Aalto University
School of Science
and Technology

Why, What and How Are We Doing Our Research?

Lauri Malmi

Aalto University, School of Science

CSEDU 2011

Aalto University

- Aalto University
  - Formed 1.1.2010 by merging
    - Helsinki University of Technology
    - Helsinki School of Economics
    - University of Art and Design Helsinki
- Second largest university in Finland
  - 20000 students
  - 4000 staff members
  - 3 campuses in Espoo and Helsinki

Learning + Technology
LETECH group

- Established 2000
- Currently
  - 1 Professor
  - 1 Senior researcher, 1 Postdoc
  - 6 full time PhD students
  - 2 teachers & PhD students
  - Several MSc. students

Main areas of investigation

- Development of advanced learning environments / (software) tools for programming education
  - visualization tools
  - automatic assessment of / feedback on exercises
  - visual simulation tools
- Evaluation studies of the developed LEs
- Investigation of students' understandings of programming concepts and processes
- General purpose educational technologies

Contents

- Motivation for this work
- Research process and paradigms
- Categorizing research
- Observations on publications in computing education research and educational technology research
- Suggestions for future research in the field
  - research design, writing papers, research training

Motivation

- My own research background for my PhD
  - MSc in Computer Science, majoring in software technology
  - PhD research in database algorithms
  - Research = ”solve technical problems, design new algorithms, implement them and analyze their time complexity”.
  - No formal research training. Doctoral courses mostly covered novel software technologies.
  - ”How to do research” was learned from supervisor’s examples and discussions with colleagues.

Motivation cont.

- Change of field
  - Moved into designing software to support computing education in late 90's.
    - Especially visualization and automatic assessment tools for programming education
  - Here design/implement the software solution was not enough.
    - For writing specifications we need to understand the problems our students have
      - How to collect and analyze data on this?
  - Some theoretical framework from education is needed to interpret data
  - Evaluating the educational impact of software tools calls for appropriate research settings, data collection and analysis methods

Motivation cont.

- How to support PhD students working in the field, when their background is in computer science?
- Currently supervising 8 students with varying topics within computing education research and educational technology.
- What should I teach them about doing research? And how?

Question:

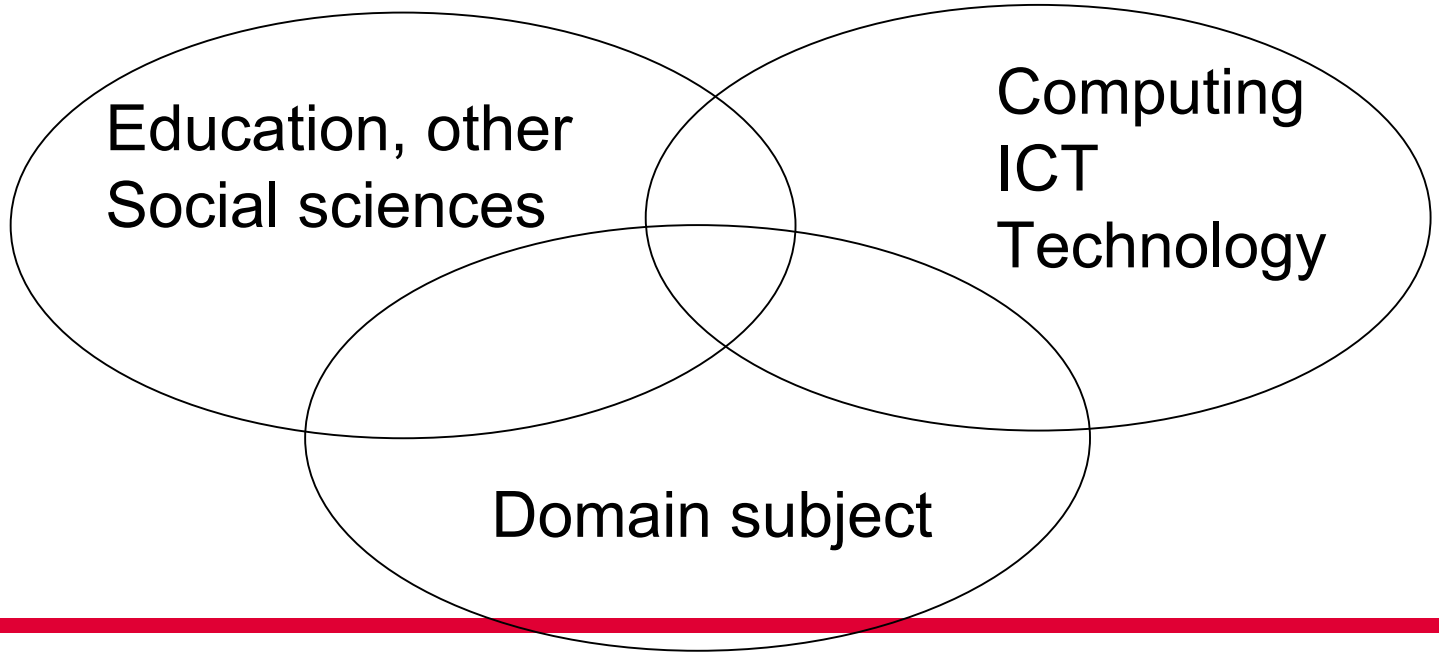
- How many of you have taken some formal research training course, which addressed, for example:
  - How to design a research project?
  - How to make a good research plan?
  - How to formulate research questions?
  - How to choose appropriate research methods?

