Concept Mapping for Supervisory Meetings in Doctoral Studies: An Action Design Research Approach

No Author Given

No Institute Given

Abstract. Because the supervisor is such an important part of the PhD process, it is unavoidable that the process will be slowed down without good communication. Concept mapping is a time-honored intervention to assist students in externalizing the conceptual knowledge they hold, and in doing so, it becomes a means for student-instructor communication. However, supervisors in tertiary education may not necessarily be experts in the research field, and there is no fixed "correct" concept map that students can present. The supervisor's role is often to aid with the methodology rather than evaluate the concept map itself. If the supervisor's role is more of a 'methodology scaffold' than a 'concept checker', then concept maps may better contain 'the hints' that help supervisors navigate the paths that led the student to the concept map in the first place. Traditional concept maps, however, do not reveal the sources that inform the student's understanding or the discursive role that concepts and relationships play in the research narrative. This work, utilizing Action Design Research, examines the use of concept maps in supervisory meetings in two doctoral projects utilizing Design Science Research (DSR). We also discuss the limitations encountered in using a concept-map editor (*CmapTools*), and an intervention to enhance this editor with a dedicated color-coded highlighter that provide supervisors with greater insights into the student's concept mapping process

Keywords: Concept Mapping · Doctoral Studies · Action Design Research · Annotation

1 Introduction

Concept mapping is a tool that has been shown to improve student learning quality [17]. However, we can not take it for granted that an intervention (i.e., concept mapping) that is being successfully applied in some settings (i.e., predominantly in primary and secondary studies) can project its utility (i.e., meaningful learning and smooth communication) to other settings (i.e., tertiary studies). Even though the goal of all the scenarios is for the student to learn something by completing a task with the help of an instructor, the nature of the student, the instructor, and the task might jeopardize the intervention.

In a doctoral setting, we cannot pretend that supervisors are knowledgeable enough to assess the convenience of concepts and relationships found in the student's concept map right away. Unlike other educational scenarios, the added value of the instructor is not so much in providing a competent external perspective about the goodness of the concept map as it is in providing methodological support about the research schedule, monitoring the progress of the project, finding a balance between problem and solution concerns, and the like [12].

This scaffolding role of the supervisor represents a major departure from other educational scenarios. In secondary education, the instructor knows 'the right answer', and hence, the instructor is able to identify shortcomings in the concept map with only the help of the concept map itself [20]. By contrast, a doctoral setting is one where supervisors do not often know 'the right answer', and their guidance is mainly about the journey (i.e., concept mapping) rather than the destiny (i.e., the concept map). In this respect, we experienced two shortcomings when using concept maps in supervisory meetings:

- the difficulty in delving into the student's readings. When students were questioned about some aspect of their concept maps, they rightly turned to the literature. Yet, this was time-consuming with students struggling for finding the supporting excerpts in the bibliography,
- the difficulty in determining the discursive role of concepts and relationships in the research narrative. For instance, students tend to entangle problem concerns with solution concerns, or have difficulties ordering causes and consequences.

Concept maps might well have promoted meaningful learning among our students, however, with few cues available to assess *the process* undertaken by the students. If the supervisor's job is more of a 'concept mapping scaffold' than a 'concept checker', then concept maps should better contain 'the hints' that help supervisors navigate the paths that led the student to the concept map in the first place. Process-wise, concept maps were clueless. This was our troubling experience.

As we are addressing a problematic situation *in research*, our research team is an appropriate stakeholder. Specifically, we encountered a class of problems (i.e., 'clueless concept maps') in a local context (i.e., supervising our own doctoral students with the assistance of concept maps), which required an intervention (i.e., the introduction of systematic highlighting as part of the process of concept mapping (see later)). We resort to Action Design Research (ADR). Sein et al. define ADR as a research method for generating prescriptive design knowledge through building and evaluating IT ensemble artifacts in an organizational setting [22]. Our research group is this 'organizational setting'. Contributions are those expected from an ADR intervention, namely:

- practice-inspired research: a study on the challenges of using concept mapping for supervisory meetings in a research group (Section 2),
- theory-ingrained artifact: an intervention to face these challenges by extending a popular concept-map editor called *CmapTools* [7], with a dedicated color-coded highlighter (Sections 3, 4 and 5),
- generalization from local practice: a discussion of the scope of the problem and the generalizability of the intervention (Section 6).

The ensuing section starts with the first ADR principle: practice-inspired research.

2 Concept mapping at the (-Anonymous-) research group

An ADR's major insight is the key role played by the organization (i.e., our research group) in driving and shaping the design knowledge that ends up being instantiated in the artefact (i.e., an intervention upon *CmapTools*). Hence, the term *ensembled artifact* denotes the artifact taking on its full meaning in conjunction with the context where it displays its utility. This section describes this context.

2.1 Why we decided to use concept maps in supervisory meetings?

Smooth communication between supervisor and student is a critical concern in higher education [28]. Ineffective communication can lead to the supervisor being unaware of the amount and type of feedback that the student requires [4], or it can cause ambiguity about the next step, leading to PhD delays and ultimately student frustration [15]. Design Science Research (DSR) is no exception, but rather the opposite. Several DSR factors challenge this communication: transdisciplinarity with the inclusion of non-academic stakeholders; interdisciplinarity which involves the combination of multiple academic disciplines; or the scarcity of concrete and agreed-on operationalization and tools for DSR [26]. This makes supervisory meetings even more relevant.

