THESIS DEFENCE
PRELIMINARY RESULTS

Inquiry Based Learning Efficacy on Software Engineering Competencies - A Systematic Review

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OVERVIEW & AGENDA

Inquiry Based Learning Efficacy on Software Engineering Competencies - A Systematic Review

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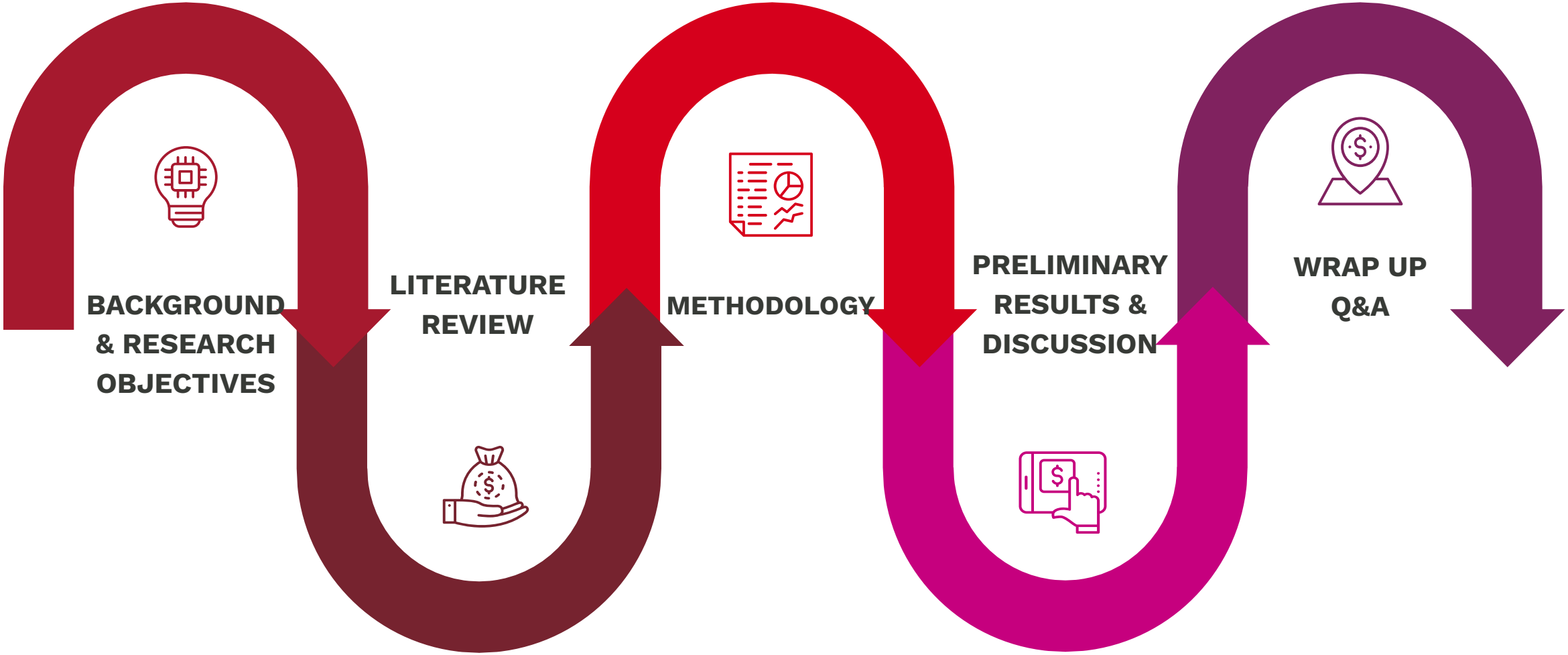

Background

Inquiry Based Learning Efficacy on Software Engineering Competencies - A Systematic Review

