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Report EUGENE Line B.

Taxonomical classification of EER papers

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Abstract

This paper presents a taxonomy for classifying EER papers. The taxonomy includes the following dimensions for categorizing research: theoretical background of the paper, general research strategy, type of collected data, data analysis methods, and the general type of paper (research paper, case report, position paper). The taxonomy also allows recording how explicitly the paper presents these aspects. We have used the taxonomy to analyse a set of papers from central European forums of presenting EER: two years of volumes of European Journal of Engineering Education, and the EER track of the SEFI conference.

1. Introduction

Engineering education research is a wide and rich field of investigation. It covers research on learning and teaching not only in all engineering disciplines but also in supporting sciences, like physics, chemistry, computing and mathematics, which form the scientific base of engineering research. On the other hand, EER also applies theories and research methodologies from social sciences, like education, psychology and sociology to investigate many-faced aspects of learning and teaching engineering.

In order to get an overview of the whole field, there is a need to look at both *what* is being researched and *how* the research is carried out. This paper focuses on the latter aspect. We aim at building a big picture of how EER is carried out, regardless of the topic of teaching/learning. By doing our analysis of the selected publications we would like to highlight some of the factors that make the publications to meet the scientific standards (e.g., proper evaluation of the effectiveness of the pedagogical innovations vs. anecdotal notions that “students seemed to like it”). We believe that emphasizing various aspects of scientific inquiry and how they are reported in publications will a) encourage writing publications which more useful/reliable to the reader, and b) helps to raise the status of EER as a rigorous and respectable research area among other sciences.

To enable such investigation we have looked at publications in the field, and built a taxonomy for describing various aspects of the *research process* reported in the publications. This includes the following aspects:

- Theoretical background, on which the paper is built

- Types of research questions and research paradigm or general research design how they are addressed
- Type of collected data and subjects of study
- Methods used to analyse the data
- How these aspects of the research process have been reported in the paper.

We recognize the richness of the papers published in the field. There are papers that focus on investigating a clearly defined change in, for example, a teaching or assessment method. There are papers that survey a wider setting, for example, student success in a curriculum. There are papers reporting on-going development of a course, papers defining new curricula or course syllabi. And there are papers, which address relevant themes in Engineering Education with the aim of raising awareness and discussion of current or future challenges. As the purposes of these papers differ from each other, it is natural that they do not always include the same dimensions as the full taxonomy covers. We therefore have included a separate dimension, which tries to capture the full nature of the paper, such as research paper, theory paper, case report or position/proposal paper.

Novel ideas often emerge first as case reports that describe the rationale for new development, and present initial results of its evaluation. The purpose is to bring the idea to the awareness of a larger community, and the data collection and analysis aim more at demonstrating the feasibility of the new idea than building strong evidence that could be generalized in wider settings or gaining deep insight on what is actually happening in the investigated phenomenon. Such evidence and deeper knowledge can be presented in subsequent research papers in more rigorous settings. Typically quantitative analysis and results can provide evidence for generalizing the idea into other contexts and qualitative analysis can provide better understanding of an investigated phenomenon, such that is above personal opinions and experiences of a single teacher or researcher. It is important to recognize that without proper data collection and analysis these kinds of conclusion are not possible to achieve.

When presenting the taxonomy, we must ask ourselves, who could benefit from this? We see several aspects that could support building the EER community. First, a general awareness of the richness of the field will be increased, if we can show in numbers the how various research paradigms are applied in the field, what kind of theories are used as frameworks, and how data is analysed. Moreover, the taxonomy could be used as a measurement tool to reveal differences between various publication forums, thus giving suggestions for authors where to submit certain types of papers. Furthermore, it could make visible hidden trends or emerging research paradigms in the field. By clarifying the difference between case reports and research papers, we can also point out how scientific level of papers should be increased when we aim at more generalizable results and deeper insights. The taxonomy could also be used as a reference when the publication forums are defining review criteria for different types of papers. At the moment we see it clearly problematic that the review criteria in many conferences and also in some journals do not give clear enough guidelines both for authors and for reviewers what is expected for the papers. Finally, as EER is gradually gathering recognition as an emergent field moving from the margins to the mainstream (Streveler and Smith 2010, NEERC 2006), a taxonomy can help to provide a map of the terrain for new scholars entering the field.

2. Literature study

To allow comparison with computer education research (CER) classification papers, we could partially apply classification schemes developed in that area. See (Malmi et al. 2010, Simon et al. 2008a, Vessey et al. 2005) for the classification schemes and (Glass et al. 2004, Simon 2007, Simon 2008b, Simon et al. 2008c) for some results see Wankat, 2004).

