COMPUTER SCIENCE EDUCATION RESEARCH METHODOLOGY

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RESEARCH PROCESS IN CSER

- RESEARCH PROCESS
  - IDENTIFY THE PROBLEM
  - LITERATURE AND RELATED RESEARCH
  - FORM YOUR RESEARCH QUESTIONS
  - SELECTING METHODS
  - COLLECTING DATA
  - ANALYSING
  - REPORTING

COMPUTER SCIENCE EDUCATION RESEARCH

- COMPUTER SCIENCE
  - SCIENCE OF COMPUTING
- EDUCATION
  - PROCESS OF FACILITATING LEARNING
- RESEARCH
  - SYSTEMATIC INVESTIGATION OF PHENOMENA BY USING THE SCIENTIFIC METHOD

RESEARCH PROBLEM

- IS THE REASON TO DO THE STUDY
- RESPONDS TO A GAP IN KNOWLEDGE
- EXAMPLE PROBLEMS
  - ”LACK OF KNOWLEDGE ABOUT FACTORS THAT INFLUENCE THE USE OF MOBILE LEARNING IN SCHOOL EDUCATION” (THEORETICAL)
  - ”LACK OF KNOWLEDGE ABOUT IMPACTS OF EDUCATIONAL TECHNOLOGY IN PRESCHOOL EDUCATION” (EVALUATION)
  - ”LACK OF KNOWLEDGE ABOUT BEST WAYS TO DEVELOP AN ELECTRONIC INTERVENTION TO INCREASE STUDENT GROUPWORK SKILLS” (DESIGN, EVALUATION)

LITERATURE AND RELATED WORK

- SYSTEMATIC PROCESS OF
  - TYPING KEYWORDS TO SCIENTIFIC SEARCH ENGINES
  - RETRIEVING THE MOST RELEVANT ARTICLES
  - READING AND SUMMARISING THE FINDINGS
- IMPORTANT FOR
  - FINDING THE RESEARCH GAP
  - PROVIDING A MODEL OR FRAMEWORK TO COLLECT AND ANALYSE DATA
  - RELATING YOUR FINDINGS

- DOES A PERSON'S TO DEEP OR SURFACE LEARNING APPROACH (MARTON & SÄLJÖ 1976) AFFECT THEIR USAGE PATTERNS OF X-LEARN
- DOES A STUDENT'S MINDSET ORIENTATION (DWECK 1999) HAVE AN IMPACT ON ACADEMIC ACHIEVEMENT IN CS STUDIES IN FINLAND
- INVESTIGATE THE CONTEXTUAL ASPECTS OF E-LEARNING BY USING THE CATEGORIES OF E-LEARNING AS DESCRIBED BY NGUMBUKE (2011)

RESEARCH GAP

”There is a very large amount of research about using educational technology in schools [1,2,3,4,5,6,7,8,9]. However, it is still unclear whether educational technology in preschool education has any impact on learning outcomes. This lack in knowledge has been highlighted in [3,5,12]."

RESEARCH AIMS

- A GENERAL DESCRIPTION ABOUT WHERE YOUR RESEARCH IS AIMING AT
  - ”THIS RESEARCH AIMS AT DESCRIBING HOW EXPERT PROGRAMMERS CONCEPTUALISE VARIABLES”
  - ”THIS RESEARCH AIMS AT EVALUATING EDUCATIONAL EFFECTS OF X-LEARN IN PRESCHOOL IN LOWLANDS REGION”
  - ”THIS RESEARCH AIMS AT EXPLORING THE ASSOCIATIONS BETWEEN CSE STUDENTS’ MINDSETS (DWECK 1999) AND THEIR ACADEMIC ACHIEVEMENT IN HIGHLAND UNIVERSITY”

- COMMON VERBS IN AIMS: EXPLORE, DESCRIBE, DESIGN, EVALUATE

RESEARCH OBJECTIVES

- OBJECTIVES DEFINE IN CONCRETE TERMS WHAT ARE YOU GOING TO DO TO REACH THE AIMS
  - ”COMPARE LEARNING OUTCOMES OF EDUTECH-BASED TEACHING TO NON-EDUTECH-BASED TEACHING IN 8TH GRADERS IN LOWLAND SCHOOL”
  - ”TO CLASSIFY USERS’ USABILITY ISSUES WITH X-LEARN IN MATHEMATICS COURSES IN LOWLAND SCHOOL”
  - ”TO EXPLORE STUDENTS’ MINDSETS AS DEFINED BY DWECK (1999) AND THE STUDENTS’ MINDSETS’ ASSOCIATIONS TO LEARNING OUTCOMES”

