dispositions in their studies. Despite the small number of studies some guidelines can be drawn concerning the development and stimulation of critical thinking dispositions:

- Allowing and or stimulating academic control can be helpful (Stupnisky et al., 2018).
- A problem-based learning environment might help although results are not consistent (Ding, 2016; Eren & Akinoglu, 2013; Temel, 2014).
- Problem solving in combination with metacognitive support in the sense of asking specific questions (Aküz et al., 2015) as well as inquiry learning (Zeki, 2017) might be beneficial.

- Cross cultural learning tasks (Harrigan & Vincenti, 2004) as well as previous involvement in a diversity course can be supportive (Laird, 2005)
- A context that allows students to take a critical position and talk with an authorial voice can be supportive. This allows students to focus on intellectual engagement, especially when the disposition of truth-seeking is targeted (Vardi, 2012).
- Interpersonal controversies using moral dilemmas provided that these learning activities take place in a cooperative context (Tjosvold & Johnson, 1978).
- Reflective diaries in an online community of practice may stimulate open-mindedness (Didem, 2017).

Interaction with peers, but even more so with teachers, seem essential ingredients. It helps students to stay focused, make their thinking explicit and public and hence open for questioning and discussion.

Chapter 5. The CRITHINKEDU educational protocol on supporting the development of critical thinking

The educational protocol builds on literature reviews, on lessons learned from classroom experiences with new approaches and on ample discussion within the CRITHINKEDU team.

Critical thinking is considered to be an important goal for European Higher Education Institutions. In view of supporting the achievement of this goal, an educational protocol is proposed. The protocol builds on all the outputs developed in the CRITHINKEDU project. That means, it builds on the reviews of the literature, the experiences with new approaches and on ample discussions in the project team.

Considerations with regard to the CRITHINKEDU educational protocol

As an introduction to the protocol a number of considerations are highlighted. These reveal the strength as well as the limitations of the current protocol.

a. The protocol is not static given, it is a *construction* made at a particular intersection of time and place. Any change in time and place may result in changes with respect to both its particular elements and its structure.

b. The protocol is the result of a European project in which a group of staff members of European Higher Education Institutions (HEIs) shared their scholarship.

c. The protocol is fundamental and general. It specifies a number of essentials that may guide and promote the development of critical thinking.

d. In assessing and using the protocol, the specific meaning given to critical thinking in this endeavour needs to be considered.

e. Any initiative to support critical thinking must be of high quality. This means that in the design of the initiative, the best possible 'evidence' is considered. Similarly, it is presumed that the development of critical thinking remains consistent with highly valued ethical principles.

An educational protocol to support the development of critical thinking

This educational protocol reflects a historically situated, operational understanding of the theoretical and empirical research on critical thinking on the one hand, and actual experiences with developing critical thinking on the other.

The educational protocol rests on two major claims:

1) students will develop their critical thinking by explicitly engaging in appropriate learning activities, and

2) becoming stronger in critical thinking requires repeated engagement in critical thinking processes.

The educational protocol has three parts: goals, conditions and supportive interventions.

Goals

In order to support the development of critical thinking, critical thinking has to be a goal of education. This is shown by:

- At the institutional level: A clear mission statement recognising critical thinking as an important goal and explaining how it can be accomplished.
- At the teaching program level: A clear description of critical thinking as an important goal of the teaching program, detailing how it can be reached.
- At the course level: A clear description of critical thinking as an important learning outcome, explaining how it can be realized.

In the above, '*clear*' means that an explicit clarification (by referring to the relevant literature) of the meaning of critical thinking is provided. In other words, the goals are explicit and transparent; they can be read and understood by all those involved.

The protocol has three parts: goals, conditions and supportive interventions. In each part, different examples are provided to guide its implementation at the institutional, program and course levels.

In the above, '*important*' means that not reaching the goal would be considered a failure. At the institutional level, it means that the institution would not be accredited unless the goal was realized. At the teaching program level, it means that a student could not graduate unless the goal is realized. At the course level it means that a student could not progress unless evidence of critical thinking is provided. In other words, considering critical thinking as an important goal implies that it is part of assessment and evaluation.

Given substantial conceptual and methodological differences between the fields and the disciplines, it is to be expected that clear descriptions of critical thinking as an

important goal at the teaching program and/ or course level will vary between the fields and between the disciplines.

Conditions

Critical thinking requires that at the institutional, the teaching program and course levels, critical thinking is *continuously* and *congruently* allowed and made possible.

'*Continuously*' implies that the development of critical thinking is not a one-shot operation. Critical thinking does not occur automatically or effortlessly. It needs continuous practice, reinforcement and support.

'*Congruently'* implies that all actions with respect to critical thinking are aligned to the goals.

Allowing critical thinking implies that critical thinking cannot have a negative consequence for the institute, its staff and/or its students. More specifically, it requires autonomy of the institution, the staff and the students who are enabled to think for themselves and with an authorial voice.