3. Taxonomy

The taxonomy categorizes research in several dimensions. Basically we consider the dimensions independent of each other, but we recognize that certain research paradigms prefer certain types of collected data and analysis methods.

3.1 Explanatory framework dimension

Neither research nor practical development takes place in isolation. We are building on previous work by other researchers and practitioners. This is the basic premise of all academic work. Scholarly work should also always recognize the premises of one's work and methods. Equally important is to give credit to others' work on which we are building our own work by mentioning this in the text and properly referencing their publications and works.

The explanatory framework dimension aims at making it visible how the target publication is linked to previous work (Jolly 2011). An obvious choice here would be to look at the referenced papers and reports, how those works have been used in the analysed paper. This, however, brings us two practical problems. Firstly, analysing referenced works and their relation to the target publication is simply beyond the resources we have for such work. Moreover, such work would overwhelm us with details. What we wish to seek is to get a broader and coarser picture of what are the most relevant areas and works on which EER builds on.

Therefore, we limit our investigation to such conceptual constructs that we expect to be known in a wider community of EER researchers. These constructs, which we call *Explanatory Frameworks (EF)*, can be, for example, the following:

- *Theory* can refer to well-established theories, such as constructivism, situated learning, or cognitive load theory.
- *Model / framework / taxonomy / formal construct* refer to established conceptual constructions, which are not generally called theories. Some examples could be Bloom's or Solo taxonomies, concept maps, IEEE curriculum definitions, pedagogical patterns.

Very often papers build on previous research, which does not have an established widely known status, in various ways. These could be:

- Using previous work as motivation. For example, addressing open questions, which were identified in other publications.
- Extending previous research to a new data set or reanalysing previous data sets in a new way
- Using previous results as a starting point for new research.
- Applying a methodology, which was developed in another paper.

To simplify the analysis we do not classify the latter types of references, but list only such EFs that we consider well-known within EER community. Though, at the same time we recognize that "well-known" is an ambiguous concept, and thus needs to be negotiated.

We also do not list links to technical tools or frameworks. There is a multitude of such applied in EER, as engineering is about designing, implementing and applying technologies. Neither do we classify methodological references here, such as phenomenography, content analysis or various statistical tests or analysis methods. The methodologies are captured by other dimensions.

Each EF is counted with face validity. If the authors claim they are using it, we do not question this, as we can analyse in reasonable time only the publication we have.

We do not report EF's, which are not explicitly mentioned in the paper, i.e., we do not try to interpret from the paper whether the work is based on some EF.

3.2 Research strategy dimension

There are many different ways how research is carried out. Here we differentiate the general research design from more detailed level data analysis methods. The former captures the choice of research questions and how they are generally approached, while the latter concern the concrete analysis methods used in processing collected data. Here we face a problem which terminology we should use for the wider design of the research. In some contexts, we could use here either term *research paradigm* or *research approach* but these are not used in all cases we cover, and especially the term paradigm is a too wide concept for us. On the other hand, the term *research design* typically refers to a rather detailed description of the research setting. (Malmi et al, 2010) used a term *research framework*:

Research framework "...is an overall orientation or approach that guides or describes the research, as opposed to a specific method or technique. A research framework may have associated theoretical, epistemological, and/or ontological assumptions (e.g. phenomenography), may prescribe or suggest the use of particular methods (e.g. grounded theory), or may simply be a descriptive term for a kind of research activity that has certain characteristics (e.g. action research, case study). Not all papers will have a research framework."

A similar dimension has also been proposed by several other researchers, though with different names: *emerging methodologies* (Case and Light 2011), or *research strategies* (Chism 2010). Also Merriam (2002), Creswell (2007), and Denzin and Lincoln (2005) present a similar type classification for methodologies. We will adopt the term *Research Strategy*, instead of Research Framework, to avoid confusion with Explanatory Framework.

We use the following set of research strategies, though we recognize that the list can be extended in the future¹. The definitions are from (Malmi et al., 2010)², clarifying comments have been added.

- Action Research (AR)
 - A self-reflective systematic inquiry undertaken by participants to improve practice. Typically conducted as an iterative cycle of planning, action, change and reflection.
- Case Study (CS)
 - A case study is an in-depth, descriptive examination conducted in situ, usually of a small number of cases/examples.
- Constructive Research (CR)
 - Research that aims to demonstrate and/or evaluate the feasibility of a proposed idea (concept implementation; proof-of-concept research). Revolves around the development of, e.g., software, technology, a teaching approach, or an evaluation instrument.

¹ Some possible extensions could be, if encountered in EER literature, discourse analysis, narrative analysis, and critical research. Merriam (2002) lists also *basic interpretive research*.