- FOCUSED AND FEASIBLE

RESEARCH QUESTIONS

- DERIVE DIRECTLY FROM AIMS AND OBJECTIVES

- EXAMPLES
  - WHAT FACTORS AFFECT ADOPTION OF M-LEARNING SYSTEMS IN PRESCHOOL IN TURKU REGION?
  - HOW DO 8TH GRADERS IN HIGHLAND SCHOOL USE MOBILE TECHNOLOGY FOR LEARNING ON THEIR FREE TIME?
  - TO WHAT EXTENT DO LEANERS' MOTIVATIONAL STATES INFLUENCE THEIR ATTENDANCE TO EXERCISE SESSIONS IN PROGRAMMING COURSES IN UNIVERSITY X?
  - WHAT IS THE EFFECT OF X-LEARN SYSTEM TO LEARNING OF COLLABORATION SKILLS IN HIGHLAND SCHOOL?

PLANNING THE RESEARCH

- RESEARCH PROBLEM
- RESEARCH GAP
- LITERATURE AND RELATED RESEARCH
- RESEARCH AIMS
- RESEARCH OBJECTIVES
- RESEARCH QUESTIONS

QUANTITATIVE RESEARCH DESIGNS

- DATA
  - ANY QUANTIFIABLE DATA IN NUMBERS OR CATEGORIES
  - PSYCHOMETRICS: ATTITUDES, BEHAVIORS, PERSONALITY-INDICES, LEARNING ORIENTATIONS
  - RATING SCALES, PERFORMANCE MEASURES, LEARNING DATA, SENSOR DATA

- POSITIVES (+)
  - GENERALIZABLE (+)
  - EXAMINE CAUSE AND EFFECT (+)
  - EFFICIENT DATA ANALYSIS (+)
  - SHOW RELATIONSHIPS IN DATA (+)
  - PEOPLE LIKE NUMBERS (+)

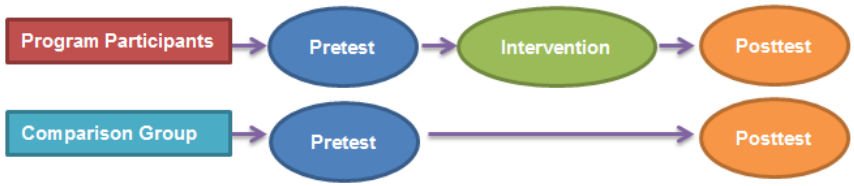
- NEGATIVES (-)
  - IMPERSONAL, DRY (-)
  - DO NOT HEAR THE WORDS OF PARTICIPANTS (-)
  - YOU CAN'T MEASURE WHAT YOU DON'T UNDERSTAND (-)

COMMON QUANTITATIVE DESIGNS

- EXPERIMENTAL
  - ”WHAT IS THE IMPACT OF A NEW TEACHING INNOVATION TO LEARNING OUTCOMES”
- SURVEY DESIGNS
  - ”WHAT ARE THE LEARNING APPROACHES OF CSE STUDENTS IN UNIVERSITY X”
- ASSOCIATIONS IN DATA
  - ”WHAT ASSOCIATIONS CAN BE FOUND BETWEEN MOTIVATIONAL ORIENTATIONS (RYAN & DECI) AND LEARNING APPROACHES (MARTON & SALJO) OF CSE STUDENTS IN UNIVERSITY X”
- PREDICTING
  - (HOW) DO PREVIOUS SKILLS IN SCHOOL MATH PREDICT ACADEMIC ACHIEVEMENT IN UNIVERSITY COURSES IN DATA STRUCTURES AND ALGORITHMS?