Making critical thinking possible implies that the resources needed for critical thinking are made available. It implies that students can flourish in an environment that is well-designed and offers them the time needed for development. It also implies that teaching programs can operate within a transparent and open structure, and institutions can work within clear legal frameworks.

Supportive interventions

Research suggests that with regard to the development of critical thinking (skills, dispositions or combinations of both), four categories of intervention (to model, to induce, to declare, to surveil) can be identified. For all supportive interventions the rule is that the support gradually withdraws.

- To model

Critical thinking development is supported when the institute (through its management structures), the teaching program (through its representatives) and the course (through its teachers) shows what it is to think critically. This can take various forms.

The following are only examples:

- At the institutional level: decisions made are documented and discussed by considering different perspectives and alternatives.
- At the teaching program level: courses reflect different (opposing) perspectives, the teaching program reveals the complexities of the discipline / the field it represents.
- At the course level: the teacher offers ill-structured problems, addresses multiple sites of a problem, weights alternatives, engages in critical discourse and conversation, and values different approaches.

- To induce

Critical thinking development is supported by inducing critical thinking. This implies that open questions are raised, ill-structured tasks are provided, complex problems are discussed and/or authentic, real-world issues remain at the core. What '*inducing'* entails and how it can be done may vary for different fields and disciplines and may be done in different ways.

The following are only examples:

- At the institutional level: organize referenda on institutional issues, invite speakers with very different backgrounds, provide resources for research on institutional processes, provide autonomy to schools, faculties, departments.
- At the teaching program level: establish course teams, organize reflection days for staff and students, ensure international exchange; provide autonomy to course teams.
- At the course level: offer ill-structured problems; provide authentic tasks; confront students with dilemmas; make use of constructive controversies; use prompts to make students think deeper; engage students in elaborating research questions, interpreting and discuss research results; provide tools that orient students thinking and reflections; ask why-questions; provide autonomy; have students make their thinking explicit / open for feedback and discussion; have students take position; have students argue from different perspectives; foster self-regulation, by asking self-regulation questions such as what is the next step, how far are you in the process, how are you performing, how could you improve yourself, ...

- To declare

Critical thinking development is supported by declaring or making explicit what is at stake, what strategies can be used and what criteria are to be met. Declaring can be either spoken or written, but in all the cases it is both explicit and specific. What '*declaring'* entails and how it can be done may also vary in different fields and disciplines.

The following are only examples:

- At the institutional level: present a statement on the importance and components of critical thinking; ask representatives to offer their points of view on critical thinking in public; give awards to those who represent the institutionally adopted meaning of critical thinking.
- At the teaching program level: have teachers/teaching teams exchange their rubrics on assessing critical thinking; have researchers from different disciplines make explicit what type of critical thinking they aim at in their courses; have representatives from the professional fields share their expectations with respect to critical thinking.
- At the course level: use critical thinking rubrics; elaborate concept maps; make models, heuristics and strategies available; discuss issues.

To surveil

Critical thinking development is difficult. To increase the probability that sustained action is taken, surveillance may help. Surveillance monitors the ongoing efforts and activities, provides feedback on those efforts and activities and helps to keep the efforts and activities oriented towards the (development of) critical thinking. While differing in its concrete content and form among fields and disciplines, surveillance will always entail monitoring, feedback and orientation.

The following are only examples:

- At the institutional level: based on a dedicated report discuss yearly progress with respect to the development of critical thinking, ask staff to document their critical thinking initiatives in their portfolio, invite external experts to audit the institution from the perspective of developing critical thinking.
- At the teaching program level: ask teachers to share their approaches to assess critical thinking, invite peers from the disciplines and the professional fields to discuss the teaching program from the perspective of critical thinking; provide explicit feedback and discuss further plans.
- At the course level: when discussing issues ask students to reflect and share their reflections, provide feedback and set targets together with the students, in case of problem-solving tasks engage in peer assessment and peer-feedback about the learning processes engaged in.

Discussion

In elaborating the educational protocol, the following elements of discussion became prominent:

a. The protocol is a construction made at a particular intersection of time and place. Any change in time and place may result in changes both with respect to the particular elements and with respect to its structure.

b. The protocol is the result of a European project with European research working in European institutes of higher education. It might be affected by that context.

c. The protocol is general. For its actual implementation the specific context (institute, teaching program, course) needs to be considered.

d. In implementing the protocol or its elements, the learner is to be considered. Especially important are the (general and domain-specific) prior knowledge of the learners (and even more specifically their epistemological beliefs).

e. In assessing the protocol, the specific meaning given to critical thinking in this endeavour needs to be considered.

f. Any initiative to support critical thinking requires to be of high quality. It means in its design the best possible 'evidence' is considered.

Implementing the CRITHINKEDU educational protocol

a. Given the generality of the protocol, it needs to be contextualized during implementation. For the actual implementation of the protocol and its constituent rules the specific context (institute, teaching program, course) needs to be considered.

b. In implementing the protocol or its elements, learners and their characteristics are to be considered. Especially important are learners (general and domain-specific) prior knowledge (and even more specifically their epistemological beliefs).

c. The protocol presents statements at the course, teaching program and institutional level. This indicates that starting to support the development of critical thinking can happen at any of these levels, irrespective of what happens at the other levels. There are no prerequisite relationships between the levels.

d. The protocol presents the essentials. Its implementation requires careful planning and ensuring that all concerned are well prepared. Initiatives on professional development may positively affect the implementation of the protocol (and hence the development of critical thinking).