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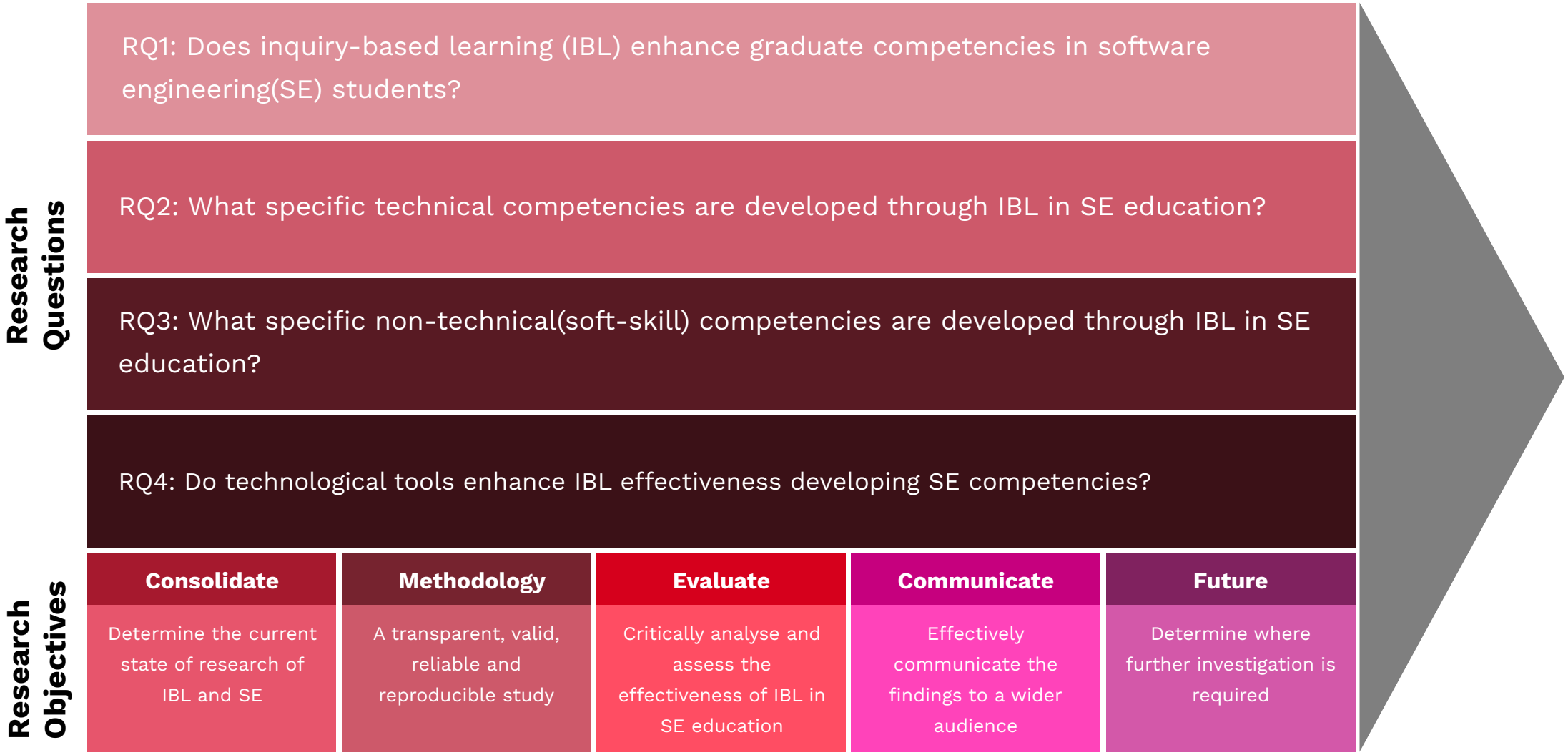
"Inquiry Based Learning Efficacy on Software Engineering Competencies"

- Traditional educational pedagogies may not fully equip SE graduates with the necessary competencies (Karp et al., 2020).
- Software Engineering (SE) graduates need both technical and non-technical competencies for success in the workforce (Gurcan & Köse, 2017).
- Modern society's information abundance requires a shift in educational paradigms. (Ješková et al., 2024)
- Individual Inquiry-Based Learning (IBL) research is SE shows positive results in developing specific competencies, but no research to determine its efficacy for graduate competencies.
- A comprehensive understanding of IBL's **overall** impact on key SE competencies is still lacking and what I set out to uncover.

Research Questions and Objectives

IBL on SE Competencies - A Systematic Review



Background: Literature Review

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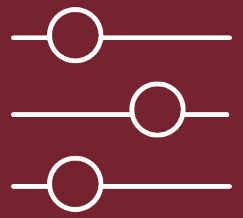

Inquiry Based Learning (IBL)

Inquiry-based learning is an educational approach that encourages students to explore problems, ask questions, and actively engage in the learning process, fostering critical thinking and self-directed learning.

(Chu et al., 2021)

Engineering Competencies

Engineering competencies encompass both technical and non-technical skills, including programming, problem-solving, teamwork, and communication, essential for success in software engineering and adaptable to evolving technological demands.