Different strategies for supervision have been proposed [12, 1]. Specifically, Harding et al. advised resorting to *structured meetings* where the student's knowledge is analyzed against what the student needs to learn [12]. This means that supervisors are more like guides who help students become active learners by building on what they already know. This constructivist approach to learning highlights the active role played by learners in constructing and developing knowledge and extracting meanings from their prior knowledge and experiences [18]. This resulted in Ausubel's Meaningful Learning Theory [3] which was later operationalized in terms of concept mapping by Novak [18]. Concept maps can be used to externalise the conceptual knowledge (both correct and incorrect) that students hold in a knowledge domain. Students create concept maps by adding labelled nodes to represent concepts and labelled links between two nodes to represent the relationships between them. Students need to figure out what the main ideas are and how they fit together. This way, they can learn more than just by rote memorization. This provides students with a deeper, more comprehensive understanding of the subject. But for our purposes, we thought of concept maps as a means for structuring meetings: a mediating representation for supporting interaction among learning actors.

2.2 What was the experience of using concept maps for supervisory meetings?

Table 1: Context Differences: Secondary Education vs Tertiary Education

	Secondary Education	**Tertiary Education**
Learner	graduate; limited autonomy	postgrad; ample autonomy
Instructor	teacher; subject expert; knows the answer	supervisor; knowledgable but not necessary and expert in the research field; ignores the answer
Reading material	textbooks; curated content; concepts are explicit	research articles; raw content; concepts might be implicit
Task	bounded; straight	unbounded; wicked

Ausubel stated that meaningful learning requires three conditions (see next). Provided these conditions are met, concept mapping has proven to be effective in promoting meaningful learning during the reading of texts [27]. The question is whether Ausubel's preconditions are met in our setting, namely:

- "The material to be learned must be conceptually clear and presented with language and examples relatable to the learner's prior knowledge." Yet, this might not always be the case in doctoral studies, where students might not always resort to textbooks where content is already curated. Rather, the student faces research articles where concepts and relationships are often implicit, dispersed, and vague, being tangled and scattered among different articles. Furthermore, unlike in other educational settings [20], there is no 'correct concept map' to which students can compare their progress. Nor is always the supervisor an expert in the particular field where the research develops, leaving the student on their own in the pursuit of the 'correct concept map'.
- "The learner must possess relevant prior knowledge about the task." Yet, DSR introduces a socio-technical challenge. If the student has a technical background, familiar with the solution realm, then the challenge may come from the limited knowledge about the problem realm, and the other way around. If the student has a 'socio' background, the shortcoming may come from ignorance about advanced technologies.
- "The learner must choose to learn meaningfully." We can expect this condition to be met to a greater extent for graduates than for undergraduates. Yet, meaningful learning requires not only being cognitively engaged but also goal-oriented [23]. The latter might be a hindrance for postgraduates when research goals are blurred.

Therefore, it is our experience that Ausubel's preconditions are harder to meet in a DSR setting. Table 1 compares the context of concept mapping for secondary education with our setting. But these differences do not take away from the benefits of concept maps but may change the role of the instructor.

When the instructor is a PhD supervisor, the instructor might not always have enough knowledge about the domain to assess what 'the right concept map' is. Yet, the instructor can provide the means and appreciate the practices that increase the chances of coming up with 'the right concept map'. On these premises, the added value of the supervisor is not so much in providing a competent external perspective about the goodness of the concept map as it is in providing methodological support. This assistance is provided by going over the steps that lead to the student developing the concept map. In this respect, concept maps are clueless. When we used concept maps for supervisory meetings, it was hard to 1) get into the student's readings and 2) figure out how concepts and relationships fit into the narrative of the research. This was a problematic situation.

ADR does not just point out a problem; it also comes up with a way to fix it. The intervention is gradually and iteratively developed over distinct cycles, informed by existing theories. As a result, we developed *Concept&Go*, a dedicated highlighter for *CmapTools*. *CmapTools* is a free software environment developed at the Institute for Human and Machine Cognition (IHMC) used by thousands of individuals [7]. We can make a bigger difference by building on an already large user community and using a popular tool. *Concept&Go* is available for download at Chrome's Web Store and its source code is publicly available under the MIT license on GitHub [1].

The next three sections condense eighteen-month work into three major cycles that ended up in *Concept&Go*. From now on, we will refer to *'Cmap'* to denote the student's concept map in *CmapTools*, and *'concept'* to refer to either of the concept-map constructs, i.e., concepts or relationships. The creation of propositions, i.e. linking concepts through relationships, is not described here. Refer to the tool manual [2].

3 First Cycle: in search of the missing link with the bibliography

Issue. During the supervisory meetings, students often went back to their articles to explain why they chose the concepts and relationships they did. Students used the paragraphs of the articles to argue about whether or not the idea at hand was right. These paragraphs were highlighted in some cases (but not always) to help with focus while reading. Yet, this process left no trace in the *Cmap*, i.e., it was not possible to trace concepts back to the underlying highlights. As a result, a significant amount of the meeting was spent on the student browsing through the bibliography.

Supporting theory. With annotations like tags, comments, and highlights, the text can be changed to fit the mindset and goals of the reader. The 'annotation theory' posits that because annotating slows the reading down, students discover and uncover ideas that would not have emerged otherwise [21]. Indeed, highlighting has been proven to be an effective way of aiding in the comprehension and interpretation of written information [16]. On these premises, we consider highlights as the prelude to concept maps. What is needed is a way *to link* concepts back to the highlighted excerpts.

