Inquiry Frameworks for Research Question Scoping in DSR: A Realization for ChatGPT

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Abstract. Research Question (RQ) Scoping refers to defining and refining a research question before conducting research. This step is crucial for ensuring the relevance and focus of the study, particularly in Design Science Research (DSR), where problems and solutions develop gradually. Literature reviews are a traditional method for comprehending the problem and determining key questions; however, they can be time-consuming and not worth it at the onset when lashing out in the dark. NLP chatbots such as ChatGPT can serve as a cost-effective alternative to clearing the way due to their capability to interact with users in a natural language-based manner and provide intuitive responses. The requirements for RQ Scoping extend beyond conversational support to include a framework for a sustained and iterative scoping process. An inquiry framework is necessary to guide and assist students and supervisors in fully harnessing the potential of NLP chatbots. This work incorporates ChatGPT into an inquiry framework for RQ Scoping, with mind maps as the visualization and the 5 Why technique as the inquiry strategy. Contributions include Design Principles, an IT artifact, and a Technology Acceptance Model evaluation (n=9). Regarding perceived usefulness, the results indicate agreement on the intervention's effectiveness in maintaining focus. However, there is less enthusiasm for mind maps as a communication tool. Perceived ease of use was also positive but revealed concerns about the query templates used by the framework.

Keywords: RQ Scoping · Chatbot · ChatGPT · Mind maps

1 Introduction

Research Question (RQ) Scoping refers to defining and refining the research question before beginning the research. It involves analyzing the research context and determining specific questions necessary to evaluate the investigation results effectively. This process is crucial for ensuring focused and relevant research. However, in DSR, scoping can be particularly challenging as problems and solutions evolve iteratively and gradually. If the scope is too narrow, the results may not be comprehensive or relevant to more significant problems. Conversely, if it is too broad, the research may lack focus, leading to less valuable insights. This raises a 'Goldilocks issue' whereby researchers struggle to balance focused and relevant research whilst addressing topics of interest [16].

RQ Scoping is a challenging task due to its abductive nature [10]. Abductive reasoning starts with observations or experiences (e.g., empirical data that causes 'the gut feeling'). Then it seeks to find the most straightforward and likely explanations for the observations: the hypotheses [21]. This starts an exploration journey where the recently acquired hypotheses are tested, more data are generated, and a new hypothesis emerges. In this scenario, researchers are involved in continuous decision-making, beginning with discovering an interesting phenomenon to investigate. To that end, reviewing the literature is a common practice for identifying the most promising RQs and gaining a deeper understanding of the problem or opportunity. However, a literature review takes time, and its rigor and thoroughness may not pay off for preliminary questions that are initially nothing more than 'gut feelings'. Alternatively, AI-powered chatbots might be a good-enough alternative to clear out the research space, even if they lack the confidence that literature reviews offer.

This work's central tenant is that AI-powered chatbots may offer a satisfactory trade-off between effort and potential outcomes for RQ Scoping. The conversational aspect reduces effort, while AI language models increase the chances of valuable results. However, relying solely on a conversation may not be sufficient for RQ Scoping. RQ Scoping is explorative, which calls for the search to be systematic and structured to prevent losing focus. The need for such an *Inquiry Framework* increases for users who take control of their learning at their own pace [18,24]. This setting very much resembles that of doctoral students. This leads to our research question: *How could AI-powered chatbots be integrated into an Inquiry Framework (i.e., the artifact) for RQ Scoping (i.e., the task) when conducting DSR projects (i.e., the practice) conducted by doctoral students (i.e. the target audience)?*

We address this question for ChatGPT [1] as the AI-powered chatbot, the *5 Why* as the inquiry strategy, and mind maps as the recording support for the chatbot conversation. We contribute by

- exploring the capabilities and limitations of ChatGPT for RQ Scoping (Section 2).
- introducing *Chatin*, an inquiry framework combining ChatGPT and the 5 Why inquiry strategy (Sections 4 and 5).
- generalization of the learning through three Design Principles for Inquiry Frameworks (Section 3) and comparison with sibling interventions in the inquiry-based learning literature (Section 6).

We start with a brief on ChatGPT.

2 A Brief on ChatGPT

ChatGPT is a chatbot based on the OpenAI GPT-3 language model. ChatGPT lets people ask questions or tell stories, and the bot will respond with answers and topics that make sense and sound natural. ChatGPT is being fed by a huge amount of data (up to September 2021), yet its scope may not have the same breadth, depth, and timeliness of information as traditional search engines that use real-time information [5]. That

[1] `https://chat.apps.openai.com/`

said, first evaluations conclude that the use of ChatGPT "can help researchers more efficiently and effectively process and analyze large amounts of data, generate realistic scenarios for testing and evaluating theories, and communicate their findings in a clear and concise manner" [17].