(Ouhbi & Pombo, 2020)

(Cico et al., 2021)

Systematic Review

A systematic review is a rigorous, methodical approach to identifying, evaluating, and synthesising existing research, ensuring transparency and reproducibility in order to derive evidence-based conclusions on a particular topic.

(Kitchenham, Budgen, & Brereton, 2015)

(Zawacki-Richter et al., 2020)

Methodology - Stage 1

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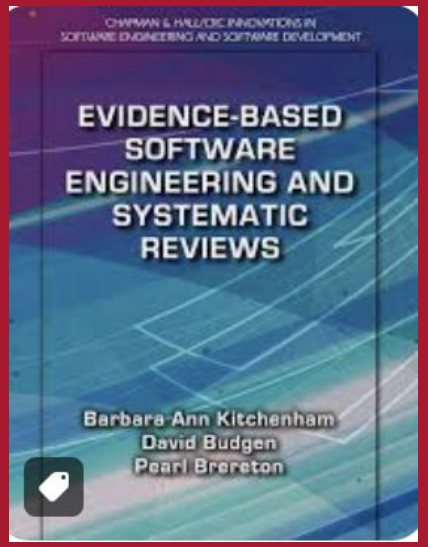
Formulating the Research Question

Research Question Criteria:

- Precise and well-defined
- Systematically answerable
- Developed through literature review

PICO framework used:

- Population - Software Engineering Students
- Intervention - Inquiry Based Learning
- Comparison - Traditional Pedagogies
- Outcome - Improvement of SE Competences



Methodology - Stage 2

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Conducting the Review

- Define Search Strategy
  - Predefined Keywords (Table 3.2)
  - Boolean operators (“AND”, “OR”, “NOT”)
- Define Databases Utilised
  - IEEE Xplore, ACM, Springer
- Selection Process – Inclusion/Exclusion Criteria
  - Quality Assessment - GRADE method (Molenda, 2003)

Focusing on individual research

Primary Keyword	Search Term Keywords
Inquiry-Based Learning	”inquiry-based learning” ”IBL” ”inquiry learning” ”project-based learning” ”active learning” ”student-centred learning” ”problem-based learning” ”inquiry cycle”
Software Engineering	”software engineering”
Software Engineering Competencies	”competencies” ”soft skills” ”technical skills” ”problem-solving skills” ”collaboration skills” ”teamwork skills” ”skill acquisition” ”learning outcomes”

Table 3.2: Keywords

Table 4. Strength of evidence in the GRADE system [20]

High	Further research is very unlikely to change our confidence in the estimate of effect.
Moderate	Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
Low	Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
Very low	Any estimate of effect is very uncertain.

Table 5. Factors that may decrease or increase the strength of evidence [20]

Factors that may decrease the strength of evidence:

- Serious (–1) or very serious (–2) limitations to study quality
- Important inconsistency (–1)
- Some (–1) or major (–2) uncertainty about directness
- Imprecise or sparse data (–1)
- High probability of reporting bias (–1)

Factors that may increase the strength of evidence:

- Strong evidence of association (RR > 2 or RR < 0.5) based on consistent evidence from two or more observational studies, with no plausible confounders (+1)
- Very strong evidence of association (RR > 5 or RR < 0.2) based on direct evidence with no major threats to validity (+2)
- Evidence of a dose response gradient (+1)
- All plausible confounders would have reduced the effect (+1)

RR = relative risk

Methodology - Stage 3

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Synthesis of Data

- Preliminary Synthesis: Summarises and organises data into competencies a theme
- Exploring Relationships: Identifies similarities, differences, and patterns across studies
- Assessing Robustness: Evaluates the quality of studies to ensure reliable conclusions, prioritising those with strong methodologies.
- Identifying Patterns: Highlights recurring themes, trends, and challenges

(Kitchenham, Budgen, & Brereton, 2015)

Focusing on collective research

Preliminary Results

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Initial analysis:

- Research screening total: 20
- Research findings using keywords: 357
- % Papers screened 20/357 = 6%

Number of Research papers meeting Inclusion/Exclusion criteria: 12

Research included method count:

- Experimental Studies: 2 papers
- Comparative Studies: 3 paper
- Systematic Reviews and Mapping Studies: 2 papers
- Qualitative Studies: 3 papers
- Interdisciplinary and Mixed-Method Studies: 2 papers