Motivation cont.

- It is worthwhile to look at around
  - How research is carried out in the field
  - Computing education research as well as educational technology research are rich multidisciplinary fields, which combine theories, practices and methods from several fields (computing, education, psychology, sociology, ...)
  - However, many, perhaps a clear majority of researchers have a background in technical sciences, often in computing sciences.

Research paradigms

- Educational technology combines many fields



Research paradigms

- These fields apply different paradigms
  - Positivism
  - Naturalistic inquiry
  - Constructive research

Positivism

- Aims at building neutral, objective information about target of investigation
- Emphasizes objectivity, generalizability, replicable research (controlled experiments, prediction)
- Typically presents results using numbers and uses statistical analysis
- In ET:
  - suggests experimental set ups, getting numerical data and using randomized groups

Naturalistic inquiry

- Guba-Lincoln 1985
- Aims at building deep understanding of the investigated phenomena by collecting and analysing a rich description of the target.
- Typically uses qualitative and interpretive methods
- Accepts that the researcher has a role in interpreting data (there is a subjective component in the results)
  - Has its own criteria for trustworthiness of results
- In ET:
  - suggests interviews, observations, open questionnaires to build new understanding

Constructive research

- Aims at creating / designing / implementing something new
- Aims at solving new problems or enhancing existing solutions
- Emphasizes building concrete demonstrations or prototypes, ”proof-of-concept research”
- Works much in the domain of the artificial (technical sciences, computing sciences)
  - Simon: Sciences of the artificial
- In ET:
  - Suggests designing and implementing novel applications, tools or frameworks to support education

So let us see what there is...

Analysis project

- TMMCER (Theories, Methods and Models in Computing Education Research)
  - Research carried out by 10 researchers from Aalto University, University of Eastern Finland, Monash University and University of Newcastle, Australia
  - Analysing research publications in Computing Education Research (CER)
  - (Malmi et al. 2010)

Previous work

- Many other works have classified or characterized CER
  - Subfields of CER
    - Fincher-Petre (2004), Pears et. al (2005)
  - What kind of work is carried out, including comments on quality
    - Randolph et al. (2005), Randolph (2007, 2009), Simon (2007, 2008), Simon et al. (2008a, 2008b), Joy et al. (2009)
  - Analysis of programming education research
    - Valentine (2004), Pears et. al (2007), Sheard et al. (2009)

Our goal

- Previous work has mainly concentrated in discovering topic, context and scope of research
- We are interested in HOW the research has been carried out, thus focusing on:
  - What theories, models, frameworks, instruments, technologies or tools have been used, built upon, or extended by the research?
  - What other disciplines does the research link to?
  - What was the general purpose of the research: describing something new, formulating new tools or methods, or evaluating them?
  - What research frameworks have been used?
  - What kind of data has been collected for the research and how has it been analyzed?

Why this goal?

- We wished to better understand the research process:
  - How versatile goals and approaches there are?
  - How CER is practically carried out?
  - Do we really build on previous work, instead of just referring to it?
  - Do we look at relevant things outside CER scope in other disciplines?
  - This would support commenting and learning of the quality of the work done.
  - What could be improved in our own work, as well as more generally in the field?

How did we do this?

- How to analyze?
- What to analyze?

Analysis process 1

- We needed to develop a new categorization scheme, as none previous CER work provided enough dimensions for us.
- We built on previous work by Glass, Ramesh and Vessey, who analyzed research in software engineering (2002), information systems (2002), and computer science (2004), summarizing their classification scheme in (2004) and results in (2005).
  - Some modifications and augmentations were though needed to match our case and needs.