ChatGPT is claimed to offer the potential to increase motivation and engagement among self-taught learners with the potential to guide and structure users' exploration of a research space [14,3]. A recent systematic review and meta-analysis on the impact of AI components on student performance (n=25) support a positive impact on their performance, finding a rise in their attitude towards learning and their motivation, especially in the STEM (Science, Technology, Engineering, and Mathematics) areas [9]. More specifically, for our purposes, the advantages of self-directed learning include [7]:

- Support unique to each learner: ChatGPT can help learners in charge of their learning by adapting suggestions and responses to each learner's choices and goals. This could be very helpful for students who might not have access to more conventional support networks like a teacher or a mentor.
- Real-time feedback and direction: As self-taught learners move through the course materials and resources, ChatGPT can give them real-time feedback and direction. This can assist students in staying on task and addressing any issues or problems they might encounter.
- Accessibility: Learners who might not have access to traditional educational materials will find ChatGPT easier to use because it can be accessed through a website, a smartphone app, or a messaging service.
- Convenient and flexible learning: Autodidacts can study at their own pace and on their own terms with ChatGPT, as they can interact with the chatbot whenever it's convenient for them.
- Enhancing the use of open educational resources: ChatGPT can help self-directed learners find and use open educational materials by giving them personalized tips and advice on using these resources. This can allow students to use the many tools and resources for learning that are available online.
- Self-assessment and reflection: Learners can use ChatGPT to reflect on their own progress and learning and to identify areas where they may need further support or guidance.

This study investigates the potential utilization of ChatGPT in RQ Scoping.

3 Design Principles for an AI-empowered Inquiry Framework for RQ Scoping

This section introduces a set of generalized requirements for an inquiry framework (i.e., the intervention) for AI-powered RQ Scoping (i.e., the task) in DSR-based doctoral studies (i.e., the practice). In our search for justificatory theories, we characterize RQ Scoping as a practice of inquiry-based learning, specifically, an open inquiry-based learning practice.

"Open inquiry" engages students in decision-making throughout the entire process, from identifying an interesting phenomenon to investigating. Encouraging students to take ownership of their learning, this approach can increase their self-esteem and lead to a deeper understanding of the topic being studied. [23]. However, it may present more of a challenge for some students, particularly those who struggle academically [4]. A study of over 2,800 students over three years found that many students needed assistance with scientific research, experimental techniques and procedures, and phrasing inquiry questions [25]. Overcoming interventions include:

– online forums, where students present their challenges and receive guidance from teachers and peers [25]. However, this concept is not applicable in a doctoral setting, as there are typically no peers to engage with.
– software scaffolds, like *Hypothesis Scratchpad* [20]. One problem is that noticing relevant variables in a hypothesis requires substantial conceptual domain-specific knowledge, which students may lack [15]. Without sufficient surface knowledge, engaging effectively in deeper learning activities can be difficult because the fundamental building blocks are missing [11]. It is sensible to argue that doctoral students face similar matters.

This work builds upon a software scaffold intervention, i.e., an inquiry framework. Unlike *Hypothesis Scratchpad*, RQ Scoping serves as the preliminary step for generating hypotheses by establishing domain-specific conceptual knowledge.

3.1 Inquiry Frameworks: Design Principles

We define an inquiry framework as a structured approach to problem-solving that guides the scope and analysis of an RQ [13]. We qualified an inquiry framework as 'AI-empowered' if a language-model chatbot is introduced. The next paragraphs introduce three design principles for this intervention.

RQ Scoping is exploratory, i.e., it is focused on seeking new information and gaining a general understanding of a subject rather than confirming preconceived ideas or hypotheses [12]. The difficulty lies in comprehending the range of options available so researchers can gain a comprehensive perspective. Inquiry frameworks document and track the scoping map, ensuring all pertinent information is considered. This necessitates the existence of a visual framework that enables prompt and effective visualization of the alternatives at stake, allowing students to move seamlessly among them, especially in a doctoral setting where the exploration is conducted collaboratively with the supervisor. This leads to our first design principle (DP):

> (DP1) **Provide the framework with** effective visualization **in order for researchers to** get an overview of the RQ alternatives at stake to be shared with the supervisor

RQ Scoping, like the other DSR stages, is iterative. Iterative means gradually narrowing down the scope of the problem rather than cycling through possible solutions. There is a need for the inquiry framework to allow students to narrow the scope of their RQ gradually. This is when the 5 Why technique comes into play. 5 Whys is an iterative interrogative technique to explore the cause-and-effect relationships underlying a particular problem [1]. The technique is based on the premise that asking "why" five times will lead to identifying the underlying cause of a problem. The process involves asking "why" a problem happened and then using the answer to that question as the basis for the next question. The technique is simple yet effective enough to shift the focus from general concerns to their causes.

(DP2) **Provide the framework with** a searching strategy **in order for researchers to** gradually reduce the RQ scope.

The 5 Why technique focuses on explanatory questions to understand the cause-and-effect relationships of a particular phenomenon, but it says nothing about the phenomenon itself. The technique offers no help in assessing the context where “the why’ is posed. Chatbots offer little help either [8]. Yet, ‘context’ is critical in DSR, where interventions are not general but show utility in a specific context. Indeed, Design Science is defined as "the design and investigation of artefacts *in context*" [22]. As a result, the inquiry framework should supplement the chatbot by managing its own contextual variables throughout the conversation. In a DSR setting, this may include the practice, the task, or the stakeholders that conform to the setting where the problematic phenomena arise [12].

(DP3) **Provide the framework with** a contextual state **in order for researchers to** keep the context throughout

4 Proof-of-concept: An Inquiry Framework for RQ Scoping

This section describes *Chatin*[2], an inquiry framework for RQ Scoping using ChatGPT as the AI-powered chatbot, and MindMeister[3] as the mind-map editor. ChatGPT is considered to be at the very edge of AI technology. As for MindMeister, rationales for its selection include performance (support for large maps), popularity (25 million users at the time of this writing, as seen on the application’s website), and web support. The latter is significant. MindMeister uses an online mind map editor that enables users to create, edit, share, and present mind maps right inside a web browser. No software download or update is necessary.