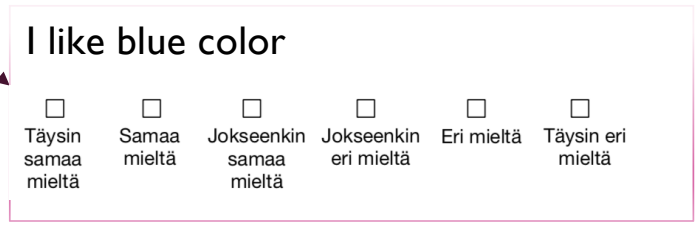
EXPERIMENTAL DESIGN

- EXPERIMENTAL DESIGN
  - RANDOM ASSIGNMENT TO TWO GROUPS
  - ONE GROUP LEARNS ALGORITHMS BY USING THE NEW Z-LEARN VISUALISATION SYSTEM
  - THE OTHER GROUP LEARNS ALGORITHMS BY ”TRADITIONAL METHOD”
  - ESTABLISHES CAUSE AND EFFECT BETWEEN
    - INDEPENDENT VARIABLE (TYPE OF INTERVENTION)
    - DEPENDENT VARIABLE (LEARNING OUTCOMES)
- STATISTICAL METHODS
  - ANALYSIS OF VARIANCE, STUDENT’S T-TEST



SURVEY DESIGNS

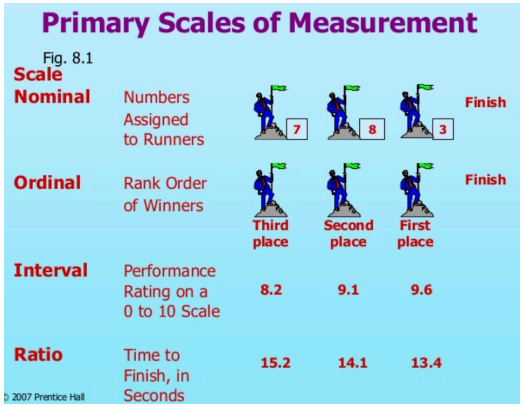
- SURVEY DESIGN EXAMPLES
  - MEASURE STUDENTS' BELIEFS, OPINIONS, LEARNING APPROACHES (MARTON & SALJO 1976), PREVIOUS SKILLS, MOTIVATIONAL ORIENTATIONS (RYAN & DECI), SELF-ESTEEM, MINDSET (DWECK 1999) GROUPWORK SKILLS, PERSONALITY, SOCIAL INTELLIGENCE, ETC.
  - TYPICALLY LIKERT-SCALE QUESTIONNAIRES
  - VALIDITY (ARE YOU MEASURING WHAT YOU THINK YOU ARE MEASURING?)
  - RELIABILITY (DOES YOUR MEASURING INSTRUMENT PRODUCE CONSISTENT RESULTS?)
- THEORETICAL BACKGROUND AND RELATED RESEARCH IS IMPORTANT



BASICS IN ANALYSING QUANTITATIVE DATA

- SCALES
  - NOMINAL, ORDINAL, INTERVAL, RATIO
- DESCRIPTIVE STATISTICS
  - MEAN, MEDIAN, MODE, STANDARD DEVIATION
- STATISTICAL ASSOCIATIONS BETWEEN VARIABLES
  - PEARSON'S CORRELATION (CONTINUOUS SCALE)
  - SPEARMAN'S CORRELATION (ORDINAL SCALE)
  - CHI-SQUARE TEST FOR NONPARAMETRIC (CATEGORICAL) DATA
- COMPARING GROUPS
  - STUDENT'S T-TEST OR ANALYSIS OF VARIANCE (ANOVA)
- PREDICTING
  - REGRESSION ANALYSIS

Provides:	Nominal	Ordinal	Interval	Ratio
"Counts," aka "Frequency of Distribution"	✔	✔	✔	✔
Mode, Median		✔	✔	✔
The "order" of values is known		✔	✔	✔
Can quantify the difference between each value			✔	✔
Can add or subtract values			✔	✔
Can multiple and divide values				✔
Has "true zero"				✔



