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A Pilot Study for Promoting Students' Critical Thinking through an Upper-Secondary Biology Class in Austria

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Abstract

Students need scientific literacy and critical thinking in order to tackle socio-scientific issues appropriately. However, we hardly know anything about the role science education plays in supporting students to develop critical thinking. We plan to evaluate necessary conditions for implementing critical thinking in the science classroom. Therefore, a case study design to monitor adolescent students attending an Austrian upper-secondary academic school class in standard biology and chemistry lessons was developed. The longterm study will cover three school years using a multi-perspective approach. This pilot study was implemented in the area of sex education. Teaching diaries, writing tasks and audiotaped student discussions were qualitatively analysed. The results show that students rarely used prior knowledge and they experienced difficulties when asked to evaluate an ethically controversial subject "critically". The promotion of students' critical thinking is a time-consuming and challenging process, which requires a high level of teacher knowledge and a carefully crafted teaching environment. Science education research needs to put more emphasis on evaluating critical thinking under real life conditions to provide teachers with a clear and understandable concept as well as subject-specific and realisable solutions for teaching practice.

Keywords: *socioscientific issues, ethics, sex education*

1. Theory

According to the Austrian educational standards, science education is supposed to confront students with problems at the interface of science and society. These socioscientific issues are open-ended, debatable, challenging and realistic [1]. They produce a social or moral dilemma and require scientific knowledge as well as moral reasoning or ethical evaluation [1]. Biology, environmental and life science education is offering a variety of socioscientific issues which can be used to stimulate students' reflection on their positioning and structure of thinking. The Austrian educational standards expect students to not only consider these issues, but to make evaluations and decisions. However, students live in a rapidly changing world and the Internet is an important part of their lives offering a vast amount of unfiltered information. In order to tackle these socioscientific issues appropriately they need scientific literacy and critical thinking [2]. Critical thinking is widely considered as a fundamental educational ideal and key to scientific literacy, however, there is too little knowledge about the role science education plays in supporting students to develop critical thinking. Research results indicate that critical thinking is encouraged by precise instructions [3]. In order to explain the concept to teachers and students, we developed a theory-based synergy-model of critical thinking (see Fig. 1). In our model, critical thinking is accompanied by a complex interplay of various characteristics, namely intellectual standards, knowledge, motivation, cognitive skills, and self-regulation, which are interconnected, but do not necessarily build on one another [4]. A thorough involvement with a subject, e.g. a problem or a claim, leads to an individual and alterable positioning. This involvement is controlled by intellectual standards providing autonomy, fairness, accuracy, breadth, depth, rationality, logicalness, relevance and significance [5]. For a thorough involvement, a critical thinker needs domain-specific knowledge [6; 7] and training [8] as well as cognitive skills [9; 8] in order to synthesise (e.g. search, collect, learn), determine (e.g. systematise, categorise, define), evaluate (e.g. judge, analyse, question), interpret (e.g. understand, explain), reflect (e.g. think, deepen) and discuss (e.g. argue, debate) certain aspects. He or she is aware of own values and emotions and has a motivation for truth-oriented problem solving as well as an aspiration for learning and expertise [5; 10; 9]. Finally, a high level of self-regulation [9] affecting all other characteristics is crucial for changing perspective, but also realising something and, as a result, modifying thoughts or actions.