Intervention. We use the web-based version of *CmapTools*. We need to link two objects: concepts and highlighted excerpts (hereafter just 'highlights'). The first issue is that highlights are not objects. If concepts are to be linked back to highlights, the highlights need to be amenable to being linked, i.e., being turned into Web resources. Specifically, main duties of *Concept&Go* include:

- Converting highlights into Web resources. Besides the rendering implications (e.g., displaying the excerpts with a yellow background), *Concept&Go* creates a Web resource out of each highlighted excerpt [3].
- Qualifying highlighting resources in terms of the underlying code the highlight embodies. Codes are named after the concepts and relationships of the companion *Cmap*. If the excerpt contains brand-new code, the student can create it at reading time. *Concept&Go* generates a first list of possible codes from the companion *Cmap*. Fig. 1.3 depicts a screenshot with the interactions for creating a concept.

[1] https://anonymous.4open.science/r/ConceptAndGo-DSR-0B97/
[2] https://anonymous.4open.science/r/ConceptAndGo-DSR-6D7F/README.md
[3] This is achieved through *Hypothes.is*, an open source project that supports online social annotation [14].

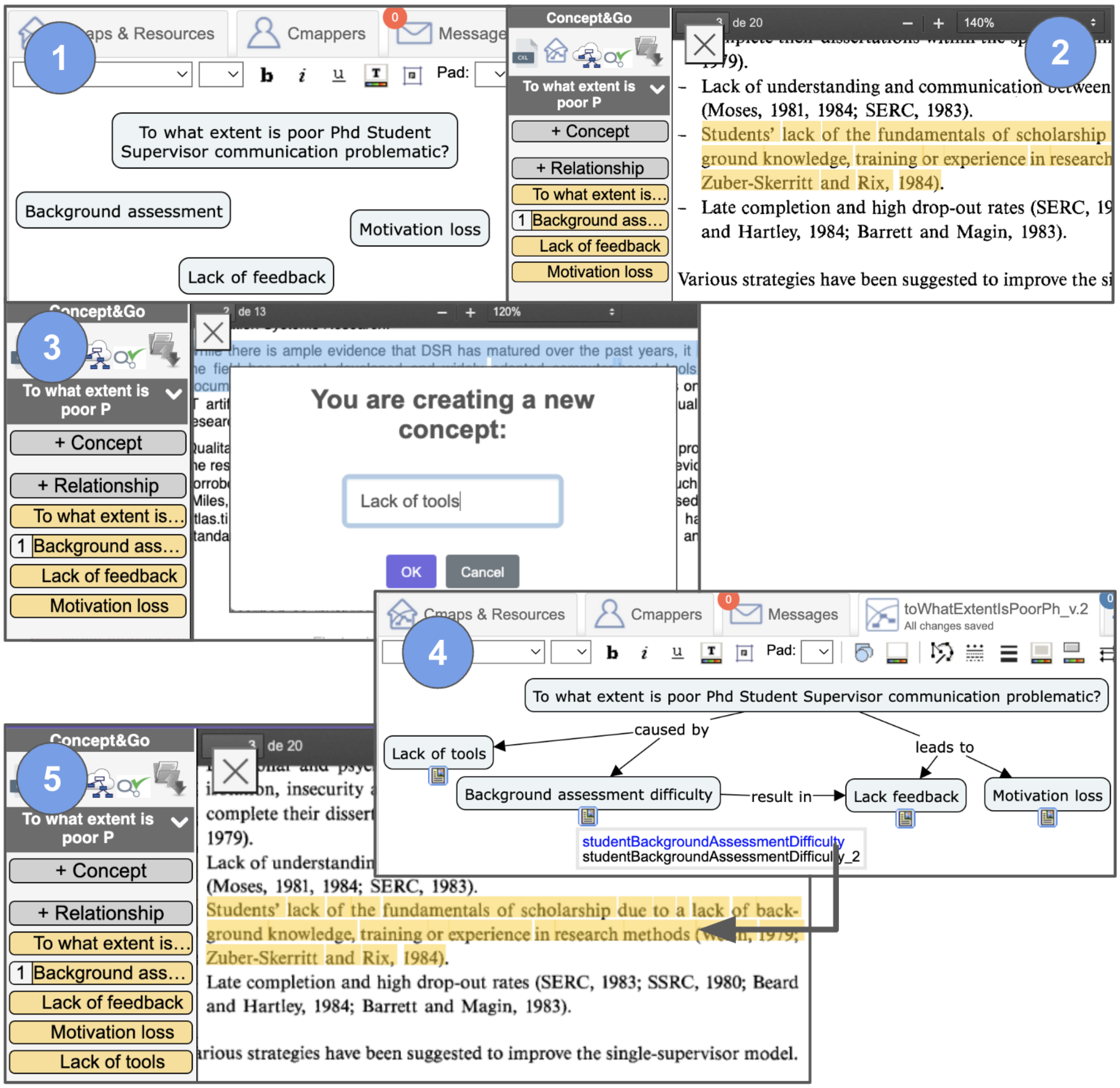

Fig. 1. Concept mapping with *Concept&Go* in the first cycle: (1) *Cmap* at the onset; (2) on displaying a PDF, the highlighter shows up, which is derived from the *Cmap* counterpart; (3) a new concept is identified while reading; (4) back to the *Cmap*, this time extended with the highlight resources and manuscript-identified concepts; (5) click on a resource URI to go back to step 2.