Analysis process 2

- Initial classification scheme developed by two principal authors
- Trial analysis and discussion of a set of papers with the whole group to get a concensus of their classification
- Analysis of a new trial set by pairs followed by joint discussion in two workshops. Many clarifications needed in the classification scheme.
- Another trial set analyzed in pairs and discussed in a fourth workshop. More clarifications agreed on.
- Further analysis in pairs with independent data.
- Inter-rater reliability test showed good enough match between pairs

Source of data

- Long papers
  - allow more space for theoretical and methodological considerations
  - allow presentation of both quantitative and qualitative results
  - => Journals, ICER, ACE, Koli Calling
- We chose ICER conference papers (2005-2009) to test our classification scheme
  - This also allowed us to analyze whether ICER has met its general goals, as stated in all CFPs.
    - A clear theoretical basis, drawing on existing literature in computing education or related disciplines
    - a strong empirical basis, drawing on relevant research methods.
- In total 72 papers were analyzed

Classification scheme 1

- Theory/Model/Framework/Instrument
  - *TMFI helps to provide a more solid theoretical or conceptual framework for the research*
  - This dimension describes how the work is linked to other research
    - TMFI may have a commonly known name or it is just a reference to certain paper(s)
    - We listed only TMFI if they were really used in the work or developed further.
      - References as related work only were not listed
      - TMFI developed in the paper itself were not listed

Classification scheme 2

- Tool / Technology
  - *Technical research should preferably build on previous work, and avoid reinventing the wheel*
  - This similar dimension describes how the work builds on or extends previous technical research
    - Listed only if tool/technology is relevant for the research (and not used so that any other tool could have been used instead)

Classification scheme 3

- Reference discipline
  - *CER claims to be an inter-disciplinary field*
  - To which disciplines do the TMFIs or Tools/Technologies belong to?
    - CER was considered inherent in all papers
    - Computing was listed in some papers due to their technical nature

Classification scheme 4

- Research purpose
- *What is the general goal of the research*
  - *Descriptive* – description of a tool, technology or system. This may involve detailed explanation of features, functionality and rationale for development.
  - *Evaluative* – assessment of a tool, method or situation, typically through a systematic process involving data gathering, analysis and reporting. This may involve hypothesis testing and may be exploratory or investigative in nature.
  - *Formulative* – development and/or refinement of a theory, model, standard, or process, or proposition of a new concept.
  - All with several subcategories
- A single paper often has more than one goal

Classification scheme 5

- Research framework
  - *The overall design of the research*
  - May imply associated theoretical or epistemological assumptions, or methodological suggestions
  - One paper could include multiple ones
  - Not all papers have any
  - Often implicit
  - Examples: Action research, Case study, Constructive research, Experimental research, Grounded theory, Phenomenography, Survey

Classification scheme 6

- Data source
  - *Where does the data come from*
    - Naturally occurring data
    - Research specific data
    - Reflection
    - Software
    - Literature
  - Often many data sources

Classification scheme 7

- Analysis method
  - *How the data is analyzed*
  - A set of analysis methods identified in the papers
    - Not a predefined list
  - Examples
    - Descriptive statistics, Exploratory statistical analysis, Statistical analysis (with tests)
    - Interpretive classification
    - Interpretive qualitative analysis

Results

- Full results available in the paper Malmi et. al 2010.
- Here I present some new results from several publications forums
  - ICER 2005-2009
  - Computer Science Education (part of 2005-2010)
  - ACM Transactions on Computing Education (part of 2005-2010)
  - CSEDU 2010 (full papers only)

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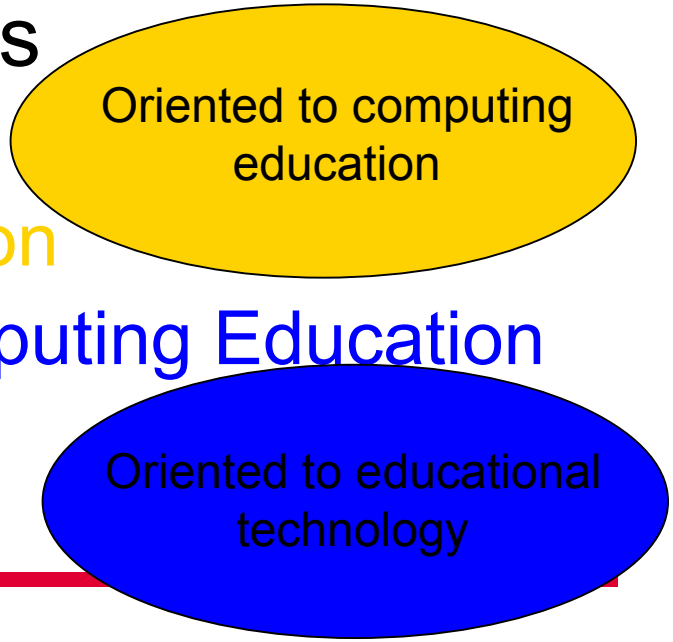

