Emotions in engineering education: Towards a research agenda

***Abstract*—This Work-in-Progress research paper describes preliminary work on a research agenda for emotions in engineering education. Emotions play an important role for teaching and learning in engineering education, but research on the topic is scarce. To spur research in this area, the authors participate in an international collaboration that aims to map existing research, identify questions that are under-researched, and outline important questions for future research on emotions in engineering education. In this paper, we describe preliminary work that has been done in preparation of an international symposium during which a first draft of the research agenda on emotions in engineering education will be developed. At FIE 2020, we will present both this preparatory work and the agenda itself.**

Keywords— emotions, engineering education, research agenda

I. Introduction

This Work-in-Progress research paper describes first steps towards a research agenda on emotions in engineering education — a topic that is rapidly gaining interest among engineering education researchers and practitioners alike. This surge of interest has been spurred, in part, by a large body of (science) educational research suggesting that emotions are important for learning at all levels of education. For example, emotions may influence learning when students or teachers experience emotions related to a specific content matter or perceived success or failure. Other questions about the role of emotions may relate to mental health issues or students' and teachers' ability to deal with emotions. Yet, despite the importance of emotions for learning, there is a dearth of research on the role of emotions in engineering education.

This contribution aims to address this gap by presenting the outcomes from an international research symposium on emotions in engineering education. The symposium takes place in April 2020 and aims to map existing research on the topic and to develop a research agenda that can stimulate and facilitate future research. At the time of writing, the symposium has not yet taken place. In this paper, we therefore present preparatory work for the symposium and expected outcomes. At the conference, the actual outcomes will be presented.

II. Background

Educational research has shown that emotions "profoundly affect students' and teachers' engagement, performance, and personality development" [1] and there is a growing interest in the role of emotions in education. Most of the research to date has focused on how individual students and teachers experience emotions related to academic achievement (achievement emotions) and how these emotions affect teaching and learning. Lately, researchers have also begun to explore the role of emotions related to the contents of teaching and learning (topic emotions), cognitive learning processes (epistemic emotions), and social interaction (social emotions) (*ibid.*).

Research has also shown that emotions are discipline specific and therefore must be explored in each domain [2]. While research on emotions is scarce in engineering education, there is a growing body of research in science education. Science, as engineering, is often described as a purely rational discipline. Yet, research suggests that emotions are as important in science as they are in other disciplines [3, 4].

As in general educational research, science education research has so far mostly focused on students' achievement emotions, such as anxiety, enjoyment, and interest. More recently, research has begun to explore the role of topic emotions in science education, particularly related to potentially controversial topics such as biological evolution or climate change. Research on teachers' emotions is scarce, but a few studies have explored science teachers' topic emotions [3].

Further, most research in science education has focused on emotions as "individual and private phenomena" [5]. This is also true for research in engineering education: the few existing studies on emotions in engineering education rely on individual and cognitivist perspectives on emotions. The focus of that research is on emotions as individual competencies or experiences, such as empathy [6], shame [7], and frustration [8] (see also [9, 10]). In the broader educational literature, however, there is today an emerging body of research from discourse analytic perspectives that explores emotions as social and cultural phenomena. Researchers in this tradition argue that a discursive focus on emotions is important because individual psychological constructs are made relevant and visible only in and through contextually situated instances of social interaction [11].

During our work with the research agenda, we focus on a broad spectrum of research topics and approaches. We intentionally including emerging topics (e.g. teachers' emotions) and approaches (e.g. discourse analysis). We also strive to identify *blind spots* [12], i.e. topics and approaches that have not yet been researched but hold potential to provide important knowledge about the role of emotions in engineering education.

III. Emotions in Engineering Education Symposium

The original plan for the symposium was to hold a three-day physical meeting at Umeå University with 16 invited scholars from Sweden, Denmark, Netherlands, Switzerland, the United Kingdom, the United States, Australia, and Malaysia. Due to the covid-19-pandemic, the symposium will be held virtually instead.