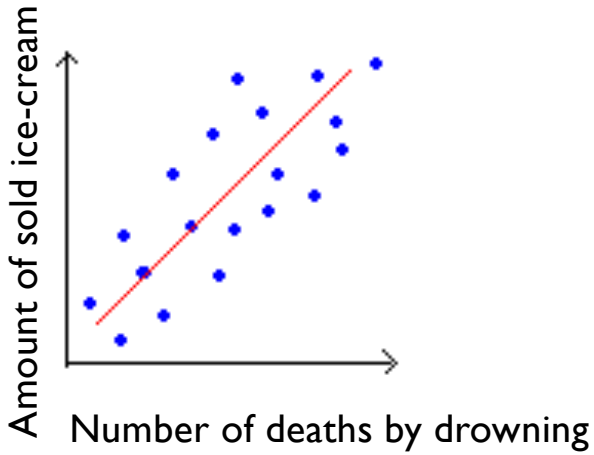
CORRELATION

- PEARSON'S OR SPEARMAN'S CORRELATION
- *EXAMPLE*: IS THERE AN ASSOCIATION BETWEEN MOTIVATION LEVEL AND EXERCISE ATTENDANCE?

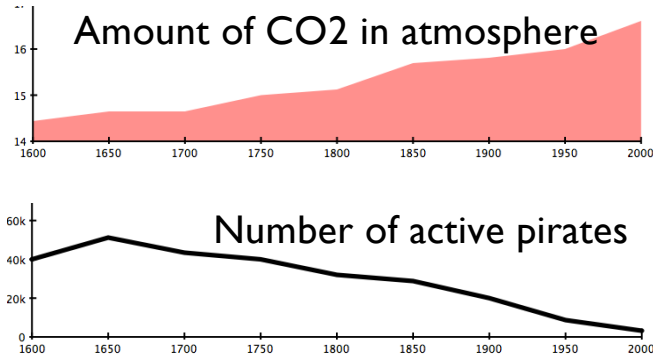
```
> cor.test(motilevel,exerci)

    Pearson's product-moment correlation

data:  motilevel and exerci
t = 3.151, df = 38, p-value = 0.003168
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 0.1673706 0.6714574
sample estimates:
      cor
0.4551496
```

r=0.455 indicates a moderate correlation, which is statistically significant (p<.01)

CORRELATION IS NOT CAUSATION



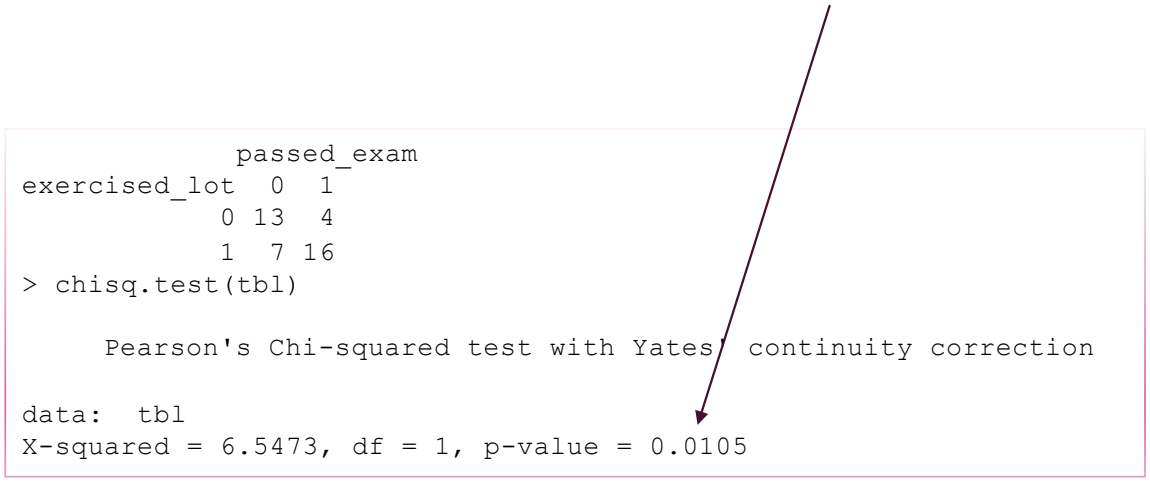
r=.82, p<0.05



r=-.87, p<0.01

ASSOCIATIONS IN NOMINAL DATA: CHI SQUARE

- CHI-SQUARE χ^2 -TEST IS A NONPARAMETRIC TEST FOR INVESTIGATING ASSOCIATIONS IN CATEGORICAL DATA.
- EXAMPLE
  - IS THERE AN ASSOCIATION BETWEEN DOING A LOT OF EXERCISES (YES/NO) AND PASSING THE EXAM (YES/NO)?
  - THE RESULTS DO NOT SAY WHY THAT MAY BE OR IF ONE HAS CAUSED THE OTHER (PERHAPS BOTH ARE A *FUNCTION* OF STUDENTS INTEREST ON THAT PARTICULAR TOPIC?)



```
             passed_exam
exercised_lot  0  1
            0 13  4
            1  7 16
> chisq.test(tbl)

     Pearson's Chi-squared test with Yates' continuity correction

data:  tbl
X-squared = 6.5473, df = 1, p-value = 0.0105
```

