Pedagogical Focus of Recent Engineering Education Research Papers

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Keywords: Engineering education research, didactic triangle, pedagogical focus

INTRODUCTION

The holistic set of activities carried out in teaching and learning some target contents or skills forms a whole, which is called the *instructional process.* Many concurrent factors affect this process reaching from teachers' and students' characteristics and actions, the nature of the subject matter, the learning environment and teaching organization, to even society-level factors. Because of these multiple, concurrently active factors it is often difficult, if not impossible, to pinpoint any single reason for a particular challenge students or teachers face. Therefore it is an important goal for the community of engineering education researchers and teachers to build a holistic understanding of the instructional process by looking at it from several different viewpoints.

In this paper, we report on a pilot study where we have surveyed recent SEFI papers to identify, which pedagogical aspects of the instructional process have been in the focus of the research. We begin by introducing the analysis tool: the typology of research papers that is based on a multi-layered extension of the classic didactic triangle. We also discuss how this typology differs from other typologies that have been used in classifying engineering and science education research. Next, we proceed applying this typology to 62 research papers published in the EER track in SEFI conference proceedings in 2010 and 2011. The outcome of the analysis gives an example of what kind of results it is possible to get using this typology, including an overview of much and less studied pedagogical aspects of instruction within engineering education research (EER). The specific research question that we aim to answer in this paper is: *Which pedagogical aspects of the*

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instructional process have been studied much and which are the less studied areas in engineering education research?

The less studied areas of the teaching and learning process are particularly interesting since they provide us with ideas for relevant research topics, which will contribute to the holistic understanding.

1. AN OVERVIEW OF EXISTING CATEGORIZATION SYSTEMS

A number of studies have been carried out to categorize EER literature. Several of these studies have covered research topics and various author data [1, 2, 3]. Osorio and Osorio [1] also analysed the generic nature of the paper, i.e., whether the paper presented a project or a research report, a case study or a survey. Wankat [2], on the other hand, also looked at the used theoretical framework, collected data, and citations in his categorization. DeGraaf and Kolmos [4] analysed the research process, categorizing papers based on their empirical analysis methods.

In computing education research researchers have used several different kinds of categorization systems to build an overview of the state of the field. For instance, Fincher and Petre [5] suggested ten research areas that cover the field. Others have used categories, such as, the influence of the paper to the field [6], curricular context, theme and scope of the investigation, and nature of the paper [7, 8, 9]. Yet another branch in categorization studies has considered the used research methods, theoretical frameworks and reference disciplines where the study borrows its theories from as their foci [10, 11].

As a summary, the existing categorisation studies have considered what has been studied (topics, context), how it has been studied (research design and methods related aspects), theoretical framework of the study, and authors of the publications. All previously mentioned categorisations have been data driven.

2. PEDAGOGICAL FOCUS BASED TYPOLOGY

The typology used in this study is based on the didactic triangle, which is a model of the instructional process first introduced by J.F. Herbard in early 19th century [see e.g. 12] (Figure 1 without arrow A visualizes the original didactic triangle). The triangle represents the essential aspects of the teaching and learning process: the two actors, the teacher and the students, the content, and the relations the actors have to each other and the content. The nodes and the relations between them are on a high abstraction level meaning that, for instance, the relation between the student and the content can denote the concrete actions reflecting students' understanding of the content, or it can also represent a more theoretical understanding of this relation.

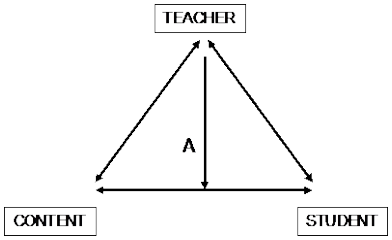

Figure 1 The extended didactic triangle [13, 14].

Even though the didactic triangle is almost a two hundreds years old mental model, it is still a viable and evolving representation. Researchers like Kansanen and Meri [13] and

Kansanen [14] have developed the model further by adding arrows representing the teachers' pedagogical actions (arrow A in Figure 2) and discussing in detail what this relation could mean. In our earlier work we took the model created by [13] and [14] as the starting point and developed it further by adding relations representing the teacher's reflections on his/her pedagogical actions (arrow 7.4 in Figure 2), and students' perceptions of and opinions about the teachers' pedagogical actions (arrow 8 in Figure 2). We also added two new layers to the triangle. The original triangle visualizes the instructional process at the individual or course level. We added two other layers to the model to illustrate what the instructional process means at the teaching organization and society level (or even at the international level).