Further elaboration and validation of the CRITHINKEDU educational protocol

As already specified the CRITHINKEDU educational protocol on developing critical thinking provides the essentials for fostering critical thinking in higher education institutions. While the protocol is the result of scholarly work that has considered theoretical perspectives, empirical studies as well as practical experiences and was approved after intensive discussions, it remains a construction that is due to be validated and elaborated. Different lines can be identified.

A first line is the discussion of the protocol in diverse bodies such as educational and professional associations. A second line is its elaboration for very specific disciplines and in particular fields. As such it might for instance be the basis for further research on internships and how such collaborations between institutes from higher education and organisations from different fields may help to foster the development of critical thinking. Another line is engaging in systematic validation and design-based elaboration research. It would be worthwhile to engage in a research program that systematically investigates the effects of implementing the educational protocol for different contexts, different fields and disciplines and for different types of learners. In order to be fruitful, such elaborations rest on a shared framework for describing educational reality.

Efforts along these lines may finally help to contribute to realizing that ultimate goal of higher education: the development of critical thinking.

References

Abdullah, C., Parris, J., Lie, R., Guzdar, A., & Tour, E. (2015). Critical analysis of primary literature in a master's-level class: Effects on self-efficacy and science-process skills. *CBE Life Sciences Education, 14*(3).

Abrami, P. C., Bernard, R. M., Borokhovski, E., Wade, A., Surkes, M. A., Tamim, R., & Zhang, D. (2008). Instructional interventions affecting critical thinking skills and dispositions: A stage 1 meta-analysis. *Review of Educational Research, 78*(4), 1102-1134.

Abrami, P. C., Bernard, R. M., Borokhovski, E., Waddington, D. I., Wade, C. A., & Persson, T. (2015). Strategies for teaching students to think critically: A meta-analysis. *Review of Educational Research, 85,* 275–314.

Adams, A. E., Rogers, W. A., & Fisk, A. D. (2013). Skill components of task analysis. *Instructional Science, 41*, 1009-1046.

Akyüz, H. A., Samsa-Yetik, S., & Keser, H. (2015). Effects of metacognitive guidance on critical thinking disposition. *Pegem Eğitim ve Öğretim Dergisi, 5*(2), 133-148.

Alexander, M. E., Commander, N., Greenberg, D., & Ward, T. (2010). Using the four-questions technique to enhance critical thinking in online discussions. *Journal of Online Learning and Teaching, 6*(2), 409-415.

Anderson, T., Howe, C., Soden, R., Halliday, J., & Low, J. (2001). Peer interaction and the learning of critical thinking skills in further education students. *Instructional Science, 29*, 1-32.

Angeli, C., & Valanides, N. (2009). Instructional effects on critical thinking: Performance on ill-defined issues. *Learning and Instruction, 19*, 322-334.

Aronson, D., & Briggs, L. (1983). Contributions of Gagné and Briggs to a prescriptive model of instruction. In C. Reigeluth (Ed.), *Instructional-Design Theories and Models: An Overview of Their Current Status* (pp. 75-100). Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

Arsal, Z. (2017). The impact of inquiry-based learning on the critical thinking dispositions of pre-service science teachers. *International Journal of Science Education, 39*(10), 1326-1338.

Baartman, L. K. J., Bastiaens, T. J., Kirschner, P. A., & Vleuten, van der, C. P. M. (2006). The wheel of competency assessment. Presenting quality criteria for competency assessment teaching programs. *Studies in Educational Evaluation, 32*, 153-177. DOI: 10.1016/j.stueduc.2006.04.006

Bandura, A. (1986). *Social Foundations of Thought and Action: A Social Cognitive Theory*. Englewood Cliffs, NJ: Prentice Hall.

Bartunek, J. M., & Moch, M. K. (1987). First-order, second-order, and third-order change and organization development interventions: A cognitive approach. *The Journal of Applied Behavioral Science, 23*(4), 483–500. https://doi.org/10.1177/002188638702300404

Behar-Horenstein, L. S., Niu, L. (2011). Teaching critical thinking skills in higher education: A review of the literature. *Journal of College Teaching and Learning, 8*(2), p. 25-41.

Belluigi, D. Z., & Cundill, G. (2017). Establishing enabling conditions to develop critical thinking skills: a case of innovative curriculum design in Environmental Science. *Environmental Education Research, 23*(7), 950-971.

Bielaczyc, K., Pirolli, P. L., & Brown, A. L. (1995). Training in self-explanation and self-regulation strategies: investigating the effects of knowledge acquisition activities on problem-solving. *Cognition and Instruction, 13*(2), 221-252.