COMPARING GROUPS

- ARE MEANS OF TWO OR MORE GROUPS DIFFERENT TO A SIGNIFICANT LEVEL?
- IS THERE SIGNIFICANT DIFFERENCE IN EXAM SCORES BETWEEN DIFFERENT KIND OF LEARNERS?
  - THERE IS A DIFFERENCE BETWEEN THE MEAN GRADES
  - BUT THE DIFFERENCE IS NOT STATISTICALLY SIGNIFICANT (T-TEST)
- WITH THREE OR MORE GROUPS, A SUITABLE METHOD IS ANALYSIS OF VARIANCE (ANOVA)

```
> group1
 [1] 48 42 26 25 65 35 34 77 23 50 50 51 50 50 50 50 51 50 51 53
34 24 67 34 23 35 63 45 50 50 56 52 50 54 60 55 32 34 33 75
> group2
 [1] 51 43 25 24 64 34 34 75 23 50 50 50 50 50 50 50 50 51 53
34 23 67 34 23 35 63 45 50 50 51 52 34 54
> mean(group1)
[1] 46.425
> mean(group2)
[1] 45.35294
> t.test(group1,group2)
        Welch Two Sample t-test

data:  group1 and group2
t = 0.3448, df = 70.902, p-value = 0.7313
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -5.127659  7.271777
sample estimates:
mean of x mean of y
 46.42500  45.35294
```

OTHER METHODS

- PREDICTING
  - REGRESSION ANALYSIS
  - CAN ONE OR MORE (INDEPENDENT) VARIABLES BE USED TO PREDICT A (DEPENDENT) VARIABLE
- UNDERSTANDING LATENT FACTORS IN DATA
  - FACTOR ANALYSIS
- STRUCTURAL EQUATION MODELING
- MACHINE LEARNING AND DATA MINING FOR BIG DATA
- NETWORK ANALYSIS