During the symposium, twelve interactive sessions will be held, each between one to two and a half hours of duration. During the first session, Dr. Alberto Bellocchi will hold a virtual keynote presentation in which he will summarize the current state of research on emotions in science education. Bellocchi in an Associate Professor at Queensland University of Technology, New Zealand, and has many years of

experience in researching the role of emotions in learning and teaching science, and becoming a science teacher. After Bellocchi's keynote, all other participants will hold short (approximately five minutes) presentations about their work on emotions in engineering education. Taken together, the keynote and the presentations will provide a broad overview over existing research.

The remaining eleven sessions will be more interactive and include practical work on the following seven topics: A) Map existing research; B) Identify blind spots in existing research; C) Define the scope of research on emotions in engineering education; D) Map topics of interest for engineering education practice; E) Identify the most urgent questions to address; F) Design the structure of the research agenda; and G) Develop an outline for a publication.

A. Map existing research

We will first summarize participants' presentations from the first session and map participants' research against the overview provided by Bellocchi's keynote. We will then add additional research topics and approaches from the peer-reviewed literature on emotions in engineering education. For this purpose, we conducted a Scopus search on 4 February 2020 with the following parameters: 1. "engineering education" is mentioned in the title, abstract, and/or keywords, and "emotion" and/or "affect" is mentioned in the title; 2. only peer-reviewed journal and conference papers are included; 3. only papers published between 2010-2020 are included. This search returned 123 titles, 98 of which were excluded because they used the term "affect" as synonymous with "cause" rather than "emotion"; focused on general education rather than engineering, science, or STEM-education; and/or focused on learning technology rather than education per se. The final sample included 25 titles.

B. Identify blind spots in existing research

Once we have mapped existing research, we will brainstorm together to identify blind spots, i.e. research that is currently missing. The breadth of participants' cultural, disciplinary, and professional backgrounds will facilitate this process. Participants have backgrounds in, for example, engineering education, science education, educational psychology, psychological counseling, and student career services.

C. Define the scope of research on emotions in engineering education

An important part of developing a research agenda for an emerging field is to delimit the field in terms of what should be in- or excluded. For this purpose, we will discuss what *should* and what *should not* count as research on emotions in engineering education.

D. Map topics of interest for engineering education practice

Engineering education research has a strong tradition of striving to conduct research that is relevant and useful for improving engineering education practice. In line with this tradition, we have developed a survey that aimed to capture engineering educators' thoughts on what could be important foci for research on emotions in engineering education and that could inform discussions during the symposium. The survey questions include the following open-ended questions:

1. Based on your experience, have you found that students' emotions influence engineering education? If so, how and in what kinds of situations?
2. Based on your experience, have you found that your own emotions influence engineering education? If so, how and in what kinds of situations?
3. Based on your experience, have you found a need for any form of support for dealing with emotions in your teaching? If so, what kind of support?
4. Can you think of any specific questions that you as a teacher consider to be most important to explore in relation to the role of emotions in engineering education?

A Swedish version of the survey has been distributed to engineering educators at Umeå University. Eleven educators from different engineering disciplines responded to the survery. An English version has been distributed to engineering educators at University College London (UK), Harding University (USA), École Polytechnique Fédérale de Lausanne (Switzerland), TU Delft (Netherlands), and three different universities in Malaysia. Again, a broad range of disciplines were represented in the sample. Most of the 41 responses to the English version of the survey were from educators at Universiti Teknologi Malaysia and TU Delft. Both surveys were distributed in February 2020.

It should be noted that the survey has not been validated and that the response rate was very low. In addition, instructors who teach engineering ethics were strongly overrepresented in the sample. Thus, we do not claim that the results from the survey are representative for engineering instructors. Instead, we will use the results to identify research needs that we as researchers may not be able to identify without input from practitioners. The survey questions were intentionally designed to be very open to capture a broad range of responses.