Title	Authors	Year	Publisher	Study Design	Research Obje	Methodologica	Sample Size ar	Size of the sar	Description of	Outcome Meas	Bias and Qualit
A Comparison of Inquiry-Based Conceptual	Lucas Cordova, Jeffrey Carv	2021	SIGCSE '21, ACM	Quasi-experimen	Investigate the e	Testing Tutor pro	Spring and Sumr	Sophomore-level	Testing Tutor we	Improved code c	Random assignm
Exploring Inquiry Learning: An EngageCSE	Clifton Kussmaul, Bo Brinkn	2017	ACM Inroads	Opinion piece dis	Explore the effec	Discussion basec	No specific samp	Qualitative insigh	N/A	Positive student	Random assignm
POGIL-like Learning in Undergraduate Soft	Bhuvaneswari Gopal, Steph	2022	ITiCSE 2022, ACM	Quasi-experimen	Assess the impac	Used pre- and po	60 students acro	60 students, sop	POGIL-like activit	Significant increa	Pre- and post-tes
Advances in Designing a Student-Centered	Camelia Serban, Andreea V	2019	EASEAI '19, ACM	Student-centerec	To design a stud	Developed an E-	Not specified.	Not specified.	E-learning platfo	Effectiveness der	Student engager
Improving Student Study Choices in CS1 wi	Gina Sprint, Erik Fox	2020	SIGCSE '20, ACM	Flipped classroor	Evaluate the imp	Analyzed three s	Data from 92 stu	92 students.	Implemented a M	Improved submis	Mixed results, wi
Creating AP® CS Principles: Let Many Flow	Marie desJardins	2015	ACM Inroads	Overview of the	To broaden parti	Collaborative des	Not applicable.	Not applicable.	Emphasizes com	Increased diversi	Not specified.
Understanding Computing in a Hybrid Worl	Laura Benvenuti, Erik Barer	2018	SIGCSE'18, ACM	Analysis of hybri	Investigate the '	Framework analy	Two curricula an	Not specified.	Discussion of cur	Recommendatior	Not specified.
How Student Centered is the Computer Sci	Scott Grissom, Renée McCa	2017	ACM Transactions on Computing Educa	Survey of faculty	Measure the exte	Survey of over 7	700 faculty respo	U.S. faculty in co	None; focuses or	Insights into ado	Varied use of stu

Preliminary Discussion

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Methodology:

- Robust methodology driving early insights
- Effective keyword selection, inclusion exclusion criteria and database selection captures relevant research
- Validates the robustness and effectiveness of the approach

Overview of the 12papers reviewed:

- 8 showed a positive correlation for **Soft skill** development
- 4 showed positive correlation of **Technical Skills** development
- A number of technologies improve learning outcomes when paired with IBL

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References

Chu, Samuel Kai Wah, Rebecca B Reynolds, Nicole J Tavares, Michele Notari, and Celina Wing Yi Lee. 21st Century Skills Development through Inquiry-Based Learning from Theory to Practice. Springer, 2021.

Cico, Orges, Letizia Jaccheri, Anh Nguyen-Duc, and He Zhang. "Exploring the Intersection between Software Industry and Software Engineering Education - A Systematic Mapping of Software Engineering Trends." Journal of Systems and Software 172 (2021): 110736. https://doi.org/10.1016/j.jss.2020.110736.

Davis, Michael, et al. "The Importance of Lifelong Learning in Software Engineering." Journal of Software Engineering, 2022.

Gurcan, Fatih, and Cemal Köse. "Analysis of Software Engineering Industry Needs and Trends: Implications for Education." International Journal of Engineering Education 33 (January 2017): 1361–68.

Ješková, Zuzana, L'ubomír Šnajder, and Ján Guniš. "Active Learning in STEM Education." In Journal of Physics: Conference Series, 2715:012019. IOP Publishing, 2024.

Karp, Andrew, et al. "Transforming Software Engineering Education." IEEE Software, 2020.

Kitchenham, Barbara Ann, David Budgen, and Pearl Brereton. Evidence-Based Software Engineering and Systematic Reviews. Chapman & Hall/CRC, 2015.

Molenda, Michael. "In Search of the Elusive ADDIE Model." Performance Improvement 42, no. 5 (2003): 34–37.

Ouhbi, Sofia, and Nuno Pombo. "Software Engineering Education: Challenges and Perspectives." In 2020 IEEE Global Engineering Education Conference (EDUCON), 202–9, 2020. https://doi.org/10.1109/EDUCON45650.2020.9125353.