EXAMPLE: SOCIAL NETWORK ANALYSIS

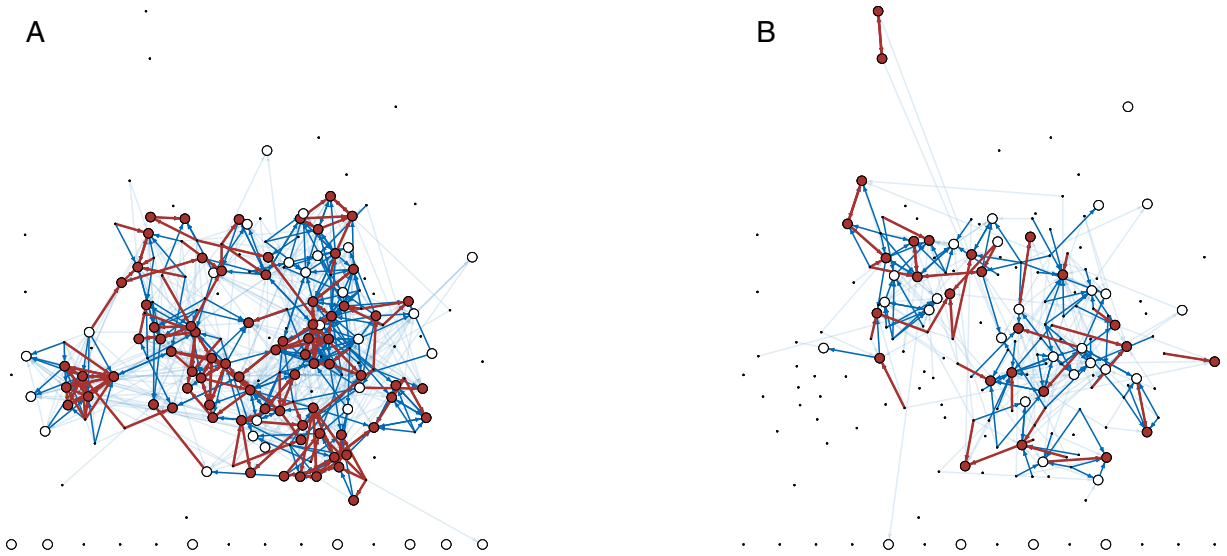


Fig. 3. Differences in the integration of successful and unsuccessful students. The social networks after 8 months, 1.5 months before the examination (cf. Fig. 1*C*), are shown. Students who are named as a study partner by someone else are shown in red and others in gray. (*A*) Students who passed the examination. (*B*) Students who failed. Only their incoming social network ties (perceptions of others) are shown.

We closely followed the emergence of multiple social networks within a cohort of 226 undergraduate university students. They were strangers to each other on their first day at university, but developed densely knit social networks through time. We show that functional studying relationships tended to evolve from informal friendship relations. In a critical examination period after one year, these networks proved to be crucial: Socially isolated students had significantly lower examination grades and were more likely to drop out of university.

Stadtfeld, C., Vörös, A., Elmer, T., Boda, Z., and Raabe, I. J. (2019). Integration in emerging social networks explains academic failure and success. *Proceedings of the National Academy of Sciences*, 116(3):792–797.

Stark, T. H. and Krosnick, J. A. (2017). Gensi: A new graphical tool to collect ego-centered network data. Social Networks, 48:36 – 45.

QUALITATIVE DESIGNS

- DATA
  - INTERVIEWS, OBSERVATIONS, VIDEOS, DIARIES, DOCUMENTS
- PROCESS
  - OBSERVATIONS ARE CODED INTO THEMES
  - RELATED THEMES ARE CATEGORIZED
  - MEANINGS ARE ASSOCIATED TO CATEGORIES (RELATIONS TO THEORY)
- POSITIVES
  - PRODUCES RICH AND DEEP DESRIPTIONS OF THINGS (+)
  - ACCOUNTS FOR MEANING IN WORDS (+)
  - HEAR THE VOICE OF PARTICIPANTS (+)
  - PEOPLE LIKE STORIES (+)
- NEGATIVES
  - LIMITED GENERALIZABILITY (-)
  - SMALL SAMPLE SIZES (-)

QUALITATIVE DESIGN, EXAMPLE

- PROBLEM: A NEED TO UNDERSTAND CSE STUDENTS' PROFESSIONAL IDENTITY FORMATION PROCESSES
- BACKGROUND: IN A SWEDISH UNIVERSITY, A NEW COURSE IN HCI WAS DESIGNED THAT IMPLEMENTED NEW STUDENT-CENTERED LEARNING PRACTICES AND PRESENTATION.
- FOR BEST PERFORMING GROUPS, THE COURSE GAVE STUDENTS AN OPPORTUNITY TO PRESENT COURSEWORK IN FRONT OF A PROFESSIONAL JURY.
- THIS LED SOME GROUPS TO DELIBERATELY DO WEAK COURSEWORK SO THEY WOULD NOT HAVE TO PRESENT
- QUALITATIVE PHENOMENOGRAPHIC STUDIES WERE LAUNCHED TO UNDERSTAND WHAT HAPPENED
  - INTERVIEWS WITH STUDENTS, DATA COLLECTED AND CATEGORISED
  - RESULTS: CSE STUDENTS STRONGLY IDENTIFY AS "BACK-END" PROBLEM-SOLVERS

EXAMPLE

- USED THEORY OF PLANNED BEHAVIOR AS ”LENS”
- SOME QUOTES
  - ”Presenting is unnecessary work”
  - ”Presentation skills and networking abilities are irrelevant for me to learn”
  - ”We do not learn through presenting”
- ”Soft skills” were not condidered as a part of a ”real” computer scientists’ identity.
- RESULTS: IN THIS CASE, MANY CSE STUDENTS STRONGLY IDENTIFIED AS ”BACK-END” PROBLEM-SOLVERS

TABLE I
TWO CASES OF MISMATCH BETWEEN INTENDED AND OBSERVED BEHAVIOUR

Identifier	Students behaviour related to the critical incident	Intended behaviour
SB1	Refusing to present. Two groups, one eligible and one selected for the presentation before jury, refused to take part in presentation.	Students would attend the final seminar, and look forward to presenting their ideas for redesign in front of a jury.
SB2	Not attending. Only two of around 40 non-presenting student showed up for the final presentation before jury.	Students would attend their peers’ final presentation before jury.