Biggs, J. B. (2003). *Teaching for Quality Learning at University* (Second edition). Buckingham: Open University Press/Society for Research into Higher Education.

Binkhorst, F., Handelzalts, A., Poortman, C. L., & van Joolingen, W. R. (2015). Understanding teacher design teams – A mixed methods approach to developing a descriptive framework. *Teaching and Teacher Education, 51*(10), 213-224.

Bixler, G. M., Brown, A., Way, D., Ledford, C., & Mahan, J. D. (2015). Collaborative concept mapping and critical thinking in fourth-year medical students. *Clinical Pediatrics, 54*(9), 833-839. doi:10.1177/0009922815590223

Borkowski, I. G. (1985). Signs of intelligence: Strategy generalization and metacognition. In S. R. Yussen (Ed.), *The Growth of Reflection in Children* (pp. 105–144). New York, NY: Academic Press.

Branch, R. M. (2009). *Instructional Design: The ADDIE approach* (Vol. 722). Springer Science & Business Media.

Bravo, A., Porzecanski, A., Sterling, E., Bynum, N., Cawthorn, M., Fernandez, D. S., Freeman, L., Ketcham, S., Leslie, T., Mull, J., & Vogler, D. (2016). Teaching for higher levels of thinking: developing quantitative and analytical skills in environmental science courses. *Ecosphere, 7*(4), 1-20.

Broadbear, J. T. (2003). Essential elements of lessons designed to promote critical thinking. *Journal of the Scholarship of Teaching and Learning, 3*(3), 1-8.

Brown, N. J. S., Afflerbach, P. P., & Croninger, R. G. (2014). Assessment of critical-analytic thinking. *Educational Psychology Review, 26*, 543-560.

Byrnes, J. P., & Dunbar, K. N. (2014). The nature and development of critical-analytic thinking. *Educational Psychology Review, 26*, 477-493.

Cheng Y. Y., Wang W. C., Wu J. J., & Hwang C.K. (1996). A preliminary report on the construction of the critical thinking scale. *Psychological Testing* (in Chinese), *43*, 213-226.

Cho, K., & Cho, M. (2013). Training of self-regulated learning skills on a social network system. *Social Psychology Education, 16*, 617-634.

Cho, K., & Jonassen, D. H. (2002). The effects of argumentation scaffolds on argumentation and problem solving. *Educational Technology Research and Development, 50*(3), 5-22.

Daley, B. J., Shaw, C. A., Balistrieri, T., Glasenapp, K., & Piacentine, L. (1999). Concept maps: A strategy to teach and evaluate critical thinking. *Journal of Nursing Education, 38*(1), 42-47.

Davies, M., & Barnett, R. (2015) (Eds.). *The Palgrave Handbook of Critical Thinking in Higher Education.* New York: Palgrave Macmillan.

Dehkordi, A. H., & Heydarnejad, M. S. (2008). The effects of problem-based learning and lecturing on the development of Iranian nursing students' critical thinking. *Pakistan Journal of Medical Science, 24*(5), 740-743.

Didem, I. E. (2017). The effects of online communities of practice on pre-service teachers' critical thinking dispositions. *EURASIA Journal of Mathematics Science and Technology Education, 13*(7), 3801-3827.

Dietz-Uhler, B., & Lanter, J. R. (2009). Using the four-questions technique to enhance learning. *Teaching of Psychology, 36*(1), 38-41.

Ding, X. W. (2016). The effect of WeChat-assisted problem-based learning on the critical thinking disposition of EFL learners. *International Journal of Emerging Technologies in Learning, 11*(12), 23-29.

Dominguez, C. (coord.) (2018a). *A European collection of the Critical Thinking skills and dispositions needed in different professional fields for the 21st century*. Vila Real: UTAD.

Dominguez, C. (coord.) (2018b). *A European review on Critical Thinking educational practices in Higher Education Institutions*. Vila Real: UTAD.

Dominguez, C. (coord.) (2018c). *The CRITHINKEDU European course on critical thinking education for university teachers: from conception to delivery*. Vila Real: UTAD.

Dörrenbacher, L., & Perels, F. (2016). Self-regulated learning profiles in college students: Their relationship to achievement, personality and the effectiveness of an intervention to foster self-regulated learning. *Learning and Individual Differences, 51*, 229-241.

Dowd, J. E., Thompson, R. J., Jr., Schiff, L. A., & Reynolds, J. A. (2018). Understanding the complex relationship between critical thinking and science reasoning among undergraduate thesis writers. *CBE Life Sci Educ, 17*(1). doi:10.1187/cbe.17-03-0052

Dreifuerst, K. (2012). Using debriefing for meaningful learning to foster development of clinical reasoning in simulation. *The Journal of Nursing Education, 51*(6), 326-33.

Druckman, D., & Bjork, R. A. (1994). *Learning, Remembering, Believing: Enhancing Human Performance.* Washington, D.C.: National Academy Press.