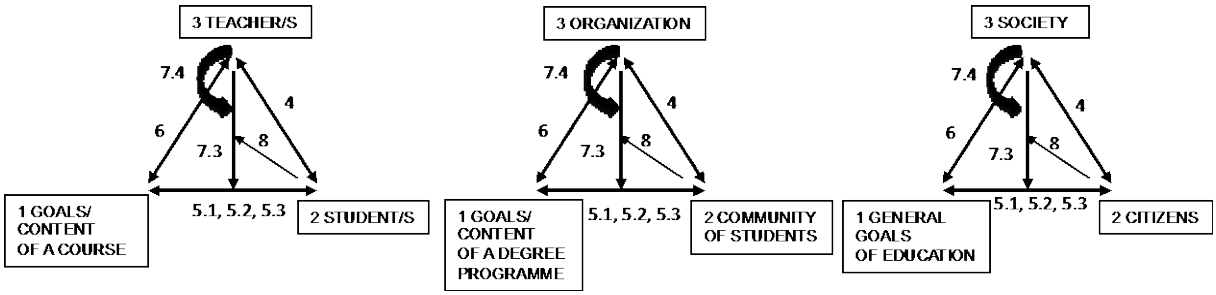

Figure 2 The Multi-layered didactic structure

This multi-layered didactic structure was the base we used to develop our typology. Each node and the relation between the nodes formed a separate category. For instance, Category 1: Goals and content (node 1 in Figure 2), Category 2: Characteristics of a student, Category 3: Teachers' characteristics and so forth. Each number in Figure 2 represents one category in our typology. Further, each category has three levels: course, teaching organization, and society. Therefore, all in all, there are 36 categories. The comprehensive list of the categories is in the appendix and in our previous papers where we have used this categorization system to analyse papers in computing education research [15, 16].

One can used this typology for different purposes. Firstly, it can be used to analyse all/a sample of papers in some publication forum/s to get an overview of the field (like we are using it in this paper). Secondly, one can apply the typology to more strictly defined data sets, such as all papers on a specific topic. This way the result of the analysis would reveal which viewpoints on a certain phenomenon (e.g., drop out) has already been studied and which viewpoints have been overlooked so far. See [16] for an example.

3. PROCEDURE

For this pilot study we used all research papers published in the proceedings of SEFI conference (EER track) in 2010 and 2011. From the total data pool of 62 papers, 56 papers were included into this study. The remaining six papers were considered out of the scope of our typology. The omitted papers typically discussed, for instance, the research methods in engineering education rather than reported results of an actual research project, which would study some pedagogical aspect of the instructional process. Incidentally, the current paper would be considered out of scope in our typology, as it focuses on research only.

During the analysis process both authors read the papers and then categorized them individually. For each paper we listed all categories, which covered substantial parts of the paper, as many papers had content addressing more than one aspect of the instructional

process. We also made a note concerning to whether certain aspect of the instructional process (=category) was strongly emphasized in the paper (main focus) or whether it had a minor role in the paper (side focus). We made our judgment based on the whole paper and not only the abstract or explicitly stated research questions. The analysis we performed can be described as being a type of content analysis. After we had analysed the data individually we compared the results with each other. In the cases where we found differences we discussed the paper together arguing why we had placed the paper in a certain category. We continued the discussion until we were able to reach the consensus on its full categorization. We used descriptive statistics to summarize the results.

3.1 Quality discussion

The categories in this analysis have been derived from a model describing the instructional process. As the model suggests, different aspects of the teaching and studying process are intertwined. Therefore, also the categories that have been derived from the model partially overlap with each other. In practice, this means that during the analysis process there is always some room for discussion whether the paper should be placed in one or the other category or both. To address this aspect we used researcher triangulation to enhance the trustworthiness of the analysis process. During the discussions both researchers had to be able to explicitly argue why the paper belonged to a certain category/categories. In this way we aimed at making our judgement explicit and transparent to better reach the consensus. In addition, one focal aspect of the researcher triangulation was the complementary educational backgrounds of the two researchers. One researcher has a strong background in education and the other one in computer science. Furthermore, both researchers have teaching experience themselves and are experienced researchers in the field of engineering education, especially in computing education research. Therefore, they have both theoretical and pragmatic understanding of the teaching and learning process, which helps when it comes to argue which pedagogical aspect the paper is discussing about.