Zawacki-Richter, Olaf, Michael Kerres, Svenja Bedenlier, Melissa Bond, and Katja Buntins. Systematic Reviews in Educational Research: Methodology, Perspectives and Application. Springer Nature, 2020.

Question: Validity Threats

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1. **Selection Bias:** Occurs when the selection criteria for studies are not clearly defined, potentially leading to the inclusion of studies that do not meet the intended scope or quality standards.

2. **Publication Bias:** Systematic reviews often rely on published studies, which may overrepresent positive findings, as studies with negative or inconclusive results are less likely to be published.

3. **Data Extraction Errors:** Mistakes during data extraction can lead to incorrect conclusions. Inconsistent or inaccurate data extraction can arise from ambiguous definitions or complex study designs.

4. **Heterogeneity of Studies:** Variability in study designs, methodologies, and metrics across included studies can make it challenging to draw consistent conclusions or conduct meaningful meta-analysis.

5. **Reviewer Bias:** Personal biases of reviewers can affect study selection, data extraction, or interpretation. Blinding or independent review can help mitigate this risk.

6. **Quality of Included Studies:** The overall validity of a systematic review is influenced by the quality of the studies included. If the included studies have methodological flaws, these limitations may impact the review's conclusions.

Reflection

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Progress

- Made fantastic headway, well set up for ThesisB
- Second half of session considerably more productive
- Large time blocks for research

Limitations

- Time and Resources
- Mental Fatigue
- No template or framework
- No clearly defined metrics

Obstacles

- No clear path forward
- Hard to set milestones
- Ensuring objectivity

Insights

- No one size fits all to research
- Community is important
- 1x answer = 2x more questions

Next Steps

- Conferences
- Teche articles
- Inform course design
- Further Research

1.5 Key Terms and Definitions

Key Term	Definition
Inquiry-Based Learning	An educational approach where students engage with questions and problems to foster critical thinking and problem-solving skills.
Engineering Competencies	A collection of skills and knowledge necessary for effective performance in engineering roles including both technical and soft skills[9].
Technical Skills	Specific abilities required to perform tasks in software engineering such as programming, software design, and debugging.
Soft Skills	Non-technical skills that relate to how individuals interact with others and approach their work
Critical Thinking	The ability to analyse information and make reasoned judgments that are logical and well-thought-out.
Problem-Solving	The process of finding solutions to complex or difficult issues crucial for software development and engineering.
Collaboration	Working with others to achieve common goals often involving communication and teamwork in projects.
Software Development Methodologies	Structured approaches to software development such as Agile, Scrum, and Waterfall, that guide project execution.
Software Testing	The process of evaluating software to ensure it meets specified requirements and is free of defects.
Continuous Integration/Continuous Deployment (CI/CD)	Practices that encourage frequent integration of code changes and automated deployment leading to faster development cycles.
Version Control	A system that records changes to files or sets of files over time allowing for collaboration and tracking of project history.
Lifelong Learning	The ongoing pursuit of knowledge and skills throughout an individual's career essential in the rapidly evolving tech landscape.
Active Learning	An instructional approach that engages students in the learning process often through collaborative tasks and discussions.
Project-Based Learning	A teaching method in which students gain knowledge and skills by working on a project over an extended period.

Table 1.1: Key Terms and Definitions

3.2.2 Selection Process

Inclusion Criteria

- **Research Question Focus:** Studies that explicitly investigate the impact of inquiry-based learning (IBL) on software engineering students.
- **Competency Focus:** Research that examines the development of Software Engineering competencies such as critical thinking, problem-solving, and teamwork within a software engineering context.
- **Study Design:** This review will include empirical studies employing quantitative, qualitative, or mixed-methods designs, as well as studies that employ a control or comparison group to evaluate the effectiveness of IBL versus traditional methods.
- **Measurable Outcomes:** Studies must provide measurable outcomes or thematic insights on student competencies with well-defined articulated metrics (e.g., rubrics for teamwork), performance assessments, surveys, validated scales, interviews, or observational data.
- **Pedagogical Focus:** All forms of IBL will be considered including subtypes such as project-based learning, case-based learning, and problem-based learning, provided they align with the core principles of IBL.
- **Student Audience:** Studies conducted in tertiary education settings specifically within undergraduate or postgraduate software engineering programs.
- **Delivery Method:** Studies that examine in-person teaching will be considered. While online or blended learning approaches will generally be excluded studies where blended or online learning does not significantly impact the IBL format may be evaluated on a case-by-case basis.
- **Geographical Scope:** Studies conducted globally are included provided they address IBL within a software engineering context.
- **Time Frame:** Studies published from 2015 up until the start of 2024 will be considered to reflect recent research.
- **Research Standard:** Only peer-reviewed journal articles and conference papers will be included to ensure research quality and credibility. Grey literature, such as unpublished manuscripts, white papers, and preprints, will not be included.
- **Quality Assessment:** Only studies that meet minimum quality assessment standards using GRADE quality assessment outlined by Yang et al[55].