The rest of this section is structured along the aforementioned Design Principles.

4.1 DP1: Provide the Framework with Effective Visualization

The 5 Why technique follows a tree-like way of conducting root-cause analysis where the next question is based on previous answers. This tree-like structure suggests the use of mind maps as a visualization approach. A mind map is a diagram used to visually organize information in a radial fashion [2]. They provide a visual overview of a topic and can help find connections, aiding comprehension, problem-solving, and decision-making. Chances are students are already familiar with this approach. Specifically, we resort to the *MindMeister* editor.

[2] *Chatin* is a portmanteau of CHAtgpt-powered INquiry. The term is informally used as a friendly nickname in Spanish.

[3] https://mindmeister.com

Fig.1 depicts a head start template provided by *Chatin* on top of *MindMeister*. Nodes are radially disposed around a root node (*"RQ Scoping"*), with two salient branches: the *"Question Model"* and the *"Scoping Analysis"*. The latter is the start of the inquiry process. *Chatin* provides a first *question node*: a RQ generated using the context variables of the Question Model (see Fig.2 and next section). The students can edit and rephrase this question using the question variables to keep consistency. Finally, question nodes can be 'enacted', i.e., the student clicks on the magnifier icon (⚲) for these questions to be transparently delivered to ChatGPT. This starts the inquiry process.

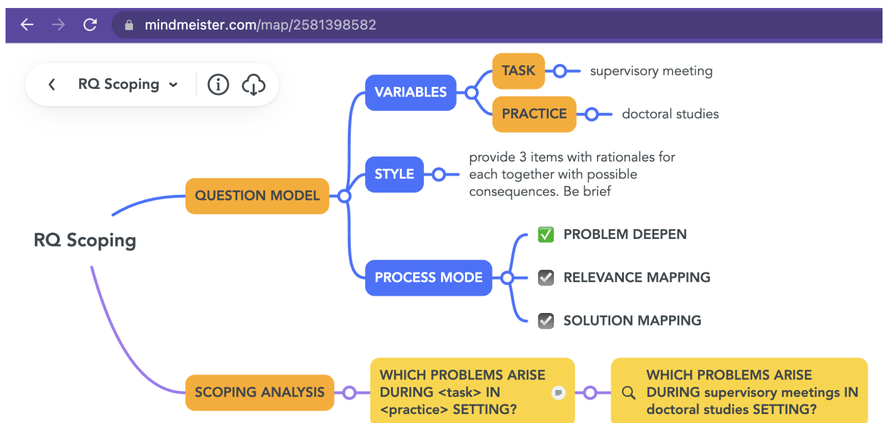

Fig. 1. A head start template provided by *Chatin* on top of *MindMeister*. The student provides the TASK and the PRACTICE variables from where *Chatin* generates the first question node in the SCOPING ANALYSIS tree. Click on this node's magnifier for this question to be issued to ChatGPT

Chatin resorts to mind maps for structuring the conversation between the student and ChatGPT. This means that the mind map is made by putting the student nodes and the ChatGPT nodes next to each other. Student nodes stand for questions. ChatGPT nodes correspond to answers. *Chatin* mediates. This implies: (1) sending the student's questions to ChatGPT (through its API [4]); (2) collecting and itemizing ChatGPT's answer; and (3), turning each of the items into a node in the mind map. Fig. 2 illustrates this: questions and answers intermingled as the map unfolds. From a rendering perspective:

- Question nodes are yellow-shaded and hold the 'magnifier' icon (⚲). On clicking, *Chatin* constructs the prompt to be issued through the OpenAI's API, collects the answer, and transforms this answer into a set of answer nodes;
- Answer nodes are green-shaded and hold the 'activation' icon (☑). On clicking, *Chatin* draws a question node from the ChatGPT answers, completing the cycle.