Finally, the goal of this paper is to get an overview of the distribution of the pedagogical foci among the research papers. The magnitude of the number of certain pedagogical foci is more important than the exact numerical values. Results telling that one aspect of the instructional process is researched in 50% of the papers while some other aspects are studied in only 10% of the papers is of interests in this study rather than differences between 8% and 10%, which could be a result of a yearly variation rather than an indication of differences in trends in the EER field.

4. RESULTS

We found altogether 115 pedagogical foci distributed over 56 papers. The number of foci per paper varied from one to five the average being 2,1 foci/paper. The distribution of the foci among different pedagogical aspects of the instructional process is displayed in Table 1. One of the first notions is that the majority of the papers reported on research that had been done on a teaching organization level. 62% (f=71) of all foci related to the teaching organization level aspect. In comparison, 27% (f=31) of all foci related to course level issues and only 11% (f=13) of the foci related to the society level aspects. At the course level, the foci tend to cluster to students' characteristics (Category 2), learning outcomes (5.3), and students' perceptions of the pedagogical interventions (8) and descriptions of those pedagogical interventions (7.3). At the organization level the coverage of the pedagogical foci is wider. At this level foci tend to cluster to the same foci than at the course level with few additional foci relating to goals and content (1), students'

understanding and actions (5.1 and 5.2), teachers' characteristics (3) and teachers' reflections of the pedagogical interventions (7.4). At the society level most foci can be found in goals and content (1), student characteristics (2) and students' understanding or attitude towards goals and content (5.1), and pedagogical interventions (7.3).

Table 1 Summary of frequencies in each category

	course	organization	society	
Category	**f**	**f**	**f**	**sum**
1 Goals and content	0	6	3	9
2 Student(s)/community of students/citizens of a nation	6	5 (2)	2	15
3 Teacher(s)/organization/society-level educational bodies	0	4	0	4
4 Relation between student(s)/community of students/ citizens and teacher(s)/organization/society-level educational bodies	1	1 (2)	0	4
5.1 The understanding of and attitude about goals and content that the student(s)/community of students/ citizens have	2	5 (1)	4	12
5.2 The actions (e.g., studying) the student(s)/ community of students/citizens do to achieve the goals	2	7	0	9
5.3 The results of the action of the student(s)/ community of students/citizens	4	6 (1)	1	12
6 Relation between teacher(s)/organization/society and goals/content	0	1	0	1
7.1 The conceptions of teacher(s)/organization/ society of students' understanding of/attitude to goals/content.	0	1	0	1
7.2 The conceptions of teacher(s)/organization/ society of students' actions towards achieving goals	1	0	0	1
7.3 Pedagogical activities	8 (1)	14 (2)	3	28
7.4 Reflections of of teacher(s)/organization/ society of the pedagogical actions	1	5	0	6
8 Relation between student(s)/community of students/citizens and teacher's/ organization's/society's pedagogical means to enhance learning	3 (2)	8	0	13
sum	31	71	13	115

note. Frequences in brackets refer to the number of the side foci

If we look at the results from the pedagogical foci (categories) point of view, we observe that student related aspects (Category 2, part of Category 4, Categories 5.1, 5.2, 5.3, and 8) are studied extensively. 56% (f=64) of all found pedagogical foci are related to students. Students' perceptions and attitudes towards goals and content (5.1), students' actions (5.2) and learning outcomes (5.3) are studied most. 29% (f=33) of all foci are related to these aspects. Students' characteristics (2) and how students perceive or feel about the teachers' pedagogical interventions (8) are studied to a moderate degree.

Engineering teachers' pedagogical actions (Category 7.3) are rather well presented in the data. 34% (f=28) of all foci related to teachers' actions. Before we make conclusions on this result, we remind that descriptions of how the course/degree programme was organized or what was the assessment policy in the course were placed in the Category 7.3. Most papers in this category did not explicitly discuss the characteristics of the teacher

or the teaching organization. If they did, the paper was placed into some other teacher related category, in addition to Category 7.3.

The other teacher related aspects (Categories 3, part of category 4, Categories 7.1, 7.2, and 7.4) were hardly represented in the data. Only 12% (f=14) of all pedagogical foci we found in the data discussed the characteristics of teachers/teaching organizations or educational bodies of the society or teachers' perceptions of students' relation to the goal and content. Another less studied area of the instructional process is goals and content. Only 8% (f=9) of all foci related to this aspect.

In summary, various aspects of students are unsurprisingly the most studied part of the instructional process. Teachers' characteristics and their perceptions, as well as goals and content are studied to a much lesser degree. For instance, teachers' relation to the goals and content, and teachers' perceptions of students' studying process are almost non-existent in this data pool.