– Attaching highlights to the *Cmap*. *Concept&Go* attaches highlights to their concept counterparts when the *Cmap* is loaded. Since highlights are now Web resources, they hold a URI; hence, they are amenable to being addressed through this URI.

In the *CmapTools* canvas, highlights-as-Web resources are denoted through the *resource* icon (see in Fig 1.4);
- Rendering highlights. Web resources are amenable to being dereferenced, i.e., the act of retrieving a representation of a resource identified by a URI. This is enacted by clicking on the URI. When you return to the *CmapTools* canvas, hover your mouse over the resource icon ( ) to see a list of highlighted URIs. If you click on a URI, it will open a new browser tab with the article at the place where the excerpt appears.

Fig. 1 displays *Concept&Go* at work (see Fig. 1):

1. The cycle starts with a *Cmap*. The student might (or might not) populate the canvas with some out-of-the-blue concepts. Besides the focus question, the student starts with three concepts *Background assessment, Motivation loss* and *Lack of feedback*.
2. Next, the student moves to the reading visor to display a research article. *Concept&Go* generates a highlighter where codes are obtained from the concepts of the companion *Cmap*. Now, the student locates excerpts that sustain these concepts. The figure shows the case for *Background assessment*.
3. In addition, new codes can be created at reading time: the student creates concept *Lack of tools* based on the highlighted excerpt.
4. After some reading, the student returns to *CmapTools*. On loading the *Cmap*, *Concept&Go* retrieves codes, relation annotations, and highlights that are turned into concepts, relationships, and resources, respectively. During the supervisory meeting, this concept map can be changed.
5. Click on a resource to go back to the reading material, specifically, to the point where the excerpt is placed. Notice *Lack of tools* at the bottom of the highlighter.

Concept&Go turns the *CmapTools* canvas into an index of the student's bibliography. This use of concept maps as navigational tools for existing material is reported in the literature [2]. What makes this work different from others is its granularity: it indexes excerpts instead of full pages. This accounts for finer-grained indexing. This is important to our goals because students need to be able to tell not only if an article is interesting or not, but also which paragraphs in the article support the concept at hand.

Evaluation. ADR promotes authentic and concurrent evaluation, i.e., authenticity is a more crucial element for ADR than controlled conditions; thus, assessment should take place within the organization and throughout the research [22]. Hence, we resort to two supervisors and two doctoral students of our research group. When comparing the use of *CmapTools* before and after the intervention, they appreciated the important benefits regarding consistency and recall. First, the act of highlighting departed from a willful reading practice to become a compulsory concept mapping practice. Though students are used to highlighting, they were not consistent in this practice. When highlighting was framed within concept mapping, students did it in a more systematic way. Second, supervisory meetings became smoother since underpinning excerpts were just a click away. No need to tediously browse through the whole article(s) in search of the right paragraph.

4 Second Cycle: the importance of color-coding

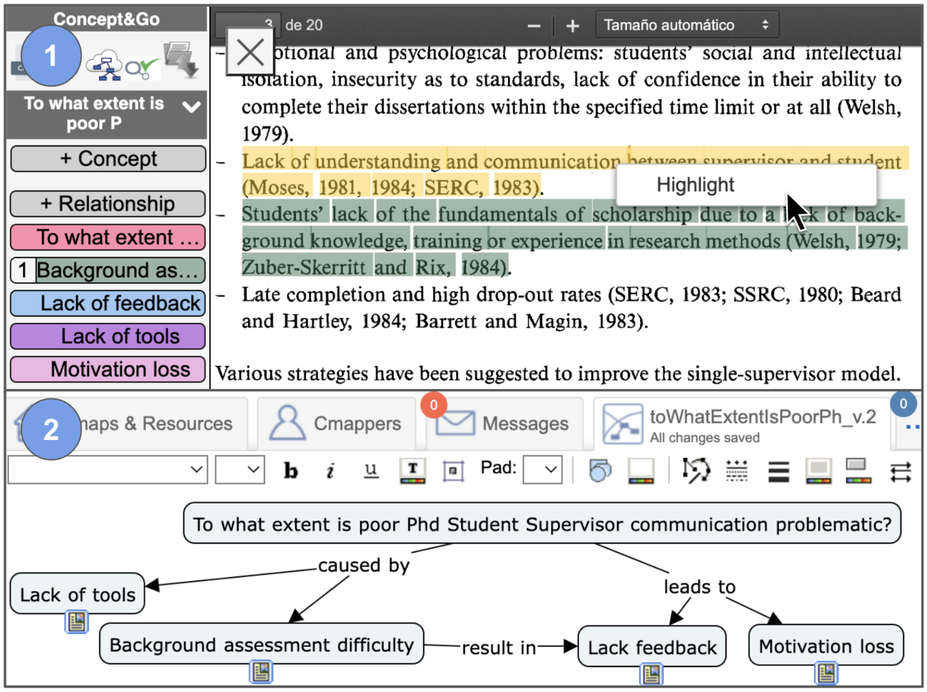

Fig. 2. Concept mapping with *Concept&Go* in the second cycle: Colors stand for concepts. Yellow is used to highlight interesting paragraphs (available via right-click). The rest of the colors are used for concept mapping. The highlighter and the *Cmap* are kept in sync.