Questions

- What was the general purpose of the research?
- What research frameworks have been used?
- What kind of data has been collected for the research and how has it been analyzed?
- How has the research process been documented?

- Note: The results concerning CSE and TOCE are preliminary, and should not be cited yet.

Research purpose

	ICER	CSE	CSEDU	TOCE
	N = 84	N = 64	N = 30	N = 46
Descr. information / human system	8,5%	5-50%	17,6%	25-30%
Descr. technical system	2,5%	0-15%	29,4%	25-55%
Descr. other	3,4%	10-35%	2,0%	0-15%
Evaluative positivist	28,0%	40-55%	21,6%	15-45%
Evaluative interpretive	28,0%	20-35%	2,0%	0-30%
Evaluative other	4,2%	5-15%	23,5%	5-30%
Formulative model	16,1%	0-30%	2,0%	0-5%
Formulative process, method, algor.	6,8%	0-10%	0,0%	5-15%
Formulative standards, guidelines	2,5%	0-5%	2,0%	0-5%

Research framework

	ICER	CSE	CSEDU	TOCE
	N = 84	N = 64	N = 30	N = 46
Action research	0,0	0-15%	0,0%	0%
Case study	3,6	0-15%	18,2%	0-5%
Constructive research	13,1	5-30%	48,5%	35-50%
Delphi	2,4	0%	0,0%	0-5%
Experimental research	13,1	0-15%	15,2%	5-20%
Survey	42,9	25-40%	6,1%	5-55%
Grounded theory	13,1	0-5%	0,0%	0%
Other qualit. methods	7,1	0-15%	0,0%	0%
None	19,0	15-35%	12,1%	10-15%

Data source

	ICER	CSE	CSEDU	TOCE
	N = 84	N = 64	N = 30	N = 46
Literature	11,9%	0-20%	3,0%	0-15%
Research data	77,4%	40-80%	36,4%	35-55%
Natural data	25,0%	15-55%	18,2%	5-40%
Reflection	1,2%	15-40%	27,3%	25-35%
Software	0,0%	0,0%	6,1%	0-5%
None	1,2%	0-5%	9,1%	0,0%

Analysis method

	ICER	CSE	CSEDU	TOCE
	N = 84	N = 64	N = 30	N = 46
Argumentation	14,3%	35-40%	44,1%	35-50%
Descriptive statistics	15,5%	5-35%	29,4%	35-40%
Explorative stat. methods	17,9%	15-30%	2,9%	0-25%
Statistical analysis	38,1%	25-35%	11,8%	5-30%
Interpretive classification	29,8%	10-20%	0,0%	0-5%
Interpretive qualit. analysis	34,5%	20-25%	2,9%	0-25%
None	1,2%	0-5%	8,8%	0,0%

Summary of findings

- ET-forums have more technical papers than CER forums
  - correspondingly constructive research is clearly the most popular approach (this is no news)
- ET forum papers formulate few models compared to education forums
- ET forums apply very little qualitative methods
- CSEDU papers report few surveys.
- ET forum papers collect less research data for evaluation and often use reflection as data source.
- ET forum papers apply little statistical methods and very little qualitative method, whereas they use heavily argumentation.
- Some papers do not report any data collection and analysis.

Additional findings

- From CSEDU data only
  - Research questions
  - Methodology description
  - Validity / trustworthiness discussion

Research questions

- 7% highlight research questions in the text
- 23% provide the questions within other text
- 37% has a technical problem as the focus
- 23% presents the goal in some way in the text
- 10% presents no goal or question
  - typically plain observations or lessons learned

Methodology

- 43% presents the methology clearly in own section
- 10% presents the methodology within other text
- In addition 30% present design/implementation as the method
- 17% does not report any clear methodology

Validity / trustworthiness

- 7% has explicit discussion on this
- 23% has some discussion on this
- 33% uses the prototype as a kind of validity proof
- 37% does not discuss this