² Research strategy may imply epistemological and/or ontological assumptions which are highly relevant for interpreting the results.. However, very few papers say anything about these; thus, we do not list them separately but let them stay as implicit data.

- Delphi
 - Seeking consensus by showing a group of raters a summary of their ratings, with justifications, then iteratively inviting them to reconsider their ratings in the light of what the others have said.
- Ethnography (Eth)
 - A branch of anthropology that deals with the scientific description of individual cultures.
- Experimental Research (Exp)
 - Quantitative research based on manipulating some variables while varying and measuring others. This requires formation of control and experimental groups of participants with random assignment of participants or use of naturally formed groups.
- Grounded Theory (GT)
 - Qualitative, data-driven research in the tradition of Glaser and/or Strauss that aims to formulate theories or hypotheses based on data.
- Phenomenography (PhG)
 - Investigation of (other) people's ways of experiencing a phenomenon (2nd order perspective).
- Phenomenology (PhL)
 - Investigation of one's own experience of a phenomenon (1st order perspective).
- Survey Research (Survey)
 - Quantitative research based on exploring the incidence, distribution and/or relationships of variables in non-experimental settings.

Each explicitly mentioned research strategy is counted with face validity. If the authors claim they are using it, we do not question this.

Contrary to EFs, we however, distinguish between cases where the authors explicitly mention some research strategy (though probably they do not use this term but say, for example, that they were carrying out action research), and cases, where we conclude from the report that some research framework was used. The reason for this is that mentioning a research strategy / framework / paradigm / approach is not a common convention. For instance, we record case study as one research strategy, but many times this is not explicitly written in a paper.

In summary we give research strategy an additional tag “explicit”, “implicit” or “none” if no research framework can be identified in the paper.

3.3 Data source dimension

Data collection implies what kind of data has been used in the empirical part of the work. Most papers have at least one data source, but very often include several. Examples of categories in this dimension include the following (the list is not exhaustive):

Do we need so detailed source descriptions?

- Students' submitted work (essays, project reports, learning diaries...)
- Examinations
- Questionnaire data
- Interviews
- Observation data
- Databases (e.g. study register data)

- Software log data
- Researchers' own experiences (e.g. "lessons learned")
- Literature (e.g. literature reviews, meta-studies)

Instrument is a special case of questionnaire. It is an established questionnaire, which is used to measure some aspect of human behaviour, such as Myers-Briggs personality test. We list such instruments, if encountered as they are useful tools in many aspects of EER and we wish to promote their wider application, instead of building similar tools ad-hoc.

Collected data is in most cases explicitly explained in the papers, and there is little room for interpretation. We thus list the data sources we recognize, expect for those papers that have no data collection at all. An example of such a paper is a paper that describes new learning resources for a specific course, or suggestions for curriculum requirement, without any analysis.

Typically most papers report some of researchers'/teachers' own experiences and reflections. However, we report them as data source only if their share of the paper is significant compared to other collected data.

Another aspect that we look at is whether the data collection is "*intrusive*" in the sense that target group members have to carry out some additional activities that they would not perform otherwise. Such data would include, e.g., targeted questionnaires, interviews, pre/post tests, and specially tailored exercises. The opposite is "*natural*" data, which can be collected without such intrusion, like student register data, students' submissions (unless they are given research specific assignments), and normal examination results. We though recognize that this distinction is not always clear, as for example, when a normal examination has specifically tailored questions, or when the class carries out a pre test to identify their current knowledge level. We list this information (research / natural) with each data source separately.

Finally, we list what is the *scope* of data collection (as a whole), i.e., has it been carried out in the *individual level*, *group level* (like classroom, student group in one course/unit, whole course/unit), *institution level* (curriculum, program, university, ...)³ or *multi-institutional level* (many universities, whole country, ...)

3.4 Data analysis dimension

Data analysis method describes how empirical research data was analysed or what other means were used to draw conclusions in the paper. Most papers have at least one kind of analysis method. If a paper has a research framework, the framework often directs the analysis methods that are used. However, the same analysis method can, of course, be found in a paper that is applying some other framework or has no specified research framework at all.