[4] `https://openai.com/api/`

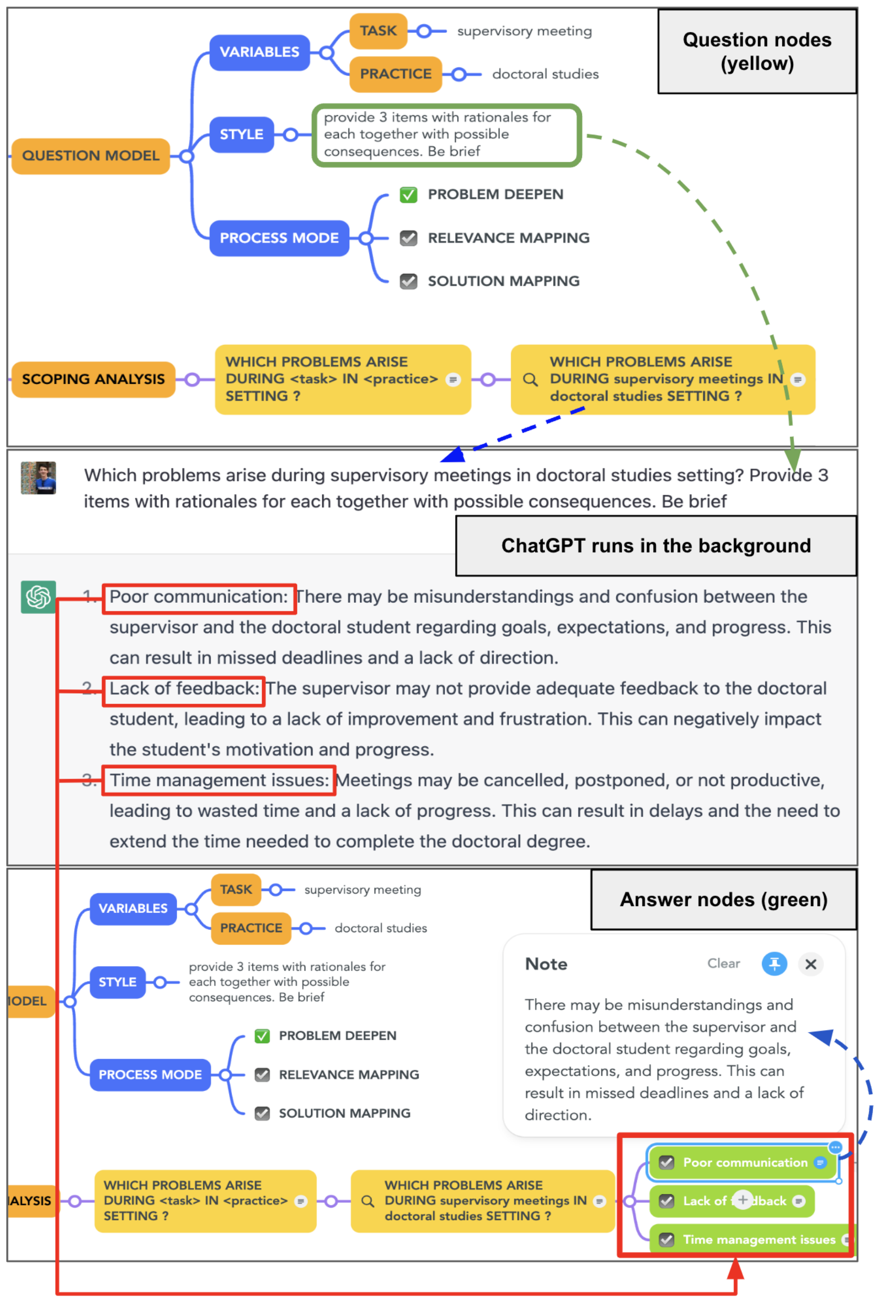

Fig. 2. Question nodes are extended by answer nodes, which in turn serve to build the next question nodes. *Chatin* takes question nodes and delivers answer nodes, and the other way around.

4.2 DP2: Provide the Framework with a Contextual State

For chatbots, 'context' refers to the background information and knowledge that the chatbot uses to understand and respond to a user's input. ChatGPT keeps its own context embedded in the engine. In addition, *Chatin* makes its own context explicitly through the 'Question Model'. This model is captured as a node in the mind map (see Fig. 1). The Question Model tackles three concerns, namely:

- *Variables*. The student can set them to be used throughout the inquiry. The example shows the case of context variables of which only two have been instantiated: *task* and *practice*. This serves to define variables to be next used to write questions, and, hence, keep consistency throughout the inquiry process.
- *Style*. In our setting, ChatGPT does not target a human being but another software agent, i.e., *Chatin*. Hence, responses should be tuned to facilitate their processing. ChatGPT allows you to provide cues about how to tune your answers (e.g., itemize, number of items, special control characters, and so on). The style node serves to provide these cues in a coherent way throughout.
- *Process mode*. This mode regulates the sort of questions *Chatin* will pose to ChatGPT: WHICH PROBLEMS MIGHT ARISE DURING the task (problem statement); WHY DOES the problem OCCUR DURING the tasks (problem analysis); WHY IS the problem RELEVANT FOR task (relevance mapping); and HOW CAN the problem BE ADDRESSED FOR (solution analysis) (see next subsection). If all questions were posed right away, the mind map would quickly become unwieldy. The Process Mode allows the student to set the dimension(s) to develop at his own pace.

4.3 DP3: Provide the Framework with a Searching Strategy

The search strategy is the cornerstone of an inquiry framework. The searching strategy structures the (partial) order in which distinct types of questions are posed. We resort to a state-transition diagram for formally specifying this strategy. A state-transition diagram captures this strategy through a set of states and the events under which the strategy progresses (transitions). States might hold *entry/exit* actions to reflect events that should happen when the system transitions into or out of a particular state. For our purposes,

- *entry* actions denote preparing and issuing the query to be posed to ChatGPT (the event) when entering the state,
- *exit* actions reflect the rendering of the ChatGPT's output

Chatin's search strategy develops along with three modes that are reflect as states (see Fig. 3):

- **Problem Deepen**. Here, the student starts by setting a very first question (i.e., Problem Statement), then moves on to assess the causes of this problem (i.e., Problem Analysis). Along with the 5 Why approach, each cause can in turn become a problem in its own right (notice the 'problem deepen' interaction in Fig. 3). The student