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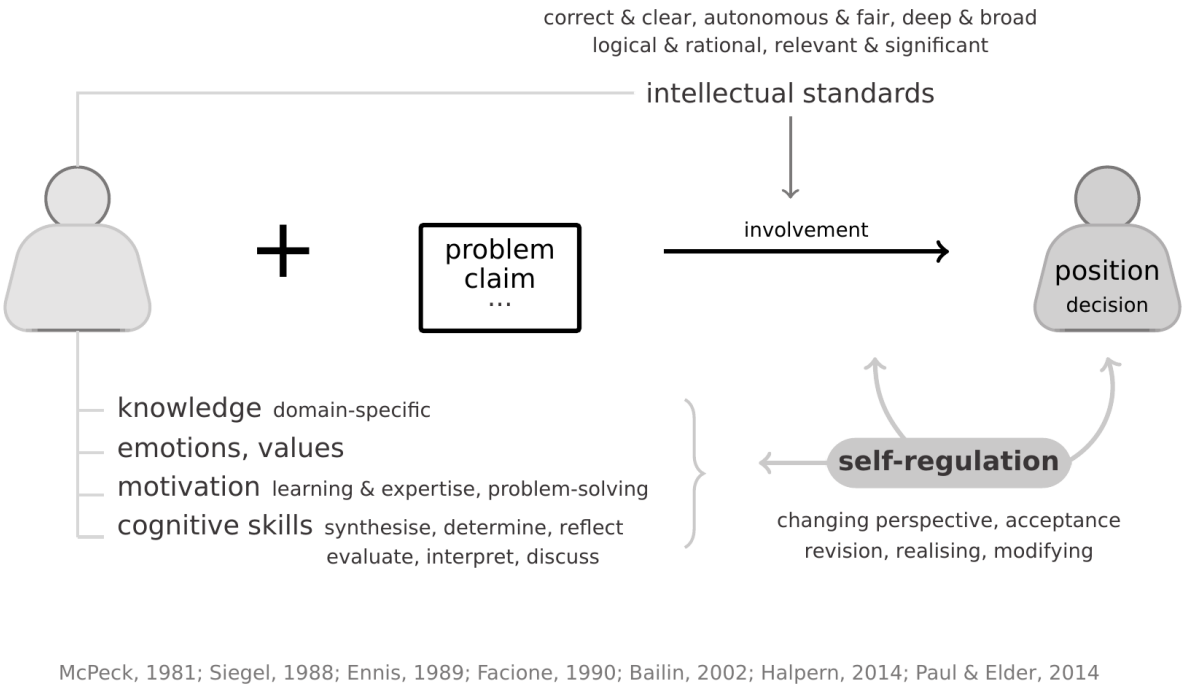

Fig. 1. Synergy-model of critical thinking

2. Study design

Our long-term perspective is to evaluate necessary conditions for implementing critical thinking in the science classroom. For this purpose, a case study design to monitor adolescent students attending standard biology and chemistry lessons in an Austrian upper-secondary academic school class was developed. The longterm study will cover three school years using a multi-perspective approach. We are using a multi-perspective, qualitative approach by collecting and analysing artefacts, such as teaching diaries, lesson plans, the results of writing tasks, class observations, audio-taped discussions and interviews. As a first step (pilot study) students (N = 27; aged 15 to 17) were introduced to the basic characteristics of critical thinking and conditions for implementing critical thinking in the classroom targeted. Therefore, this pilot study put emphasis on three aspects: a) knowledge acquisition, b) interaction with classmates and c) individual and collective reflection. In total, nineteen biology lessons (50 minutes each) were used to engage students with the issues reproduction, development and human sexuality in accordance with the Austrian curriculum for the subject Biology and Environmental Protection. The curriculum emphasises that human sexuality shall be addressed as a biological, social and ethical phenomenon. Accordingly, the teacher (first author of this paper) established knowledge on meiosis, reproductive organs, puberty and secondary sexual characteristics, sexual intercourse and pregnancy as well as embryonic development using sixteen out of nineteen lessons. At the end of this period, students were introduced to the basic characteristics of critical thinking using the model presented above (Fig. 1). These lessons preferred lecturing in dialogue with the students and occasionally on student-centred task-based learning. In the seventeenth lesson, contraception and the morning-after pill were discussed. Thus, a contextual transition to the issue of abortion was made. In the same lesson, nine teacher-selected groups (two to three students per group) were provided with a decision-making framework (Fig. 2), which was prepared by the teacher. The students were asked to read the information on the worksheet and then follow the questions. The teacher emphasised that the questions shall be discussed within the group, but every student should come to an individual decision and a group agreement is not required. Students had about 50 minutes to discuss the questions, take notes and reflect on their own position. In the final lesson, the teacher and the students collaboratively summarised and reflected on the deliberations made during the group discussions. During group discussions the teacher did intervene to address procedural matters or to remind students to focus on their work. The group discussions were audio-taped, the recordings transcribed and then deleted for reasons of data protection. The students were asked to sign a declaration of consent after they were informed about the reason for audio-taping and how their data

will be handled. The transcripts, the worksheets and the teaching diary were examined for common features. Data analysis is still in progress.

Worksheet: Induced termination of pregnancy

Information

Since 1975 in Austria, induced pregnancy termination has been legal under specific conditions (§97 Penal Code). The abortion must be performed by a physician. However, every physician has the right to refuse the procedure, if the pregnant woman's life is not endangered. The abortion is legal up until the sixteenth week of pregnancy (within the first three months of nidation), when required by the pregnant woman, also without medical or psychological reasons. The pregnant woman must obtain consultation before the procedure. Even after the sixteenth week of pregnancy an abortion can be legal, if the pregnant woman's life is endangered or her physical and/or psychological health is at risk. The same applies to pregnant women, who were underaged at the time of conception. Also, an abortion is not punishable by law, where there is a serious risk that the child will be physically or mentally disabled. The termination of pregnancy is realised surgically, through suction or abrasion, or with a drug, which repeals the effect of progesterone. Health insurances do not pay the costs in the amount of approximately EUR 500.