The number of possible analysis methods is extensively large and we need to gather them into coarse categories. Malmi et al. (2010) listed the following categories: statistical analysis (with tests of significance), explorative statistical analysis (exploring relations of variables without such tests), descriptive statistics, mathematical proof, interpretive classification, interpretive qualitative analysis, conceptual analysis and plain argumentation. De Graaf and Kolmos presented another classification

³ Note: The terms *course*, *unit*, *program* have different meanings in different contexts. Here course or unit means an instructional whole, which deals with one topic, like programming or mathematics, and has a duration of several weeks or a semester. Students take several courses per semester. A program is here an educational whole, after one gets a degree, e.g., Bachelor program in engineering.

scheme in their paper (2010) where they presented an analysis of papers published in European Journal of Engineering Education in 2008 and 2009. They identify methodologically the following different categories for such papers which deal with research data; thus literature reviews and pure case descriptions are excluded: Development case “reports systematically on the construction of the case”, followed by Qualitative descriptive, Qualitative enhanced, Quantitative simple, Quantitative complex, and Mixed methods papers.

There is clear overlap with the Analysis method dimension by Malmi et al. and this one.

Malmi et al.	De Graaf & Kolmos
statistical analysis	quantitative complex
explorative statistical analysis	quantitative complex
descriptive statistics	quantitative simple
mathematical proof	NA
interpretive classification	qualitative enhanced
interpretive qualitative analysis	qualitative enhanced or simple
conceptual analysis	NA
plain argumentation	NA
NA	development case

If we want to combine these, we can see that the difference of statistical analysis and explorative analysis is not highly significant and these could be merged, whereas it is important to have separate category for plain descriptive statistics. In qualitative research we can use a matching that interpretive classification (i.e., content analysis) and such qualitative methods, which have a clearly described analysis process are summarized as qualitative enhanced, whereas those papers which claim to have analysed qualitative data but do not give any clear enough process, are qualitative simple. However, such a distinction is not wholly clear, and borderline cases needs to be discussed.

In computing education research, mathematical proof and conceptual analysis were very rare methods, and it can be expected that the same holds for EER papers. Therefore these can be included within category Other which covers them when in need and possible other rare methods.

Finally, development case is a concept, which does not overlap with Analysis method but rather it overlaps with Constructive research in Research framework dimension. Such papers describe a novel approach, which may be technology, tool, teaching method, assessment method, or even new research method. Typically there is argumentation to support the new developed approach, and very often some data is collected to validate the approach. The data analysis, however, may be shallow, like student

feedback survey, technology evaluation (comparison with similar technical solutions) or some simple descriptive statistics.

As a summary, the following categories cover the data analysis method dimension:⁴

- Quantitative complex
 - Any statistical methods which exceed simple descriptive statistics, such as statistical tests, correlations, regression analysis, factorial or cluster analysis, data mining techniques, ...
 - If you find a p-value, the paper uses complex method
 - As almost all papers using some complex method include also descriptive statistics, we list them as quantitative complex only
- Quantitative simple
 - Descriptive statistics including cross tabulation and nothing else
- Qualitative enhanced
 - Any qualitative methods which have a clear analysis process
 - As there are many, many different qualitative analysis methods available, we focus here on the questions: does the method used in the paper have a name, or is it reported to such aspect that that it could repeated?
 - Examples: content analysis, phenomenographical analysis, analysis based on grounded theory, narrative analysis, typological analysis,...
- Qualitative simple
 - Qualitative analysis which only includes identifying important themes / topics / items of interest, without specifying a method.
 - EER papers have rather often qualitative results, which illuminate anecdotal evidence or feedback from a target group. If the report only gives the results, typically associated with subtitles, we categorize the method as Qualitative simple.
- Other
 - Other methods
- None
 - Plain argumentation and using one's own reflections as a kind of analysis methods are counted here, as well.

A paper can include several of above and we list all that we recognize regardless of whether it is explicitly stated or implicitly included. Based on that it is easy to derive whether the paper is quantitative / qualitative / mixed methods paper. We do this kind of conclusion afterwards. In the initial paper analysis phase we list all method types we identify in the paper.

3.5 Reporting dimension

Reporting the research setting and process is a central part of good scientific communication. We can make observations on the text fairly easily on the following aspects:

1. Research questions

⁴ Gavin pointed out that these names (simple, complex. Enhanced...) may be considered judgements. This may be true, but let us keep these and change, if considered necessary when we write the paper.