Å. Cajander, M. Daniels, D. Golay, J. Moll, A. Nyle´n, A. Pears, A. Peters, and R. McDermott, “Unexpected student behaviour and learning opportunities: Using the theory of planned behaviour to analyse a critical incident,” in *2017 IEEE Frontiers in Education Conference (FIE)*, Oct 2017, pp. 1–8.

I. Ajzen, “The theory of planned behavior,” *Organizational behavior and human decision processes*, vol. 50, no. 2, pp. 179–211, 1991.

MIXED METHODS

- COMBINE THE POSITIVE ASPECTS OF QUALITATIVE AND QUANTITATIVE RESEARCH
- ADD GENERALIZABILITY TO DEEP UNDERSTANDING OF ISSUES
- FOR EXAMPLE
  - CONDUCT DEEP QUALITATIVE INTERVIEWS TO UNDERSTAND CSE STUDENTS' IDENTITY PROCESSES
  - BASED ON THE RESULTS, DEVELOP A QUESTIONNAIRE FOR MEASURING IDENTITY ISSUES
  - COLLECT AND STATISTICALLY ANALYSE A LARGE AMOUNT OF DATA
- FOR MORE INFORMATION
  - GOOGLE FOR JOHN W. CRESWELL

DESIGN SCIENCE RESEARCH (DSR)

- WHAT IS DESIGN SCIENCE RESEARCH? HOW IS EG. DESIGNING A SOFTWARE ”RESEARCH”?
- AS COMPARED TO ”PLAIN” DESIGN, DSR PROJECTS UTILISE A COMBINATION OF RESEARCH METHODS IN A PROJECT’S DIFFERENT PHASES

Johannesson , P., & Perjons, E. (2014). *An Introduction to design science.* New York: Springer International Publishing.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS Quarterly, 28*(1), 75-105.

DESIGN SCIENCE RESEARCH (DSR)

- PHASES IN A TYPICAL DSR PROJECT
  - PROBLEM EXPLICATION (Qualitative, Quantitative, Action research, Case studies, Mixed methods, Lit. Review)
  - REQUIREMENT DEFINITION (Qualitative, Quantitative, Action research, Case studies, Mixed methods, Lit. Review)
  - DESIGN & DEVELOPMENT (Brainstorming, Participatory Design, Agile Software Processes)
  - EVALUATION (Controlled Experiments / Quantitative, Qualitative Interviews) (Qualitative, Quantitative, Action research, Case studies, Mixed methods)
- THE COMBINATION OF RESEARCH METHODS USED IN DIFFERENT PHASES DEPENDS ON THE CASE AT HAND AND TYPICALLY DIFFERS FROM PROJECT TO PROJECT.

WHAT IS/ARE YOUR RESEARCH DESIGN(S)?

- QUANTITATIVE
  - EXPERIMENTAL, SURVEY, CORRELATIVE, PREDICTING
- QUALITATIVE
- MIXED
- DESIGN SCIENCE RESEARCH (DSR)
  - PROBLEM EXPLICATION (Qualitative, Quantitative, Action research, Case studies, Mixed methods, Lit. Review)
  - REQUIREMENT DEFINITION (Qualitative, Quantitative, Action research, Case studies, Mixed methods, Lit. Review)
  - DESIGN & DEVELOPMENT (Brainstorming, Participatory Design, Agile Software Processes)
  - EVALUATION (Controlled Experiments / Quantitative, Qualitative Interviews) (Qualitative, Quantitative, Action research, Case studies, Mixed methods)

CONCLUSIONS: CSER PROCESS

- RESEARCH PROCESS
  - IDENTIFY THE PROBLEM
  - LITERATURE AND RELATED RESEARCH
  - FORM YOUR RESEARCH QUESTIONS
  - SELECTING METHODS
  - COLLECTING DATA
  - ANALYSING
  - REPORTING
- IN DSR, A COMBINATION OF RESEARCH APPROACHES AND METHODS IS USED

THANK YOU

CSER METHODOLOGY

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