Sources: Austrian Society for Family Planning (ÖGF): http://oegf.at
Austrian public Health Portal (Ed. Federal Ministry of Health and Women's Affairs): https://www.gesundheit.gv.at
Gynmed, Clinic for termination of pregnancy and family planning: https://www.gynmed.at
Federal Law Gazette No. 60/1974: https://www.ris.bka.gv.at

Read the information above. Discuss the questions bellow with your classmates and take notes:

1. Who is involved in an induced termination of pregnancy?
2. Who is affected by an induced termination of pregnancy?
3. Who is allowed to decide on a termination of pregnancy?
4. What are possible reasons behind the desire for a termination of pregnancy?
5. What speaks against an induced termination of pregnancy?
6. Evaluate the paragraph 97 of the Penal Code: Do you agree with it? If yes, why? If no, why not?

Arrange your notes as follows:

collected arguments, perceptions, views, etc.	my position

Fig. 2. Decision-making framework (original in German)

3. Results

Most students needed assistance when asked to consider an ethically controversial subject critically. Without assistance, most students were not making much progress in their discussions, which led to frustration in some groups. Only one group developed a dynamic of exchanging controversial ideas and asked each other for arguments and justifications. In general, students rarely used prior knowledge, got lost in details and experienced difficulties in distinguishing facts from opinions or changing their perspective. Although all students finished sooner than planned most groups used more than half of the time given for private conversations. Many students showed signs of boredom or explicitly uttered being bored. No group reconsidered their work done so far or asked the teacher for help. In every group, at least one student noticed that "nobody knows who we are, so we can talk about whatever we want" or "the teacher doesn't listen to the tape anyway". When they got stuck in discussions or deliberations, many students said things like "let's just write that down and be done with it". It is also evident that their discussions did not match the notes on the worksheets. In audio-taped talks students did not use lessons learnt, struggled in distinguishing facts from assumptions or opinions, had difficulty seeing aspects from another perspective and got lost in details. Worksheets

contained some shorthand notes, no arguments or reasons. The teacher was unsatisfied with the given process of implementing critical thinking in this learning environment, particularly since none of the students used content specific knowledge although this was addressed in recent lessons. In addition, the teacher felt to be pressed for time and doubtful in how to assess e.g. different thinking patterns or train students' self-regulation skills.

4. Discussion

Promoting critical thinking in science lessons is a broadly accepted educational goal in high school curricula, at least in Germany, Austria and Switzerland [11]. However, meeting this objective in the science classroom is challenging, very time-consuming and requires a high level of teacher knowledge as well as the willingness to design and evaluate the teaching and learning environment carefully. This pilot study has shown that students struggled in performing the given tasks, because precise critical thinking instructions were somehow missing and students appear not to be motivated enough to perform at their best. On behalf of the teacher this could be explained by a lack of time available for this purpose as well as difficulties in evaluating individual students learning progress. Students however, hardly ever practise critical thinking holistically Thus they need tailor-made oral and written assistance when practising critical thinking. The decision-making framework appears to be helpful for some students. However most students needed even more detailed instructions. Teachers may put more emphasis on rational aspects such as content specific knowledge when scaffolding student discussions. However, observed students appeared not to be motivated enough to fulfil the task at their best. Perhaps the topic was currently not in their focus of interest or they hold believes such as "an individual opinion" cannot be assessed by the teacher and thus their work will not be graded. Some explicitly mentioned that the teacher will not even listen to their thoughts. The teacher felt doubtful and uncertain in assessing the worksheets, as most of them were short on detail. Challenges became even bigger when asked to evaluate students' argumentation, self-regulation and/or intellectual standards during classroom discussions. Taking the complexity of the task into consideration, we are doubtful that it is enough to simply mention the acquisition of critical thinking skills as an educational goal in policy papers (e.g. curricula). Although promoting students capacity for critical thinking abilities enjoys broad consensus among society, teachers are left alone to deal with its practical implementation. We propose that science education research needs to put more emphasis on evaluating critical thinking under real life conditions and to provide teachers with a clear and understandable concept of critical thinking similar to the model introduced in this work. In addition, it is important to develop and empirically test domain-specific and realisable best practice models and invite teachers to tailor them to their individual teaching practice.

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