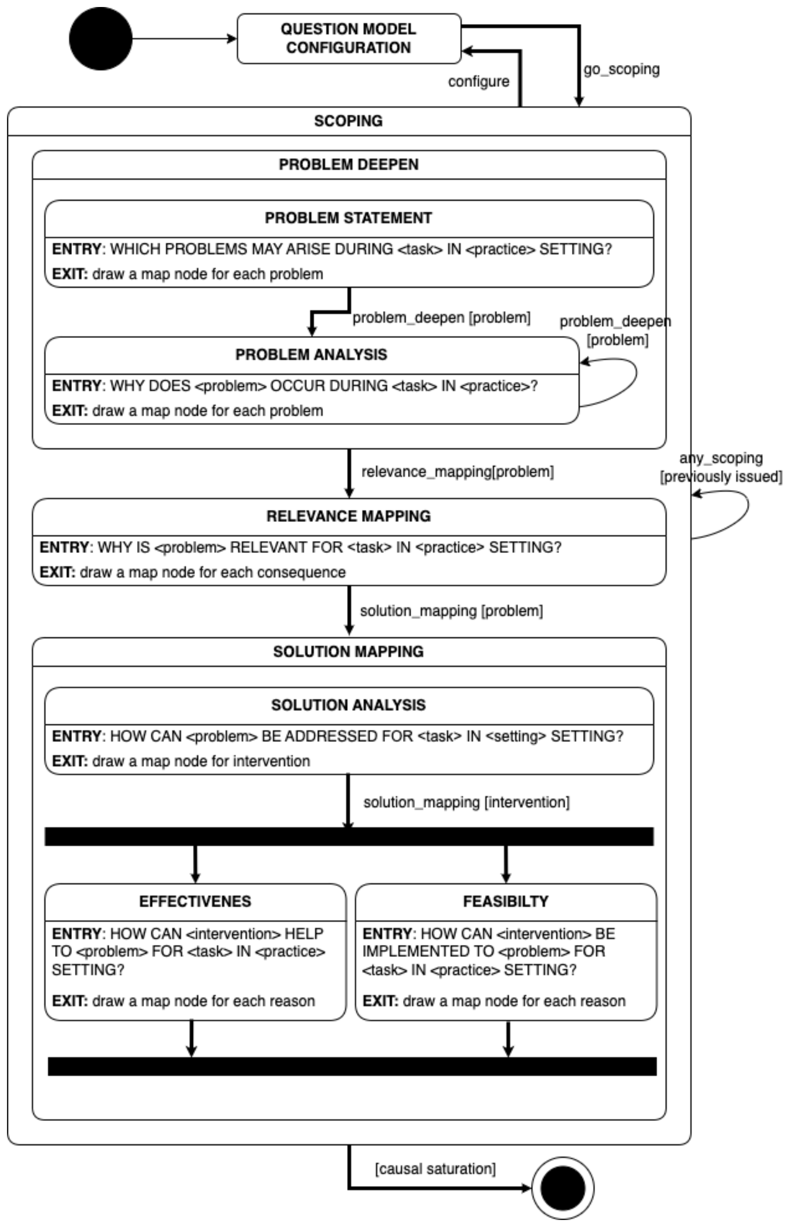

Fig. 3. State-transition diagram that governs *Chatin*'s search strategy: Problem Deepen, Relevance Mapping & Solution Mapping

delves into the causes of the problem, till he decides to investigate the relevance of the problem at hand. This is achieved by raising the *relevance_mapping[problem]* event. Notice that it is up to the student when to rise this event;

- **Relevance Mapping**. On entry, *Chatin* queries ChatGPT about the relevance of the problem at hand, delivering ChatGPT answers as nodes in the concept map. Eventually, rising the *solution_mapping[problem]* event, the student decides to move to the next state.
- **Solution Mapping**. On entry, *Chatin* queries ChatGPT about the existence of interventions to handle the problem at hand (i.e., related work). Provided any intervention exists, the student can now shift between looking into either the EFFECTIVENESS or the FEASIBILITY of the intervention at hand (notice the namesake concurrent states in Fig. 3.)