Issue. Concept maps with URIs make it easy for supervisors to quickly trace back concepts to the paragraphs and articles that help students to learn. However, highlighting is now used for two purposes: grounding concepts found in the *Cmap* and putting the focus on interesting paragraphs. Since all of the highlighted paragraphs were yellow, it was hard to tell which of the two goals was being pursued. This was confusing for the student when going back to the article.

Supporting Theory. To overcome this issue, the literature suggests color-coding highlighting [8]. Color coding does much more than just change the color of the text; it is also a coding action. This means that you can later compile the coded excerpts and work with those that are most important. This lets you code more specifically once this initial general coding run is complete. According to the literature, this approach enables a lesser time delay for locating and revisiting pertinent information, facilitating retention and integration of the learning content [19, 8]. For students who are predominantly surface learners, the use of color-coding annotation has the potential to reduce unproductive effort by facilitating manuscript revision, increasing eye fixation duration, and visually structuring relevant information [8].

Intervention. Previous insights have *Concept&Go* to be leveraged from a mere 'yellow highlighter' to a color-coding highlighter. To this end, the highlighter buttons are distinguished not only by their labels (named after concepts) but also by their distinct colors. A color-coding highlighter is generated out of the concept in the student's *Cmap* (see Fig. 2). The color yellow was used to highlight interesting paragraphs, while the other colors were used for concept mapping.

Evaluation. Students definitively appreciated color-coding highlighting. When it came to reading a PDF, this convention aided the student in quickly determining the purpose of a highlight. Questions were raised about the coverage of the annotation: should there be a minimum number of highlights per concept? Should all concepts have annotations attached? How should highlights in yellow (not associated with any concept) be handled? No clear insights were derived from the discussion, yet the fact that highlights are now being tracked opens the door for defining metrics based on this digital trace [25]. All in all, the intervention helped make the meetings smoother, but there was no guarantee the highlighted paragraphs were the right ones. Students were still dispersed in the sort of concepts gathered in their *Cmaps*. Unlike undergraduates, doctoral students might not always resort to curated textbooks where concepts await to be highlighted by the student. Instead, doctoral students need to use research articles where concepts are often vague and unfinished.

5 Third Cycle: the importance of the focus question

Issue. The instructor role is often characterized as effectively managing the supervisory process by asking the right questions [9]. This brings to the forefront the concept map's *focus question*, i.e., 'the question that clearly specifies the problem or issues the concept map should help to resolve' [5]. When it comes to DSR, questions might be framed within the three closely related cycles proposed by Hevner [13]: the *Relevance* Cycle (e.g., 'To what extent is the student-supervisor communication problematic in DSR doctoral studies?'), the *Design* Cycle (e.g., 'How could we evaluate an intervention to improve supervisory sessions?') or, the *Rigor* Cycle (e.g., 'What benefits have been reported for concept mapping in an educational setting?'). The greater or lesser emphasis on one of the cycles very much depends on the sort of contribution expected [11]: improvement (i.e., a new solution for known problems), invention (new solutions for new problems), or exaptation (known solutions to new problems)[4].

[4] Our work is an example of exaptation, where we look at an existing solution (i.e., concept mapping) in a new setting (i.e., tertiary education). Here, the supervisor should push the student to assess what sets the DSR-based doctoral setting apart from other educational scenarios and the extent to which these idiosyncrasies challenge the principles of the existing solution. By contrast, if the contribution were more about 'improvement', then the supervisor would have better guided the student about non-functional requirements or affordances that the new technology brings about in comparison with existing interventions.

The supervisor's role includes finding a balance between these three DSR cycles. However, it is often the case that the reading material covers different concerns besides those related to the focus question. Most of the time, a research article mixes up a set of ideas and concepts that build up the research narrative. DSR articles are a case in point. They talk about many different issues, like the practice, the problem, the solution, the evaluation, and so on. The student might be distracted by this plethora of concerns when addressing a question that focuses on one of the cycles. This may lead to cognitive overload.

Supporting Theory. John Sweller defines learning as the process of managing different types of competing cognitive load with finite working memory capacity [24]. Learning becomes unproductive when non-core learning tasks create excess cognitive demand. A common recipe for preventing cognitive overload is breaking tasks down into simple steps.

Intervention. Regarding concept mapping, the focus question is meant to provide 'a clearly defined goal for reading'. However, our experience is that this falls short. For example, consider the question *'To what extent is student-supervisor communication problematic in DSR doctoral studies?'*. Our experience is that this question may still be too open, risking cognitive overload. To fight this back, supervisors can set up a list of 'meta-concepts' that help structure the answer to the focus question. Back to our sample question, this question's narrative can be articulated through meta-concepts such as 'cause', 'consequence' or 'evidence', guiding the gathering of new concepts.

On these premises, the form for the focus question in *CmapTool*'s is being reinterpreted (see Fig. 1). Specifically, *Concept&Go* resorts to the *keyword* entry to hold the meta-concepts (step (1)). These meta-concepts are up to the supervisor. From these keywords, *Concept&Go* generates a dedicated color-coded highlighter. Differences are three-fold (see Fig.1). In the *Cmap*, meta-concepts are displayed as concept-map legends (steps (2), (4), and (5)). In the highlighter, color coding denote meta-concepts (3). In the highlight object, a property keeps the associated meta-concept.