Exclusion Criteria

- **Non-Student Participants:** Studies that target professionals, corporate training environments, or participants outside formal tertiary education will not be included in the review.
- **Non-Software Engineering Disciplines:** Studies focused on inquiry-based learning in other fields, such as general education, social sciences, or humanities, without any connection to software engineering will not be considered.
- **Theoretical or Conceptual Papers:** Studies that are purely theoretical or conceptual without empirical data collection will be excluded. This includes papers that discuss IBL or software engineering education without presenting primary or secondary data.
- **Language Restrictions:** Studies published in languages other than English and not accompanied by an English translation will be excluded from consideration due to language barriers.
- **Blended and Online Learning Dominance:** Studies where the primary focus is on blended or online learning formats will be excluded.
- **Inconclusive Research:** Only research that presents strong empirical evidence defined as studies with statistically significant findings or well-defined actionable insights regarding the impact of IBL on critical competencies will be included to ensure research quality and credibility.
- **Publication Quality Threshold:** Studies that do not meet an acceptable quality threshold based on quality assessment tools will be excluded to maintain the rigour and reliability of the review.

3.2.3 Quality Assessment

- **Clarity of Research Questions:** Each study must clearly state its research questions or hypotheses ensuring their relevance to the fields of engineering or education.
- **Study Design:** The appropriateness of the study design (e.g. experimental, case study, or survey) is assessed ensuring that designs align with the stated research questions.
- **Sampling:** Studies are evaluated based on the adequacy of their sample size and the relevance of participants to the research context.
- **Data Collection Methods:** The methods used for data collection must be valid and reliable as well as appropriate for the context of the research.
- **Data Analysis Techniques:** The robustness of the data analysis methods is assessed ensuring statistical or qualitative techniques are employed correctly and align with the research questions.
- **Bias and Limitations:** Each study must acknowledge potential biases and limitations within its research design and methodology.

Weighting of Studies

Each study is assigned a quality score based on the checklist. The studies are then weighted accordingly:

- **High Quality:** Studies that meet most criteria and demonstrate methodological strength, relevance, and rigour.
- **Medium Quality:** Studies that exhibit some limitations but remain methodologically sound.
- **Low Quality:** Studies characterised by significant methodological flaws or a lack of relevance.

Relevance

The relevance of each study to the systematic literature review's research questions is critical for inclusion. The relevance assessment includes:

- **Relevance to Research Questions:** Studies are assessed based on how closely their subject matter aligns with the primary research questions of the SLR.
- **Publication Date:** The currency of the studies is considered as recent research is more likely to reflect current trends and innovations in fast-evolving fields like engineering.
- **Contextual Relevance:** Studies are assessed for their relevance to specific educational or engineering contexts under investigation (e.g. higher education, K-12 education, or professional training).

Rigour

The rigour of each study is assessed to determine the depth and thoroughness of its methodology, analysis, and reporting. Rigour is evaluated using the following criteria:

- **Depth of Literature Review:** Each study must provide a comprehensive review of existing literature and offer a well-developed theoretical framework.
- **Transparency in Reporting:** The study must clearly report its methods, results, and conclusions in sufficient detail to allow for replication or secondary analysis.
- **Validity and Reliability:** The validity and reliability of the study's measurements and instruments are critically evaluated.
- **Generalisability:** The generalisability of the study's findings is considered in terms of whether its conclusions can be applied to different populations or settings.

Educational Question Framework

POSE (Population, Observation, Setting, Evaluation)
SPICE (Setting, Perspective, Intervention, Comparison, Evaluation)

Methodology - Overview

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Literature review informed key considerations when conducting an interdisciplinary Systematic Review (Education and Engineering).

Four main stages:

- Formulating the Research Question
- Conducting the Review
- Synthesising the Data
- Reporting the Review