- a. Research questions / research goals *explicitly emphasized* in the text and they are easy to identify.
 - This means that they can be found easily with some visual cue, such as within bullet or number lists or *italicised* within other text.
 - b. Research questions / goals can be found among other text, typically in introduction or in the beginning of section which describes the paper contribution. (*implicit*)
 - This means that we can identify some text in the paper, which presents the goals of the research and/or questions to which the research seeks to answer. We do not require that these are presented as questions, but may be written as ordinary text.
 - c. No research question or goals can be identified in the text. (*none*)
 - We cannot identify any text presenting the goals of the paper, either in abstract, introduction or before the method/results section.
2. Methodology section
- a. Methodology has clearly its own section in the paper (*explicit*)
 - This can be identified based on subtitles.
 - b. Methodology is implicitly described within other text, typically in the results section (*implicit*)
 - We can identify that there is text that presents the methodology used, regardless of where it is in the paper.
 - c. No clear methodology description can be identified in the text (*none*)
 - We cannot identify any text, which would present a methodology. Perhaps, only results are given.
 - Note, some educational technology papers may not have a method description, as the method is, for example, designing and implementing the software, which is considered uninteresting to report. It is a different situation, if the method includes collecting data from potential users, to build a specification, and thereafter present the tool.
3. Validity discussion
- a. The paper has a separate section / subsection discussing the validity/generalizability/trustworthiness/limitations of the research (*explicit*)
 - Such a section can be identified from the subtitle.
 - b. The paper has some critical discussion of some of these issues in the text, typically in the results section or conclusion. (*implicit*)
 - We can find critical discussion of limitations of the paper regardless of where it is, and whether it in one or several places in the text.
 - c. No such critical discussion can be found or it is very vague. (*none*)
 - We can find nothing about this, or the criticism is very vague.

These results can give us data, which strongly supports the goal of building recommendations to improve scientific writing in the EER community.

3.6 Nature dimension

Finally, the nature dimension tries capture the general character of the paper as a whole. Simon (2008a) identified the following five types of papers:

“

- An *experiment* paper is one that reports on a scientific-style experiment, with control and experiment groups and controllable variables. Papers of this sort are understandably rare in

education, as it is not generally feasible (or ethically justifiable) to split a class into groups and treat each group differently. Even so, examples can be found, such as “Pattern oriented instruction and the enhancement of analogical reasoning” (Muller 2005).

- A *study* paper reports on an experiment in the looser sense of the word. A hypothesis is formed, a study is devised and conducted to explore the hypothesis, and data is gathered from the study and analysed. An example is “What does it take to learn ‘programming thinking’?” (Eckerdal 2005).
- An *analysis* paper reports on analysis performed on pre-existing data, such as students’ results in a course over several years. A hypothesis is formed and the existing data is analysed to explore the hypothesis. An example of this would be Warren’s question (Fincher et al 2007), which analyses postings to a mailing list.
- A *report* paper focuses on informing the reader about something that was done, typically in the classroom. Report papers often describe innovations, and sometimes describe the adoptions of innovations already reported elsewhere. An example is “What do students know? An outcomes-based assessment system” (Winters and Payne 2005).
- Finally, a *position/proposal* paper presents a position that outlines the authors’ beliefs on a particular matter, or describes a proposal to carry out some work. In either case, no work has yet been carried out, so such papers do not report any results. On models of and for teaching: toward theory-based computing education (East 2006) is an example of a position paper.

“

As the first three categories are already captured by research framework dimension, we combine them into one. On the other hand, we recognize another type of paper that is not covered by Simon’s categories: a paper that discusses theoretical aspects of learning and teaching and does not have an empirical part.

We categorize the nature dimension, as follows:

- *Empirical paper* is a paper, which has the basic elements of empirical research, including clear data collection, analysis and reporting results. The paper may or may not have hypotheses. Data analysis may be based on quantitative or qualitative or mixed methods.
- *Case report* describes a novel educational setting, such as new teaching method, assessment method, learning resource, learning specific software, etc. The focus of the paper is in describing the new contribution. There is no evaluation, or the evaluation is very shallow typically reporting some student results, student feedback and/or teacher’s experiences with no clear research setting (such as comparison to previous year).
 - A case report typically has a small scope, related to some specific course and the research setting and method aspect of the paper is vague – the focus is on the novel thing, whether it be teaching method, software or something else. The focus of the paper is to improve practice.
 - A case report is never a survey or an experimental paper, or has some advanced qualitative research strategy, like phenomenography or grounded theory. Very often it can be categorized having constructive research strategy.
- *Position paper / Proposal* is paper where the authors want to raise some issue for discussion among EER community or propose some new to be considered in Engineering education practice or EER.
 - There may be but it is not necessary that there is empirical data to support the claim.

- *Theory paper* discusses theoretical aspects of teaching and learning, for example, compares some learning theories in some context. The paper is based on theoretical discussion and argumentation and has little or no empirical data to support its claims.

Here we do not distinguish whether the nature of the paper is explicit stated or implicit, as this is basically our interpretation of this issue. All papers have some nature. We, though, do not analyse editorial papers.

4. Final notes

We are not reviewing papers again. We assume that the papers have been reviewed and we only analyse what is written in the paper.

We are not judging quality of research but classifying what has been reported about the research.

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