Evaluation. Meta-concepts helped students deal with cognitive overload by increasing their focus through meta-concepts. In addition, supervisors can now see at a glance how well the question narrative is covered. Meetings can be organized to address each of the meta-concepts, quickly identifying gaps in the narrative: are there a few green-colored nodes? advice for finding additional causes. Interesting enough, the evaluation raised the question of how many focus questions (i.e., concept maps) a student should handle at the same time. Should distinct focus questions (i.e., *Cmaps*) co-exist? Should students be allowed to attach 'identical' article excerpts to 'distinct' *Cmaps*? What should be the granularity of a focus question? So far, a highlighter is obtained from a single *Cmap*. This anecdotal evaluation appears to point to a worthwhile follow-up where highlighters mix up meta-concepts from different *Cmaps*.

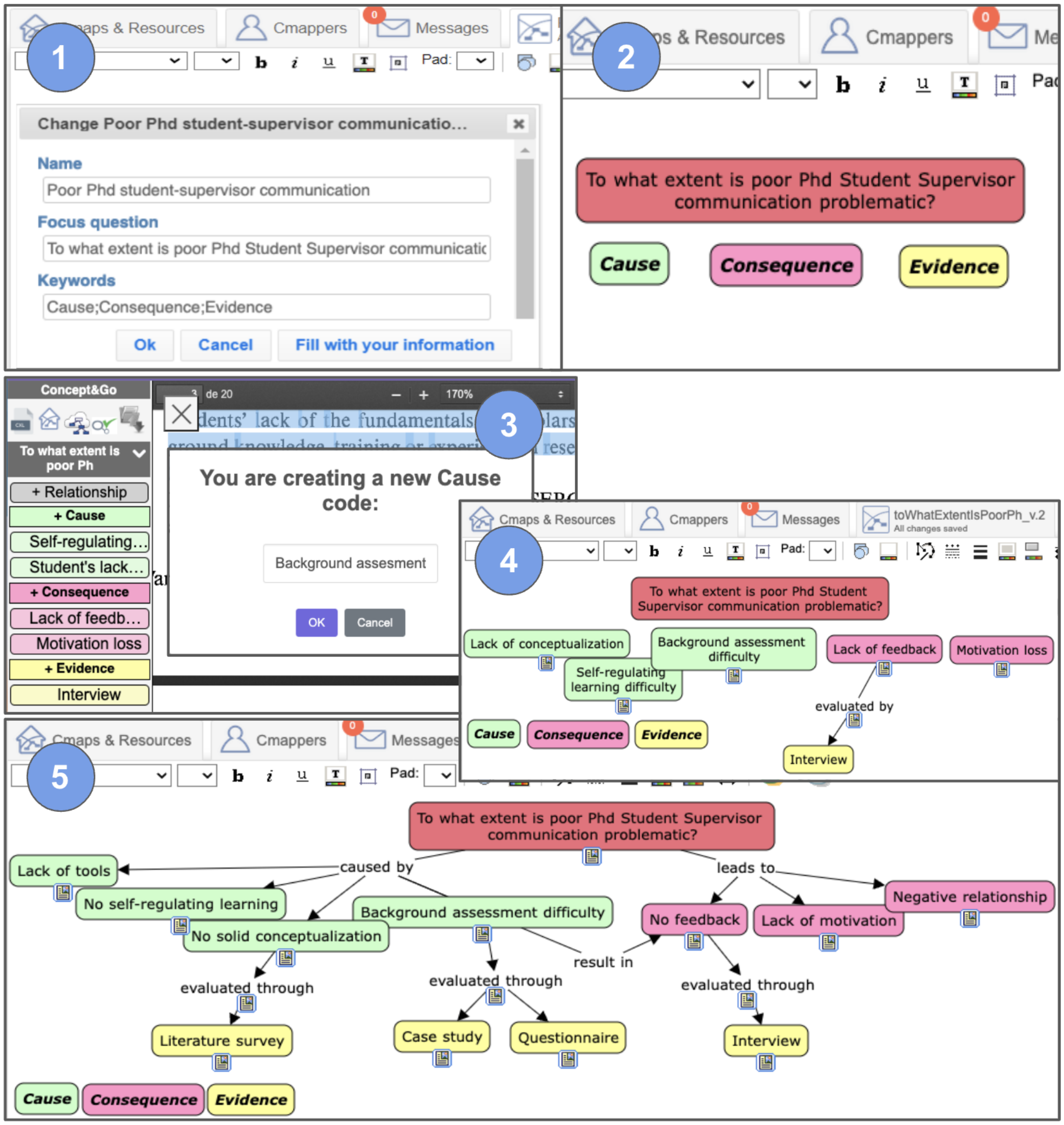

Fig. 3. Concept mapping with *Concept&Go* in the third cycle: (1) the supervisor sets the focus question, and the associated meta-concepts (keywords); (2) Concept&Go initializes the *Cmap* with the meta-concepts as a map legend; (3) on displaying a PDF, a highlighter shows up based on the *Cmap* meta-concepts; (4) on reading, the student not only identifies concepts out of excerpts, but he also associates the code with a given meta-concept; (5) back to the *Cmap*, this time the node's colour stands for meta-concepts.