During the symposium, we will first map topics of interest for engineering educators that were mentioned in survey responses. We will then combine the results from this activity with the results from our discussions on existing research and blind spots in order to develop a comprehensive overview of research areas that should be included in the research agenda.

E. Identify the most urgent questions to address

From our overview of research areas that should be included in the agenda, we will then identify the most important and urgent research topics and approaches. Importance and urgency will primarily be judged based on potential of the research to contribute to improving engineering education practice in such a way that future engineers will be better prepared to address urgent sustainability challenges, such as the United Nation's Sustainable Development Goals [13].

F. Design the structure of the research agenda

There is no commonly accepted standard format for research agendas and previously published agendas have been presented in very different formats. To design the structure of our research agenda, we will first review a selection of published agendas. We will select published agendas from relevant research fields, such as engineering education research [14] and computer science education [15], as well as agendas from research areas that—like research on emotions

in engineering education—are relatively new and emerging, such as transdisciplinary systems engineering [16] and envirodevonomics [17].

After reviewing these agendas, we will discuss how useful the different formats would be for our agenda and develop a format that we consider appropriate for a research agenda on emotions in engineering education.

G. Develop an outline for a publication

Once we have decided on the structure of the agenda, we will discuss how to present the agenda in a journal publication. The writing of this publication will be done during the months following the symposium and we expect to have developed a first draft of the publication to present at the FIE conference.

IV. Preliminary results

Since the symposium during which the agenda will be developed has not yet been held, preliminary results presented here are based on preparatory work for the symposium: preliminary results from the Scopus search for research on emotions in engineering education and preliminary results from the survey that was sent to engineering educators.

A. Scopus search results

In almost all of the 25 papers that were identified in the Scopus search on emotions in engineering education, the research participants were engineering students in higher education (undergraduate and/or graduate) (Table I). Thus, research on emotions for other participant groups (primary and secondary school students, engineering education faculty and administrators, and engineering professionals) seems to be all but absent in the peer-reviewed literature.

TABLE I. NUMBER OF PAPERS THAT FOCUS ON DIFFERENT TYPES OF RESEARCH PARTICIPANTS

Research participants	*n* papers
Higher education students (undergraduate/ graduate)	21
Secondary school students	2
Primary school students	2
Higher education faculty	2
Higher education administrators	1
Professional engineers	1

TABLE II. NUMBER OF PAPERS PER PUBLICATION YEAR

Publication year	*n* papers
2020	1
2019	5
2018	5
2017	6
2010-2016	7

Further, the search results suggest a slight increase in research activity around 2017. For the years 2017-2019, the Scopus search returned five to six papers per year. For the seven years between 2010-2016, the search returned only one paper per year on average (Table II).

The Scopus search also returned more papers published in conference proceedings (n = 16) than in journals (n = 9), which might be a reflection of the emerging status of research on emotions in engineering education (Table III). Among the conference papers, the majority is published in proceedings for US-based conferences (ASEE, IEEE, FIE, ACM), which suggests that there may be more research on emotions in engineering education in the US than in other areas of the world.

Finally, in the papers retrieved through the Scopus search, a wide range of keywords was used and most keywords were only used once in the entire sample. Those keywords that were used more than once are listed in Table IV.

TABLE III. NUMBER OF PAPERS FOR DIFFERENT PUBLICATION TYPES

Publication type	*n* papers
Journals total	**9**
International Journal of Engineering Education	2
European Journal of Engineering Education	1
Journal of Engineering Education	1
Other	5
Conferences	**16**
ASEE Annual Conference and Exhibition	7
IEEE Global Engineering Education Conference	3
Research in Engineering Education Symposium	2
Other	4

TABLE IV. KEYWORDS THAT WERE USED IN MORE THAN ONE PAPER

Keywords	*n* papers
Emotions	8
Design	4
Engineering/ engineering education	4
Motivation	3
Achievement/ success	2
Entrepeneurship/ entrepreneurship education	2
Learning evaluation/ assessment	2
Programming/ computing	2
Cooperative/ collaborative learning	2
Engagement	2

B. Survey results

1) How do students' emotions influence engineering education?