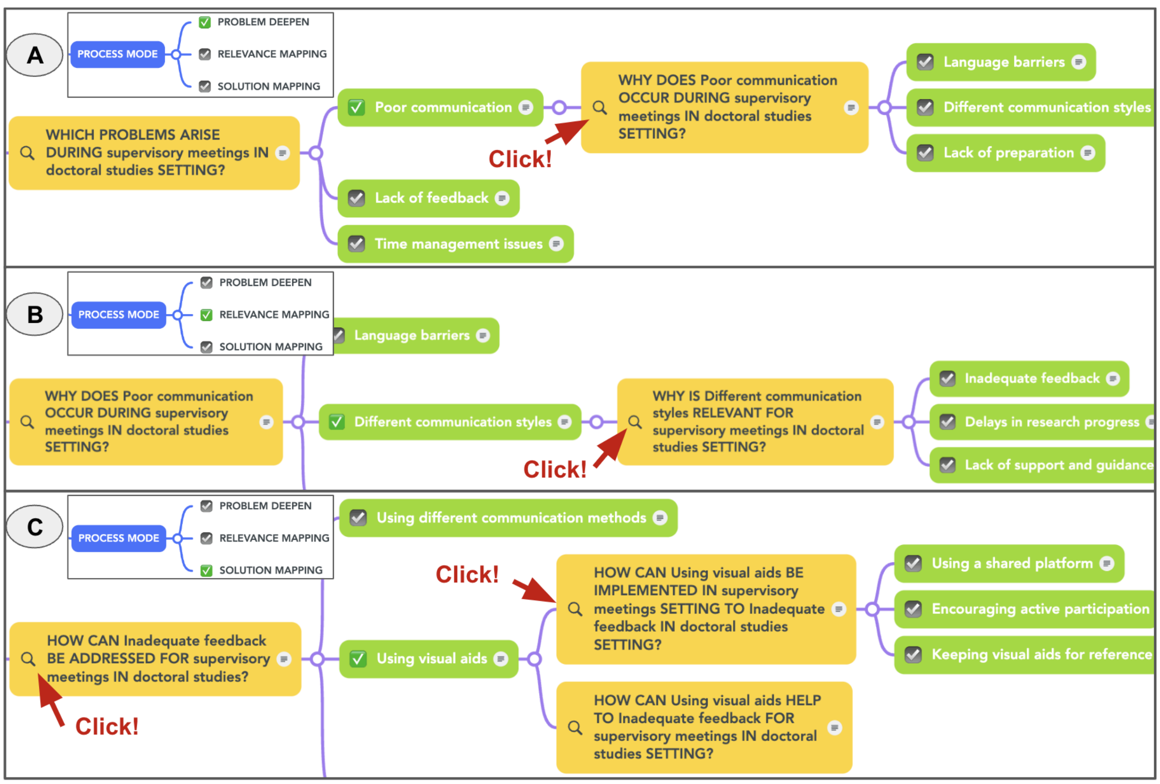

Fig. 4. *Chatin* three-mode process: PROBLEM DEEPEN transitions from a problem (*Poor communication*) to its causes (A); RELEVANCE MAPPING moves from a cause (*Different communication styles*) to study its possible relevance (B), and SOLUTION MAPPING moves from an intervention to study its effectiveness and feasibility (C). The student chooses which mode to focus on using the PROCESS MODE control variable

The inquiry unfolds by moving between states by making the appropriate transitions:

- *problem_deepen[problem]*: transitions from a problem to one of this problem's causes (see Fig. 4.A). Click on a problem node (green shadowed) for *Chatin* to generate a 'WHY PROBLEM' question node (yellow shadowed). The student could now rephrase the content of the question node. To investigate the causes of this cause, click on the question node's magnifier,
- *relevance_mapping[problem]*: transitions from a problem to one of this problem's consequences (see Fig. 4.B). Once in a problem node, activate the 'relevance mode' in the Question Model (see next). From then on, *Chatin* will generate 'WHY RELEVANT' questions,
- *solution_mapping[problem]*: transitions from a consequence to the associated interventions (see Fig. 4.C). Once in a consequence node, activate the 'solution mode' in the Question Model. From then on, *Chatin* will generate HOW questions.

This process is not inherently sequential and allows for reverting to previous stages at any moment, such as revisiting prior problems or interventions or starting afresh with a new problem statement[5].

5 Evaluation

Goal. This study aims to *assess* the perceived ease of use and usefulness of *Chatin* with respect to *RQ Scoping* from the point of view of *researchers* in the context of *DSR projects*.

Subjects. We tap into 9 participants, all with at least one year of experience on both DSR and MindMeister.

Instrument. Given the novelty of this intervention, we opt for resorting to the Technology Acceptance Model (TAM) [19]. We extended the TAM questionnaire to refine the notions of 'usefulness' regarding the aspects involved in RQ Scoping, specifically: promoting focus, systematically refining the RQ, documenting the journey, and guiding the exploration. The TAM scores highly on internal consistency validation using various measures [19]. Our case was no exception: we got an α of 0.63 and 0.70 for usefulness and ease of use, respectively. On these premises, we consider TAM an accurate predictor of usage and adoption for *Chatin*.

Results. Fig. 5 displays the Diverging Stacked Bar Chart for perceived usefulness and ease of use. Results show agreement on *Chatin*'s usefulness for focusing but less enthusiasm for mind maps as a communication tool. Perceived ease of use was also positive (see Fig. 5) but revealed concerns about *Chatin*'s query templates. Some participants suggested making question templates a configurable parameter for easier customization.

[5] Fig.3's *any_scoping[previously issued]* event accounts for any event in the *Scoping* state that has already been issued once.