Dunbar, N. E., Miller, C. H., Adame, B. J., Elizondo, J., Wilson, S. N., Lane, B. L., ... & Lee, Y. H. (2014). Implicit and explicit training in the mitigation of cognitive bias through the use of a serious game. *Computers in Human Behavior*, 37, 307-318.

Dwyer, C.P. (2017). *Critical Thinking: Conceptual Perspectives and Practical Guidelines.* UK: Cambridge University Press.

Dwyer, C. P., Hogan, M. J., Harney, O. M., & Kavanagh, C. (2017). Facilitating a student-education conceptual model of dispositions towards critical thinking through interactive management. *Educational Technology Research and Development, 65*, 47-73.

Eisner, E. W. (1979). *The Educational Imagination. On the Design and Evaluation of School Programs.* New York, NY: Macmillan Publishing.

Ennis, R. H. (1989). Critical thinking and subject specificity: Clarification and needed research. *Educational Researcher, 18*(3), 4-10. http://dx.doi.org/10.3102/0013189X018003004

Ennis, R. H. (1997). Incorporating critical thinking in the curriculum: An introduction to some basic issues. *Inquiry: Critical thinking across the disciplines, 16*(3), 1-9.

Eren, C. D., & Akinoglu, O. (2013). Effect of problem-based learning (PBL) on critical thinking disposition in science education. *Journal of Environmental Protection and Ecology, 14*(3a), 1353-1361.

Ertmer, P. A., & Newby, T. J. (2013). Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly, 26*(2), 43-71.

Facione, P. A. (1990). *Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment & Instruction: The Delphi Report.* California: California Academic Press.

Facione, P.A., Sánchez, (Giancarlo) C.A., Facione, N.C. & Gainen, J. (1995). The disposition toward critical thinking. *Journal of General Education, 44*(1), 1-25.

Frerejean, J., van Strien, J. L. H., Kirschner, P., & Brand-Gruwel, S. (2016). Completion strategy or emphasis manipulation? Task support for teaching information problem solving. *Computers in Human Behavior, 62*, 90-104.

Fry, J. P. (1972). Interactive relationship between inquisitiveness and student control of instruction. *Journal of Educational Psychology, 63*(5), 459-465.

Gentner, D., Loewenstein, J., & Thompson, L. (2003). Learning and transfer: A general role for analogical encoding. *Journal of Educational Psychology, 95*(2), 393-408.

Gerdeman, J. L., Lux, K., & Jacko, J. (2013). Using concept mapping to build clinical judgment skills. *Nurse Education in Practice, 13*(1), 11-17. doi:10.1016/j.nepr.2012.05.009

Ghabanchi, Z., & Behrooznia, S. (2014). The impact of brainstorming on reading comprehension and critical thinking ability of EFL learners. *Social and Behavioral Sciences, 98*, 513-521.

Grace, S., & Orrock, P. J. (2015). Criticality in osteopathic medicine: Exploring the relationship between critical thinking and clinical reasoning. In M. Davies & R. Barnett (Eds.), *The Palgrave Handbook of Critical Thinking in Higher Education* (pp.475-490). New York: Palgrave Macmillan.

Greeno, J. G., Collins, A. M., & Resnick, L. B. (1996). Cognition and learning. In D. Berliner & R. Calfee (Eds.), *Handbook of Educational Psychology* (pp. 15-46). New York: Macmillan.

Griffin, M. M. (1995). You can't get there from here: Situated learning transfer, and map skills. *Contemporary Educational Psychology, 20*(1), 65-87.

Halpern, D. F. (2014). *Thought and Knowledge: An Introduction to Critical Thinking* (5th Edition). NY: Psychology Press

Hargrove, R. A. (2013). Assessing the long-term impact of a metacognitive approach to creative skill development. *International Journal of Technology and Design Education, 23*, 489-517.

Harrigan, A., & Vincenti, V. (2004). Developing higher-order thinking through an intercultural assignment: A scholarship of teaching inquiry project. *College Teaching, 52*(3), 113-120.

Hayes, K. D., & Devitt, A. A. (2008). Classroom discussions with student-led feedback: a useful activity to enhance development of critical thinking skills. *Journal of Food Science Education, 7*(4), 65-68.

Heijltjes, A., van Gog, T., Leppink, J., & Paas, F. (2014). Improving critical thinking: Effects of dispositions and instructions on economics students' reasoning skills. *Learning and Instruction, 29*, 31-42.

Heijltjes, A., van Gog, T., Leppink, J., & Paas, F. (2015). Unraveling the effects of critical thinking instructions, practice, and self-explanation on students' reasoning performance. *Instructional Science, 43*, 487-506.

Horiba, Y. (2000). Reader control in reading: Effects of language competence, text type and task. *Discourse Processes, 29*, 223-267.

Iranfar, K., Iranfar, S., & Mohammadi, G. (2012). Developing critical thinking disposition in the students of nursing and midwifery through collaborative and individual methods of learning. *Healthmed, 6*(12), 4047-4052.

Johnson-Laird, P. N. (1983). *Mental Models: Towards a Cognitive Science of Language, Inference, and Consciousness.* Cambridge, MA: Harvard University Press.