6 Formalization of Learning

In accordance with ADR, the situated learning from the project should be further developed into general solution concepts for a class of field problems [22]. Specifically:

- generalization of the problem instance, i.e., to what extent is 'clueless concept maps' a *problem* for supervisors other than (-Anonymous-) research group's;
- generalization of the solution instance, i.e., to what extent is *Concept&Go* a *solution* to 'clueless concept maps'.

6.1 Generalization of the problem instance

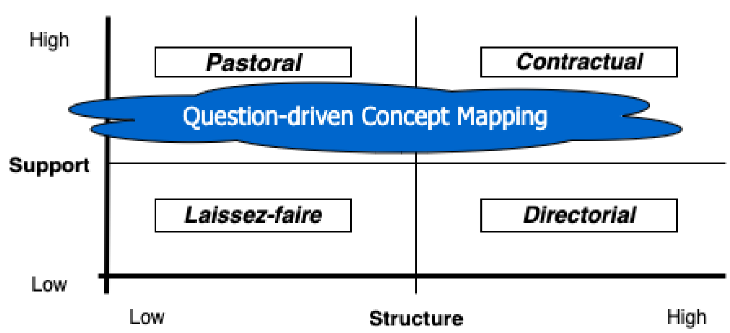

Fig. 4. Placing the intervention within Gatfield's framework for supervisory management styles (adapted from [10]).

When using concept mapping for supervisory meetings, we encounter difficulty meeting Ausubel's preconditions (see Section 2). But what sort of supervisory style faces this issue? Do all supervisors feel this problem? Gatfield's framework is popular for characterizing supervisory management styles (see Fig.4) [10]. This model introduces two dimensions: supervisory structure and support, each ranging from *low* to *high*. Structure includes things like focusing the research, making progress reports, responding quickly to feedback, and getting training in technical skills like writing, statistics, and time management. The support factor includes things like providing encouragement, infrastructure (like office space and money for research), and technical software support. Along with this framework, our approach supports 'the pastoral' supervisory style. A pastoral style entails understanding not only 'what' the student knows but also 'how' the student knows. Traditional concept maps support 'the what' but they are clueless about the provenance of concepts and relationships. We can then speculate that pastoral-like supervisors will face issues similar to ours.

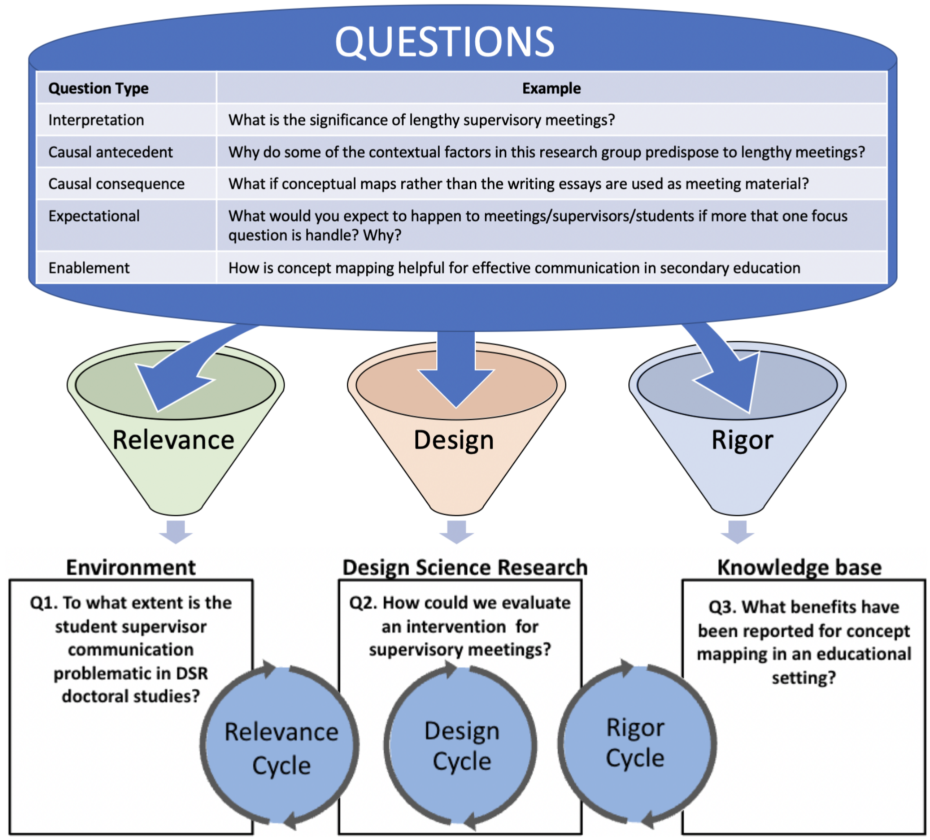

Fig. 5. Focus questions framed along with the DSR cycles.

6.2 Generalization of the solution instance

The process: question-asking concept mapping. This work envisions the role of supervisors as 'concept mapping scaffolds' through continuous inquiry. There is a question about whether or not this role of asking questions is shared by instructors in other types of education. This appears to be the case, based on the following quote from two pioneers, Cañas and Novak: "as a student is building a concept map, the teacher should probe the student to (a) find out how much the student knows about the topic and how his or her understanding evolves, and (b) help the student go deeper into understanding the subject and thereby improve, refine, or expand the concept map. Unfortunately, there is little research on question-asking during concept map construction" [6]. The role exists, yet it is not clear how to operationalize it. We provide preliminary insights by distributing focus questions (and their narrative meta-concepts) across the three DSR cycles, with the supervisor's role being to provide a timely and balanced effort across the distinct cycles (see Fig. 5).