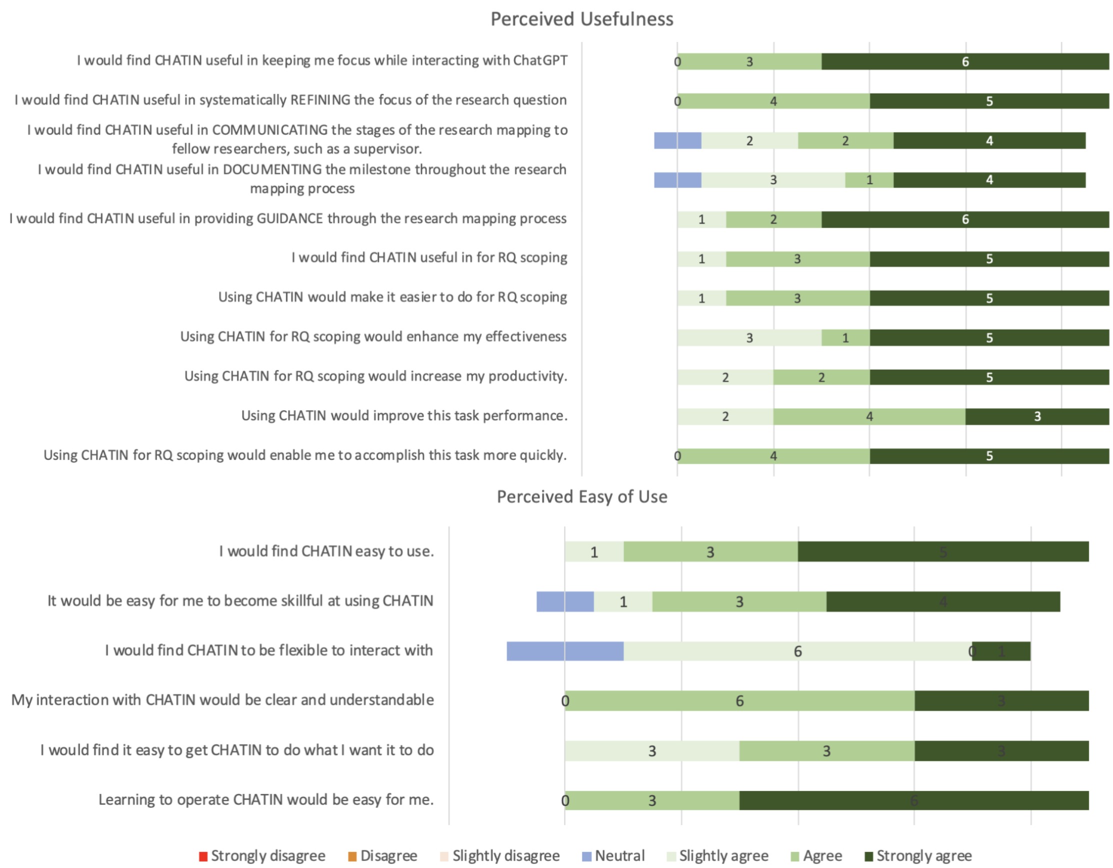

Fig. 5. Perceived usefulness and ease of use

Threats to validity. Two primary threats exist for the findings: reduced external validity as the study's tech-savvy participants may not represent all populations, and risk of construct validity as participants may have evaluated ChatGPT's technology unconsciously. The participants were warned of this potentially confounding variable, but the technology's novelty may have still impacted the results.

6 Discussion

Enholm et al. introduce a framework to place AI interventions in terms of (1) the typologies of AI use in the organizational setting; (2) the key enablers and inhibitors of AI adoption and use; and (3) the impacts of AI [6]. This section places this work within this framework.

Typologies of AI use. Enholm et al. divide AI applications into two categories: AI for automation (i.e., AI systems that replace human work) and AI for augmentation (i.e., AI systems that integrate with human expertise to improve decisions). *Chatin* is certainly AI for augmentation, specifically assisting students in developing their RQs.

Key enablers and inhibitors of AI adoption and use. The benefits that an AI intervention can bring to RQ Scoping include:

- Time efficiency: ChatGPT can provide quick and intuitive answers to RQ Scoping questions, reducing the time and effort required for traditional literature reviews.
- Cost-effectiveness: ChatGPT can serve as a cost-effective alternative to traditional methods for RQ Scoping, reducing the resources required for research.
- Accessibility: The chat-based interface and natural language interaction can make the RQ Scoping process more accessible for students and supervisors, particularly those not experts in the field.

On the downside, we envisage as main inhibitors:

- Dependence on inquiry framework: The approach's success depends on the design and effectiveness of the inquiry framework and its ability to guide and support the RQ Scoping process.
- Bias and errors. As with any AI-based system, there is a risk of bias and errors in ChatGPT's responses, which may impact the quality of the RQ Scoping process. ChatGPT's knowledge base may not be comprehensive or up-to-date, leading to inaccuracies or limitations in its ability to support RQ Scoping.
- Top Management Support. Enholm et al. note that top management support is one of the strongest determinants of AI adoption. This introduces tutors and supervisors as primary stakeholders in IA-assisted RQ Scoping. Supervisors might raise concerns not only about the accuracy of ChatGPT's answers but also the extent to which students' extensive, no-critical adoption of ChatGPT might hinder critical thinking.

We do not see ethical concerns arising in RQ Scoping. While ChatGPT can assist in mapping out the research area, it is ultimately up to the student's intuition to determine which path to take.

The impacts of AI. How does *Chatin* change RQ Scoping, and how does this lead to competitive performance? Enholm et al. report on the AI effects on companies to identify opportunities to enter the market with new offerings. We can set parallelism here whereby students identify research opportunities to be 'bought by the research market'. Despite their limitations, models for natural language processing, such as ChatGPT, allow for more agile and flexible mapping out of blurred research areas compared to traditional bibliographic search methods.

7 Conclusions

We investigate the use of Inquiry Frameworks that mediate between students and AI-powered chatbots in the search for better structuring, tracking, documenting, and communicating student progress in pursuing the 'right RQ'. *Chatin* provides first insights using ChatGPT as the chatbot and mind maps as the representation. This initial experience serves to identify three affordances for this kind of intervention: (1) *an effective visualization* to map out the research space to share with third parties (e.g., supervisors); (2) *a search strategy* to gradually narrow down the scope of the RQ to fit the resources available; and (3) *a contextual state* to keep a presence of the searching context throughout. Though results are promising, more participants are needed for more robust conclusions.