Johnson, D. W., Johnson, R. T., & Smith, K. A. (2000) Constructive controversy: The educative power of intellectual conflict. *Change: The Magazine of Higher Learning, 32*(1), 28-37, DOI: 10.1080/00091380009602706

Jones, A. (2009). Redisciplining generic attributes: The disciplinary context in focus. *Studies in Higher Education, 34*(1), 85-100.

Jones, A. (2010). Generic attributes in accounting: the significance of the disciplinary context. *Accounting Education: An International Journal, 19*(1-2), 5-21.

Kammerer, Y., Amann, D. G., & Gerjets, P. (2015). When adults without university education search the Internet for health information: The roles of Internet-specific epistemic beliefs and a source evaluation intervention. *Computers in Human Behavior, 48*, 297-309.

Kahneman, D. (2011). *Thinking, Fast and Slow.* London: Allen Lane.

Kayapinar, U. (2014). Measuring essay assessment: Intra-rater and inter-rater reliability. *Eurasian Journal of Educational Research, 57*, 113-136.

Kellum, J. A., Rieker, J. P., Power, M. J., & Powner, D. (2000). Teaching critical appraisal during critical care fellowship training: A foundation for evidence-based critical care medicine. *Critical Care Medicine, 28*(8), 3067-3070.

Kert, S. B., Uz, C., & Gecü, Z. (2014). Effectiveness of an electronic performance support system on computer ethics and ethical decision-making education. *Educational Technology & Society, 17*(3), 320-331.

Korkmaz, O., & Karakus, U. (2009). The impact of blended learning model on student attitudes towards geography course and their critical thinking dispositions and levels. *The Turkish Online Journal of Educational Technology, 8*(4), 51-63.

Kuhn, D. (1999). A developmental model of critical thinking. *Educational Researcher, 28*, 16-25.

Kuhn, D., & Angelev, J. (1976). An experimental study of the development of Formal Stage 11 thought. *Child Development, 47*, 697–706.

Kuhn, D., Ho, V., & Adams, C. (1979). Formal reasoning among pre- and late-adolescents. *Child Development, 50,* 1128–1135.

Kuhn, D., & Ho, V. (1980). Self-directed activity and cognitive development. *Journal of Applied Developmental Psychology, 1*(2), 119-133.

Kuhn, D., & Phelps, E. (1982). The development of problem solving strategies. In H. Reese (Ed.), *Advances in Child Development and Behavior* (Vol. 17, pp. 1-44). New York: Academic Press.

Kuhn, D., Amsel, E., & O'Loughlin, M. (1988). *The Development of Scientific Thinking Skills.* NY: Academic Press.

Kuhn, D., Schauble, L., & Garcia-Mila, M. (1992). Cross-domain development of scientific reasoning. *Cognition and Instruction, 9*(4), 285-327.

Kuhn, D., Garcia-Mila, M., Zohar, A., & Andersen, C. (1995). Strategies of knowledge acquisition. *Monographs Of The Society For Research In Child Development, 60*(4), i+iii+v-vi+1-157.

Laird, T. F. N. (2005). College students' experiences with diversity and their effects on academic self-confidence, social agency and disposition toward critical thinking. *Research in Higher Education, 46*(4), 365-387.

Larsson, C., & Tibell, L. A. E. (2015). Challenging students' intuitions—the influence of a tangible model of virus assembly on students' conceptual reasoning about the process of self-assembly. *Research in Science Education, 45*(5), 663-690. doi:10.1007/s11165-014-9446-6

Lee, J., Lee, Y., Gong, S., Bae, J., & Choi, M. (2016). A meta-analysis of the effects of non-traditional teaching methods on the critical thinking abilities of nursing students. *BMC Medical Education, 16*(1), 240-249. doi:10.1186/s12909-016-0761-7

Lin, Y., Wen, M., Jou, M., & Wu, D. (2014). A cloud-based learning environment for developing student reflection abilities. *Computers in Human Behavior, 32*, 244-252.

Louis, M. R., & Sutton, R. I. (1991). Switching Cognitive Gears: From Habits of Mind to Active Thinking. *Human Relations, 44*(1), 55-76.

Marttunen, M., & Laurinen, L. (2001). Learning of argumentation skills in networked face-to- face environments. *Instructional Science, 29*, 127-153

Masui, C., & De Corte, E. (1999). Enhancing learning and problem solving skills: orienting and self-judging, two powerful and trainable tools. *Learning and Instruction, 9*(6), 517-542.

Mevarech, Z. R., & Kramarski, B. (1997). Improve: A multidimensional method for teaching mathematics in heterogeneous classrooms. *American Educational Research Journal, 34*(2), 365-394.

Moulton, C. A., Regehr, G., Lingard, L., Merritt, C., & MacRae, H. (2010). Slowing down to stay out of trouble in the operating room: Remaining attentive in automaticity. *Journal of Gastrointestinal Surgery, 14*, 1019-1026.

