

Exploring problem scoping approaches: A study of third-year engineering students

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Abstract

This work-in-progress (WIP) evidence-based practice paper examines problem scoping as a critical early stage in the engineering design process. The study analyses reflection journals from 14 third-year material science and engineering students using a qualitative, inductive approach. Results identify four key aspects of problem scoping: (a) gathering information about clients, problem context, and the designers themselves; (b) setting goals based on gathered data; (c) developing solutions using divergent, convergent, and logical thinking; and (d) evaluating and managing design outcomes by reflecting on solutions by envisioning outcomes or creating backup plans. Both male and female students show similar approaches. Findings contribute to understanding students' problem-scoping processes and highlight opportunities for future research into engineering design education.

Keywords: Problem scoping, engineering education, higher education, qualitative study.

Introduction

Educating engineers begins with problem scoping—gathering data to define issues and develop ethical, effective solutions [1]. Research on problem scoping is limited, particularly in Eastern countries, where engineering education systems differ, making findings from Western studies less applicable. The primary method, verbal protocol analysis (VPA), involves analyzing think-aloud interviews to compare processes between students and experts [2]. While insightful, VPA is time-intensive and unsuitable for large-scale studies. Effective training in problem scoping equips students to address technical challenges while considering stakeholder needs, societal benefits, and commercial value [3]. A clear understanding of the design context is essential to avoid generalizations that lead to ineffective solutions and wasted resources. As problem scoping is foundational to design, it ensures engineering criteria are met while balancing environmental, social, and economic impacts. This study explores two questions: (1) How do senior engineering students approach problem scoping? (2) Are there gender differences in their approaches?

Method

The study involved engineering students from a prestigious research institution in Asia enrolled in a 13-week Industrial Design course offered in a hybrid online/offline format. A total of 104 students participated, working in groups of five to six under the supervision of academics and industry mentors. Students developed, prototyped, and evaluated solutions to real-world industrial problems. Fourteen participants (N=14) were randomly selected from the course, and written consent was obtained from all. Participants were anonymized using identifiers such as S1, S2, etc. They were required to maintain reflection journals, reflecting on their individual approaches to problem scoping, with a minimum of 200 words per entry. Table 1 shows the demographic information of the participants.

Table 1. Demographic information of the participants.

Participant	Gender	Qualifications
S1	Male	A Lvl ¹ /IB ²
S2	Male	Polytechnic
S3	Female	A Lvl/IB
S4	Male	Polytechnic
S5	Male	Polytechnic
S6	Male	A Lvl/IB
S7	Male	Polytechnic
S8	Female	Polytechnic
S9	Female	A Lvl/IB
S10	Male	A Lvl/IB
S11	Male	Polytechnic
S12	Female	A Lvl/IB
S13	Male	Polytechnic
S14	Male	A Lvl/IB
N=14		
Note: 1. A Lvl: A level; 2. IB: International Baccalaureate.		

The reflection journals were analyzed using open- and axial-coding techniques. Initially, all authors reviewed the reflection journals to familiarize themselves with the data. One author then coded the reflection journals using NVivo 12 software. Discrepancies in coding were resolved through discussions, and regular meetings were held to finalize a consensus-driven list of codes. These codes were subsequently grouped into categories representing participants' problem-scoping approaches.

Results and Discussion

The study identified 11 codes across four categories: gathering information, setting goals, developing solutions, and reflecting on solutions. Table 2 shows the code frequency and operational definitions of each code.

Table 2. Categories and codes.

Categories	Codes	Frequency ¹	Operational definitions
Gathering Information (about)	the clients	15	Participants collect information about client companies, including their background, business field, operations, and needs.
	the problem context	11	Participants gather information on the problem's context, including its cause, available resources, and constraints.
	the designers	6	Participants recall relevant knowledge and identify gaps needed to solve the problem.
Setting Goal	Client-driven	15	Participants aim to fulfill clients' needs.
	Product-driven	13	Participants aim to create an ideal product.
Developing Solutions	Divergent thinking	7	Participants generate multiple scenarios and solutions to the problem.

	Logical thinking	6	Participants follow a step-by-step process.
	Convergent thinking	5	Participants narrow down scenarios to a single solution.
	Reverse thinking	1	Participants generate solutions by reversing their goals and working backward to identify the problem.
Evaluating and Managing Design Outcomes	Products envision	4	Participants envision and evaluate the solution process and final product against their initial goals.
	Risk management	1	Participants develop backup solutions to mitigate risks of original solution failure.

Note:

Frequency¹: The number of the codes generated from the entire dataset (N=14). For any particular code, participants might demonstrate more than once in their reflection journals.

All participants gathered information, prioritizing data about clients (N=10) and problem context (N=9) over self-reflection (about designers) (N=5). Most gathered one or two types of information; only S13 considered all three. This aligns with studies emphasizing the importance of client and contextual knowledge [4] but highlights the need for educators to encourage students to recognize and address their own knowledge gaps.

All participants set goals, categorized as client-driven (N=10) or product-driven (N=8). Some (S2, S5, S12, S14) combined these approaches, setting sub-goals to create ideal products meeting client needs. Goals influenced the type of information gathered and guided solution development. This study highlights goal setting as a distinct and essential step, distinguishing it from previous studies and emphasizing the need for its explicit integration into educational practices.

Most participants proposed solutions using divergent thinking (N=7), convergent thinking (N=5), or logical thinking (N=6). S9 uniquely employed reverse thinking, envisioning an ideal scenario where the problem did not exist and working backwards to identify issues. This finding underscores the diversity of cognitive strategies in problem scoping.

Few participants evaluated and managed design outcomes by reflecting on their solutions. Some (N=4) envisioned final products and assessed alignment with goals and constraints. S4 demonstrated risk management by developing backup plans. Although less common, reflection is crucial for assessing solution viability and identifying limitations.

Male and female participants exhibited similar approaches, suggesting consistency across genders. However, further research with larger samples is needed to explore potential nuances.

This study introduced reflection journals as a tool for examining students' problem scoping processes. Unlike VPA, reflection journals allow participants to document experiences naturally and at their own pace, offering richer insights into thought processes [5] [6]. Future educators and researchers can leverage this method for more in-depth exploration of engineering students' approaches. This study, conducted in the Asian context, provides a detailed examination of

iterative processes in problem scoping, complementing findings from non-Asian studies [4] [7] [8]. It emphasizes goal setting as a pivotal step interlinked with information gathering, solution development, and evaluation. Educators should integrate explicit goal-setting frameworks into problem-scoping instruction to enhance student outcomes.

Conclusion

The study provides a detailed, contextualized perspective to assist stakeholders in refining practices. The small sample size limits its generalizability [9]. However, we prioritize transferability, enabling readers to assess whether the findings apply to their own contexts [10]. By providing detailed descriptions of our participants, research setting, and coding framework, we aim to generate meaningful insights that others can interpret and build upon. Furthermore, we acknowledge that data saturation has not yet been fully achieved in this WIP study [11]. Two codes—reverse thinking and risk management—were identified by only one participant, indicating that additional data collection may offer further insights. As we expand this study in the future, we intend to increase the sample size to allow for a more comprehensive exploration.

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