Users of *Chatin* should be aware of the potential limitations and concerns regarding the thoroughness, accuracy, and reliability of AI technology, particularly ChatGPT. It is essential to approach AI-generated responses critically and consider seeking additional sources when necessary. The mandate is clear: *Chatin* should integrate information sources other than ChatGPT that can be checked upon request.

Finally, it is essential to remember the words of Ray Kurzweil: "The ultimate goal of AI is not to create machines that are intelligent but to create machines that make us more intelligent". *Chatin* as AI for augmentation does not endow intelligence but aims to enhance students' focus, which is necessary for manifesting natural intelligence.

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References

1. Andersen, B., Fagerhaug, T.: Root Cause Analysis. ASQ Quality Press (2006), https://psnet.ahrq.gov/primers/primer/10/root-cause-analysis
2. Buzan, T.: Mind maps at work: How to be the best at your job and still have time to play. HarperCollins UK (2004)
3. Cahan, P., Treutlein, B.: A conversation with ChatGPT on the role of computational systems biology in stem cell research. Stem Cell Reports **18**(1), 1–2 (2023)
4. Chang, K.E., Sung, Y.T., Lee, C.L.: Web-based collaborative inquiry learning. Journal of computer assisted learning **19**(1), 56–69 (2003)
5. Cochrane, L.: Is ChatGPT Manipulating You? (Or Are You Manipulating It?), https://logancochrane.com/blog/is-chatgpt-manipulating-you-or-are-you-manipulating-it
6. Enholm, I.M., Papagiannidis, E., Mikalef, P., Krogstie, J.: Artificial intelligence and business value: A literature review. Information Systems Frontiers **24**(5), 1709–1734 (2022)
7. Firat, M.: How ChatGPT can transform autodidactic experiences and open education? (Jan 2023), https://doi.org/10.31219/osf.io/9ge8m
8. Følstad, A., Araujo, T., Law, E.L.C., Brandtzaeg, P.B., Papadopoulos, S., Reis, L., Baez, M., Laban, G., McAllister, P., Ischen, C., et al.: Future directions for chatbot research: an interdisciplinary research agenda. Computing **103**(12), 2915–2942 (2021)
9. García-Martínez, I., Fernández-Batanero, J.M., Fernández-Cerero, J., León, S.P.: Analysing the impact of artificial intelligence and computational sciences on student performance: Systematic review and meta-analysis. Journal of New Approaches in Educational Research (2023)

10. Hassan, N.R.: Constructing the right disciplinary is questions. In: AMCIS 2017 (2017)
11. Hattie, J.A., Donoghue, G.M.: Learning strategies: A synthesis and conceptual model. npj Science of Learning **1**(1), 1–13 (2016)
12. Johannesson, P., Perjons, E.: An introduction to design science. Springer International Publishing, Cham (2014). https://doi.org/10.1007/978-3-319-10632-8
13. Pedaste, M., Mäeots, M., Siiman, L.A., De Jong, T., Van Riesen, S.A., Kamp, E.T., Manoli, C.C., Zacharia, Z.C., Tsourlidaki, E.: Phases of inquiry-based learning: Definitions and the inquiry cycle. Educational research review **14**, 47–61 (2015)
14. Qadir, J.: Engineering education in the era of chatgpt: Promise and pitfalls of generative ai for education. TechRxiv. Preprint (2022), https://doi.org/10.36227/techrxiv.21789434.v1
15. Quintana, C., Reiser, B.J., Davis, E.A., Krajcik, J., Fretz, E., Duncan, R.G., Kyza, E., Edelson, D., Soloway, E.: A scaffolding design framework for software to support science inquiry. In: The journal of the learning sciences, pp. 337–386. Psychology Press (2018)
16. Rai, A.: Avoiding type iii errors: formulating is research problems that matter (2017)
17. Rizzo, G., Pietrolucci, M.E., Capponi, A., Mappa, I.: Exploring the role of artificial intelligence in the study of fetal heart. The International Journal of Cardiovascular Imaging **38**(5), 1017–1019 (2022)
18. Schweder, S., Raufelder, D.: Examining positive emotions, autonomy support and learning strategies: self-directed versus teacher-directed learning environments. Learning Environments Research **25**(2), 507–522 (2022)
19. Turner, M., Kitchenham, B., Brereton, P., Charters, S., Budgen, D.: Does the technology acceptance model predict actual use? a systematic literature review. Information and software technology **52**(5), 463–479 (2010)
20. Van Joolingen, W.R., De Jong, T.: Design and implementation of simulation-based discovery environments: the smisle solution. Journal of Artificial Intelligence in Education **7**, 253–276 (1996)
21. Walton, D.: Abductive reasoning. University of Alabama Press (2014)
22. Wieringa, R.J.: Design science methodology for information systems and software engineering. Springer (2014)
23. Windschitl, M.: Inquiry projects in science teacher education: What can investigative experiences reveal about teacher thinking and eventual classroom practice? Science education **87**(1), 112–143 (2003)
24. Zhai, X.: ChatGPT user experience: Implications for education. SSRN (2022), https://dx.doi.org/10.2139/ssrn.4312418
25. Zion, M.: On line forums as a 'rescue net' in an open inquiry process. International Journal of Science and Mathematics Education **6**(2), 351–375 (2008). https://doi.org/10.1007/s10763-006-9051-x