Trustworthiness of this analysis

- Analysis of ICER, CSE and TOCE data done with a colleague, with confirmed interrater reliability when compared to other pairs.
  - Results concerning CSE and TOCE are preliminary.
- Analysis of CSEDU data done alone by an experienced analyzer.
  - Numbers would probably change slightly if carried out in a pair. However, the big picture is not likely to change.
- The ET field is vast, and the results may not be generalizable to other conferences / journals of the field.
- The whole analysis process is interpretive, also when carried out in pairs. The categories have some overlaps, and some decisions, especially concerning Argumentation as an analysis method could be questioned.
  - However, the big picture is more important than individual numbers.
- Observations on reporting research are more likely subject to personal interpretation

Discussion

- How could we improve our research and reporting research?
- Reflections on these findings and from my personal experience.

Implications for research design

- When designing new educational tools/software, consider the following:
  - Your problem
  - Your methods
  - Have you solved your problem
  - Will you create new problems...

Solve the problem

- Make it clear to yourself, what is the problem that you are addressing.
  - Whom does the problem concern: students? teachers, application developers?
  - What is your hypothesis of the impact of your solution?
  - Will you be able to provide evidence of this impact?

Solve the right problem

- How do you know that you are solving the real problem?
  - Many tools have been developed to support teacher's work or vision of learning.
    - For example, early algorithm visualization research believed that viewing visualizations helps learning. It did not. (Hundhause et al. 2002)
    - Automatic assessment tools reduced (drastically) teacher's work, but students stopped testing their programs self. (Edwards, 2003)
  - Students' problems may be elsewhere
    - Investigate your students' point of view. What is he/she thinking, what is difficult, how does he/she work?

Choose methods

- How will you demonstrate that your tool or method of using a tool fulfills the goals you have set (solving the problem)?
  - Implementing a prototype/method is not a proof of success in applying it.
  - How do you show that the prototype/method is good?
    - What would be your evidence?
    - How would you collect it?
    - How would you analyze it?

Evidence

- What is your evidence that you have improved something?
  - Enable something ≠ Improve something
  - Students' / teachers' feedback?
    - Anecdotal data has often little value. Use questionnaires, interviews, observations...
  - Reflection of experiences is interesting but is it proper evaluation?
  - Learning results?
    - How do you measure? How do you compare? Pre/post tests? Randomization?
  - Activity data?
    - Logging activity data is a marvellous source of data.
  - Do not forget time! Students generally learn better if they use more time for a learning activity.

New problems

- Students may use the tool in a way that you did not anticipate
  - Visual interaction may be just fun playing
  - Frequent formative feedback may lead to trial-and-error behavior with no thinking
  - Students do not test their programs self, if they can use an automatic assessment tool to test it for them.
- Allow students to do errors (and learn from them)
  - Note: this is not a usability issue! Usability is very, very important for success.

Implications for writing papers

- Make it clear what is the focus your paper
  - Specify explicit research questions, if appropriate
    - and make sure you answer them in the paper
  - Specify the goal of your research clearly, such as:
    - What is the technical problem you are solving?
    - What is it that you want to enable and why?
  - Discuss the methodology that you use.
    - What is your general research framework, if any?
    - What data do you collect and how do you analyze it?
    - If you build a prototype, how does is act as a proof-of-concept and how do you evaluate its quality?
  - Discuss validity / reliability / generalizability / trustworthiness of your research

Role of conferences

- Conferences are the main forum for presenting novel ideas and approaches.
  - Thus, requirements for papers cannot be on the level of journal submissions.
  - Is it clear what is expected from a research category paper (or long or full paper) in a conference?
  - Are the instructions for reviewers clear?
- Journals are the main forum for presenting rigorous research with full data analysis.

Implications for research training

- Emphasize research planning for PhD students.
  - Doctoral consortia could be used will for this
- PhD students working in ET field should learn to understand the richness of the field, and the variation in research paradigms and methods.
  - Understand how your colleage with a different background thinks!
- Research methods training is needed.
  - Practical hand-on workshops are valuable.

Thank you for listening

- I hope you got something to think
  - even if you disagree in some aspects.

- Improving the quality of our research is our common goal!

References

- Listed either in CSEDU keynote abstract or in the reference list of
  - Malmi, L, Sheard, J., Simon, Bednarik, R., Helminen, J., Korhonen, A., Myller, N., Sorva, J., Taherkhani, A., 2010. Characterizing research in computing education: a preliminary analysis of the literature. In Proceedings of the Sixth international workshop on Computing education research (ICER '10). ACM, 3-12.