5 DISCUSSION AND CONCLUSIONS

In this paper we have introduced a typology that can be used to categorise research papers in the field of engineering education research. The results of our pilot study show one example how the typology can be used and what kind of results it is possible to obtain by using it. The summary of our results gives an overview of which pedagogical aspects of the teaching and studying process recent SEFI papers have focused on - and more importantly - which are the overlooked aspects of the instructional process. Based on the limited data set of the study, engineering teachers in general are studied much less than some other aspects of the process. Similarly, goals and content are studied only in few cases. Since the goal and content and the teacher/teaching organization do have a central role in the teaching and studying process, they should be taken into account when studying systematically the instructional process related phenomena.

The results of this pilot study corroborate to some degree previous studies on computer science education research [16]. In both fields, it seems that teachers and goals are overlooked research topics compared to students. Our on-going study on science education research papers indicates that the same trend of how pedagogical foci are distributed can also be found in that field. Therefore, it seems that engineering education researchers have similar research interests and that they overlook the same topics than researchers in the computer science education and science education.

Further studies with larger data set and several publication forums are needed to see if the current results indeed reflect the state of the recent engineering education research. It would also be interesting to do a literature review on some specific EER related topic and analyse the papers using this typology to see if the results can provide ideas for new viewpoints to the topic. Another future research topic would be to combine the typology introduced in this paper and some other paper categorization system. For instance, it would be interesting to know which research methods or theories have been used to study different aspects of the instructional process.

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APPENDIX

Table 2 List of the categories

Category name (the number of the category corresponds the number of the node/arrow in Figure 2)	**Definition**
1. Goals and content of the course/curriculum/ education at the society level	Research papers that discuss the goals or content of a course, study module, goals of a degree program, or even the goals of the general education will be placed into this category.

2 Student(s)/community of students/citizens of a nation	Research papers that highlight the characteristics (e.g., gender, level of education) of students' or community of students or citizens (e.g., certain cohort of people) belong to this category.
3. Teacher(s)/organization/society-level educational bodies	Papers that focus on the characteristics of teachers', the teaching organization or the society level educational bodies are place into this category.
4. Relation between student(s)/community of students/ citizens and teacher(s)/organization/society-level educational bodies	Research that discusses how the students/community of students perceive the teachers or the teaching organization or the educational bodies of the society is place into this category (e.g., studies on how competent students think the teacher is). Similarly, the papers, which focus on how teachers perceive students belong also to this category.
5.1 The understanding of and attitude about goals and content that the student(s)/community of students/ citizens have	For instance, papers that discuss the variation in students' understanding of a central concept at the course belong to this category. Similarly papers that study how interesting students/possible future students find the topic/degree program/certain occupation are placed in this category.
5.2 The actions (e.g., studying) the student(s)/ community of students/citizens do to achieve the goals	Students' actions include all actions/lack of actions that are in relation to achieving the goals and learning. For instance, studies on how much time students use for studying or what kinds of resources they use belong to this category
5.3 The results of the action of the student(s)/ community of students/citizens	This category emphasises the outcome of the studying process. For instance, studies that discuss the learning outcomes after using a new teaching method would be placed into this category.
Relation between teacher(s)/organization/society and goals/content	Studies discussing how teachers understand, perceive or value different aspects of the goals and content belong to this category.
7.1 The conceptions of teacher(s)/organization/ society of students' understanding of/attitude to goals/content.	This category includes research papers that focus on how teachers think about students' perceptions and attitudes towards goals and content. For instance, studies on what kind of knowledge teachers have on students' understanding of some central concept/process in the course would be placed into this category.
7.2 The conceptions of teacher(s)/organization/ society of students' actions towards achieving goals	This category is similar to the previous one. The difference is that research papers that are in this category are focusing on teachers' perceptions of the students' actions.
7.3 Pedagogical activities of teacher(s)/ organization/ society	This category focuses on the teachers'/teaching organization's/society's pedagogical actions, e.g., lecturing, providing guidelines and framework for studying, providing incentives or financial support for students.
7.4 Reflections of teacher(s) /organization/ society of the pedagogical actions	Papers where teacher or the teaching organization or the society reflects on the pedagogical actions it has taken. E.g., the teacher's reflection on how well the course was organized.
8. Relation between student(s)/community of students/citizens and teacher's/ organization's/society's pedagogical means to enhance learning	This category includes research papers that discuss, for instance, how the students feel about the teachers' pedagogical actions. A course feedback is one example of the type of data that could be used in the papers in this category.