The respondents described a large range of situations in which students' emotions influence engineering education, such as when student-active and team-based pedagogies are used (e.g. PBL), when students are confronted with controversial topics and uncertainty, when they start courses that they believe to be excessively challenging (e.g. mathematics or programming), during exams, during individual research work (e.g. BSc, MSc, or PhD thesis work), or when they encounter personal problems. While most respondents answered that students' emotions do influence engineering education, some argued that teaching and learning about very technical course content is only marginally influenced by emotions since "there is not much room for emotional responses". In fact, one respondent answered that the "only emotions I encountered was when students thought their grades were not fair!"

Interestingly, some of the responses to this question were very polarized: some respondents who answered that emotions are not important seem to think that the survey questions are "a complete waste of time", while others commented that they found survey difficult to answer because, for them, it so obvious that emotions matter: "I am really struggling with how these questions are formulated. Of course emotions influence the students and the educator, since we are emotional beings."

2) How do instructors' emotions influence engineering education?

Again, respondents described a variety of ways in which instructors' emotions influence engineering education. They suggested that instructors' emotions influenced teaching as well as student learning and that instructors therefore often try to manage how they display their emotions in interaction with students. For example, one respondent wrote that they have received feedback on their teaching about a certain topic, saying that their passion for the topic becomes visible and can serve as "a source of inspiration" to students. Other respondents noted that instructors' emotions may influence course content (sometimes irrespective of the designated intended learning outcomes) and grading.

Respondents also suggested that instructors' emotions are influenced by students' behavior and emotions and that they therefore also try to control students' emotions. For example, instructors can feel upset or "betrayed" when students do not engage with course material in a way the instructor had hoped.

3) Have you found a need for support for dealing with emotions in engineering education?

Interestingly, many respondents answered that they had never thought about this question. Others suggested that any form of professional development activities (not specifically related to emotions) provide support because they offer an opportunity to discuss problematic situations and experiences with colleagues. Many respondents also mentioned that informal talk with colleagues provides sufficient support. Yet others described a need for practical support to deal with a heavy workload rather than support directly related to emotions. They mentioned, for example, practical tools for teaching, a teaching assistant and more time allocated to each course. The fact that many respondents describe a need for general (rather than emotion-related) support suggests that the role of emotions in teaching is seldom discussed explicitly among engineering educators.

Some respondents, however, did provide suggestions for emotion-related support, such as professional development for instructors to learn how to better understand and deal with their own and students' emotions and how to constructively use emotions in teaching.

4) What do you consider to be important questions for future research?

The respondents mentioned a broad range of topics and questions that they would like to see researched in the near future. Some of the questions are already in focus in educational research, such as questions related to how students' emotions affect their learning and what would be optimal emotional states. Other questions focused on how instructors can control their own and students' emotions (or display of emotions) and how they can teach emotional regulation to students. Respondents also wondered how to deal with the large variation of emotional responses among students in large classrooms, how to create safe learning spaces in which students can express emotions, and what kinds of student emotions would be ethical for teachers to evoke in the name of improving students' learning (e.g. anxiety about the effects of climate change or anxiety in learning difficult topics).

Some respondents asked broader, overarching questions, such as how the role of emotions is different in engineering education compared to other educational contexts and whether emotions are "means or ends in education". For example, should instructors strive to *nurture* certain emotions in students, or should they *use* emotions to improve teaching and learning? These are certainly very important questions to address in future research on the role of emotions in engineering education.

V. Conclusions

Emotions in engineering education are an important, but so far under-research area of research. In this paper, we have described preliminary steps taken towards developing a research agenda that can stimulate future research on emotions in engineering education. In our upcoming work with the research agenda itself, we expect to identify many urgent and interesting areas for future research.

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