Naber, J., & Wyatt, T. H. (2014). The effect of reflective writing interventions on the critical thinking skills and dispositions of baccalaureate nursing students. *Nurse Education Today, 34*(1), 67-72. doi:10.1016/j.nedt.2013.04.002

Nahatame, S. (2014). Strategic processing and predictive inference generation in L2 reading. *Reading in a Foreign Language, 26*(2), 54-77.

Neilens, H. L., Handley, S. J., & Newstead, S. E. (2009). Effects of training and instruction on analytic and belief-based reasoning processes. *Thinking & Reasoning, 15*(1), 37-68.

Niu, L. N., Behar-Borenstein, L. S., & Garvan, C. W. (2013). Do instructional interventions influence college students' critical thinking skills? A meta-analysis. *Educational Research Review, 9*, 114-128.

Nussbaum, E. M., Sinatra, G. M., & Poliquin, A. (2008). Role of epistemic beliefs and scientific argumentation in science learning. *International Journal of Science Education, 30*(15), 1977-1999.

Paul, R. (1995). *Critical thinking: How to prepare students for a rapidly changing world*. Santa Rosa, CA: Foundation for Critical Thinking.

Paul, R., Elder, L., & Bartell T. (1997). *California Teacher Preparation for Instruction in Critical Thinking: Research Findings and Policy Recommendations.* Sacramento California: California Commission on Teacher Credentialing. Foundation for Critical Thinking.

Paul, R., & Elder, L. (2001). *Critical thinking: Tools for taking charge of your learning and your life.* Upper Saddle River, NJ: Prentice Hall.

Perry, W. G. (1981). Cognitive and ethical growth: The making of meaning. In A. W. Chickering & Assoc. (Eds.), *The Modern American College* (pp. 76–116). San Francisco: Jossey-Bass.

Pilegard, C., & Mayer, R.E. (2015). Adding judgements of understanding to the metacognitive toolbox. *Learning and Individual Differences, 41*, 62-72.

Pithers, R. T., & Soden, R. (2000). Critical thinking in education: a review. *Educational Research, 42*(3), 237-249.

Pugh, K. J., & Bergin, D. A. (2006). Motivational influences on transfer. *Educational Psychologist, 41*(3), 147–160.

Reigeluth, C.M. (1983). Instructional design: What is it and why is it? In C.M. Reigeluth (Ed.), *Instructional Theories in Action* (pp. 3–36). Hillsdale, NJ: Lawrence Erlbaum Associates.

Reigeluth, C. & Stein, F. (1983). The elaboration theory of instruction. In C. Reigeluth (Ed.), *Instructional Design Theories and Models* (pp. 338-381). Hillsdale, NJ: Erlbaum Associates.

Reigeluth, C. (1999). What is instructional-design theory and how is it changing? In C.M. Reigeluth (Ed.), *Instructional-Design Theories and Models: A New Paradigm of Instructional Theory* (Vol. II, pp. 5-29). Mahwah, NJ: Lawrence Erlbaum Associates.

Richter, T., & Schmid, S. (2010). Epistemological beliefs and epistemic strategies in self-regulated learning. *Metacognition and Learning, 5*, 47-65.

Roex, A., Degryse, J., & Clarebout, G. (2011). Medical trainees' epistemological beliefs and their cognitive flexibility. In J. Elen, E. Stahl, R. Bromme, & G. Clarebout, *Links Between Beliefs and Cognitive Flexibility: Lessons Learned* (pp. 157-174). Dordrecht: Springer Netherlands.

Salomon, G., & Perkins, D. N. (1989). Rocky roads to transfer: Rethinking mechanisms of a neglected phenomenon. *Educational Psychologist, 24*(2), 113-142.

Schamber, J., & Mahoney, S. (2006). Assessing and improving the quality of group critical thinking exhibited in the final projects of collaborative learning groups. *The Journal of General Education, 55*(2), 103-137

Schunk, D. H. (2012). *Learning Theories: An Educational Perspective* (6th ed.). Boston: Pearson.

Sedlak, C., Doheny, M., Panthofer, N., & Anaya, E. (2003). Critical thinking in students' service-learning experiences. *College Teaching, 51*(3), 99-104.

Seidel, R. J., Perencevich, K. C., &Kett, A. L. (2005). *From Principles to Strategies for Instruction: Empirically Based Ingredients to Guide Instructional Development.* Springer Science and Business Media, Inc.

Sin, S., Jones, A., & Petocz, P. (2007). Evaluating a method of integrating generic skills with accounting content based on a functional theory of meaning. *Accounting & Finance, 47*(1), 143-163

Sin, S., Jones, A. & Wang, Z. (2015). Critical thinking in professional accounting practice: Conceptions of Employers and Practitioners. In M. Davies & R. Barnett (Eds.), *The Palgrave Handbook of Critical Thinking in Higher Education* (pp. 431-456). New York: Palgrave Macmillan.

Stanovich, K. E., Toplak, M. E., & West, R. F. (2008). The development of rational thought: A taxonomy of heuristics and biases. *Advances in Child Development and Behavior, 36*, 251–285. https://doi.org/10.1016/S0065-2407(08)00006-2

Stanovich, K. E., West, R. F., & Toplak, M. E. (2016). *The rationality quotient : toward a test of rational thinking*. MIT.

Stupnisky, R. H., Renaud, R. D., Daniels, L. M., Haynes, T. L., & Perry, R. P. (2018). The interrelation of first-year college students' critical thinking disposition, perceived academic control and academic achievement. *Research in Higher Education, 49*(6), 513-530.

Sweller, J., van Merriënboer, J. J. G., & Paas, F. (1998). Cognitive architecture and instructional design. *Educational Psychology Review, 10*, 251–296.

Talanquer, V. (2017). Concept inventories predicting the wrong answer may boost performance. *Journal of Chemical Education, 94*, 1805-1810.

Temel, S. (2014). The effects of problem-based learning on preservice teachers' critical thinking dispositions and perceptions of problem-solving ability. *South African Journal of Education, 34*(1), 1-20.

Tiruneh, D. T., Verburgh, A., Elen, J. (2014). Effectiveness of critical thinking instruction in higher education: A systematic review of intervention studies. *Higher Education Studies, 4*(1), 1-17.

Tjosvold, D. & Johnson, D.W. (1978). Controversy within a cooperative or competitive context and cognition perspective-taking. *Contemporary Educational Psychology, 3,* 376-386.

Tsui, L. (2000). Effects of campus culture on students' critical thinking. *Review of Higher Education, 23*, 421-441.

van den Akker, J. (2003). Curriculum perspectives: An introduction. In J. van den Akker, W. Kuiper, & U. Hameyer (Eds.), *Curriculum Landscapes and Trends* (pp. 1-10). Dordrecht: Kluwer Academic Publishers.

Vardi, I. (2012). Developing students' referencing skills: a matter of plagiarism, punishment and morality or of learning to write critically? *Higher Education Research & Development, 31*(6), 921-930.

Verburgh, A. (2013). *Research Integration in Higher Education: Prevalence and Relationship with Critical Thinking* (Doctoral dissertation). KU Leuven: Leuven.

Villarroel, C., Felton, M., & Garcia-Mila, M. (2016). Arguing against confirmation bias: The effect of argumentative discourse goals on the use of disconfirming evidence in written argument. *International Journal of Educational Research, 79*, 167-179.

Wass, R., Harland, T., & Mercer, A. (2011). Scaffolding critical thinking in the zone of proximal development. *Higher Education Research & Development, 30*(3), 317-328. doi:10.1080/07294360.2010.489237

Wilson, B. (1998). *Constructivist learning environments: Case Studies in Instructional Design* (2nd print. ed.). Englewood Cliffs (N.J.): Educational technology.

Wolpaw, T., Papp, K. K., & Bordage, G. (2009). Using SNAPPS to facilitate the expression of clinical reasoning and uncertainties: A randomized comparison group trial. *Academic Medicine, 84,* 517-524.

Yue, M., Zhang, M., Zhang, C., & Jin, C. (2017). The effectiveness of concept mapping on development of critical thinking in nursing education: A systematic review and meta-analysis. *Nurse Education Today, 52*, 87-94. doi:10.1016/j.nedt.2017.02.018

Zambrano, B. S., Quevedo, I. K., & Portilla, R. N. (2012). Critical thinking through Socratic discussion in university students. *Revista Virtual Universidad Católica del Norte, 35*, 147-167.

Zeki, A. (2017). The impact of inquiry-based learning on the critical thinking dispositions of pre-service science teachers. *International Journal of Science Education, 39*(10), 1326-1338.

Zhang, C., Fan, H., Xia, J., Guo, H., Jiang, X., & Yan, Y. (2017). The Effects of Reflective Training on the Disposition of Critical Thinking for Nursing Students in China: A Controlled Trial. *Asian Nursing Research, 11*(3), 194-200.

Acknowledgments

We want to thank all the cooperation and effort of the different teachers, researchers, and students from the Higher Education Institutions of the 9 European countries involved in the study that made this work possible. We also thank the Steering Committee members of the CRITHINKEDU project, Diane F. Halpern (Claremont McKenna College, USA), Harvey Siegel (University of Miami, USA) and Ronald Barnett (University College London, UK), for their wise and helpful reflections. Finally, a special thanks to Heitor Azuaga Aires Filho (Instituto Federal de Mato Grosso, Brazil) for the authorship of Figure 1.


utad
UNIVERSIDADE
DE TRÁS-OS-MONTES
E ALTO DOURO
UC Leuven Limburg
MOVING MINDS
UNIVERSITY OF
THESSALY
UNIVERSITY OF ECONOMICS
PRAGUE
VŠE
Šiuolaikinių didaktikų centras
ROMA
TRE
UNIVERSITÀ DEGLI STUDI
UCD
DUBLIN
KU LEUVEN
UNIVERSITY OF
WESTERN MACEDONIA
USC
UNIVERSIDADE
DE SANTIAGO
DE COMPOSTELA