The tool: *Concept&Go*. The popularity of *CmapTool* facilitates the adoption of *Concept&Go* by other research groups. *Concept&Go* is an extension for Google Chrome. Together, this architecture and the use of the mediator design pattern make it easy to move the code to other Web browsers and concept map editors. Finally, *Concept&Go* leverages concept maps with clues about the process itself. Other meta-data could be added (e.g., date, version, etc.), yet we did not miss this information during our supervisory meetings.

7 Conclusion

We argue that higher education challenges Ausubel's preconditions for meaningful learning, and hence, there is a need to adjust concept mapping to this new scenario. Specifically, we instrumentalize question-asking concept mapping by introducing highlight annotations and meta-concepts as 'clues' in concept maps. Though this research builds upon a local experience, we believe no stringent contextual requirements have been introduced that may prevent this approach from being generalized to other doctoral settings (the problem) or web-based concept map editors (the solution).

The next step is to spread *Concept&Go* so that other colleagues can join us in this endeavor. In addition, this work looks at doctoral supervision from a socio-technical point of view, but we mostly focused on the technical side. The social side comes with the art of questioning and listening. Ideally, rather than directly providing students with interesting ideas, supervisors should be able to ask the right questions to allow the student to come up with his own theories and ideas. Yet, this role might evolve throughout the research: at the start of a PhD, it is the supervisor who has the knowledge, but as the PhD draws to a close, it is the student who has the knowledge and who becomes the instructor. As a result of this shift in roles, concept mapping is no longer a fixed process, but rather one that must be adapted to increase student empowerment throughout the PhD life-cycle. We need to collect more experiences from the community.

References

1. Abiddin, N.Z., Ismail, A., Ismail, A.: Effective supervisory approach in enhancing postgraduate research studies. International journal of humanities and social science **1**(2), 206–217 (2011)
2. Amadieu, F., Salmerón, L.: Concept maps for comprehension and navigation of hypertexts. In: Digital knowledge maps in education, pp. 41–59. Springer (2014)
3. Ausubel, D.P., Novak, J.D., Hanesian, H., et al.: Educational psychology: A cognitive view, vol. 6. New York (1968)
4. Beatty, S.E.: The doctoral supervisor-student relationship: some american advice for success. The Marketing Review **2**(2), 205–217 (2001)
5. Cañas, A.J., Coffey, J.W., Carnot, M.J., Feltovich, P., Hoffman, R.R., Feltovich, J., Novak, J.D.: A summary of literature pertaining to the use of concept mapping techniques and technologies for education and performance support. Report to the Chief of Naval Education and Training pp. 1–108 (2003)
6. Cañas, A.J., Novak, J.D.: Re-examining the foundations for effective use of concept maps. In: Proc. of the 2nd Int. Conference on Concept Mapping. vol. 1, pp. 494–502 (2006)

7. Cañas, A.J., Hill, G., Carff, R., Suri, N., Lott, J., Gómez, G., Eskridge, T.C., Arroyo, M., Carvajal, R.: CmapTools: A knowledge modeling and sharing environment. In: Proc. of the 1st Int. Conference on Concept Mapping. vol. 1, pp. 125–134 (2004)
8. Chiu, C., King, R., Crossin, C.: Using colour-coded digital annotation for enhanced case-based learning outcomes. Accounting Education pp. 1–21 (2022)
9. Friedrich-Nel, H., Mac Kinnon, J.: The quality culture in doctoral education: Establishing the critical role of the doctoral supervisor. Innovations in Education and Teaching International **56**(2), 140–149 (2019)
10. Gatfield, T.: An investigation into phd supervisory management styles: Development of a dynamic conceptual model and its managerial implications. Journal of Higher Education Policy and Management **27**(3), 311–325 (2005)
11. Gregor, S., Hevner, A.R.: Positioning and presenting design science research for maximum impact. MIS quarterly pp. 337–355 (2013)
12. Harding-DeKam, J.L., Hamilton, B., Loyd, S.: The hidden curriculum of doctoral advising. NACADA Journal **32**(2), 5–16 (2012)
13. Hevner, A.R.: The three cycle view of design science. Scand. J. Inf. Syst. **19**(2), 4 (2007)
14. Hypothes.is project: We've Reached 40 Million Annotations (2022), https://web.hypothes.is/blog/celebrating-nearly-40-million-annotations/
15. Katz, R.: Challenges in doctoral research project management: A comparative study. International Journal of doctoral studies **11**, 105 (2016)
16. Kawase, R., Herder, E., Nejdl, W.: A comparison of paper-based and online annotations in the workplace. In: ECTEL. pp. 240–253. Springer (2009)
17. Machado, C.T., Carvalho, A.A.: Concept mapping: Benefits and challenges in higher education. The Journal of Continuing Higher Education **68**(1), 38–53 (2020)
18. Novak, J.D., Gowin, D.B.: Learning how to learn. cambridge University press (1984)
19. Ozcelik, E., Karakus, T., Kursun, E., Cagiltay, K.: An eye-tracking study of how color coding affects multimedia learning. Computers & Education **53**(2), 445–453 (2009)
20. Pinandito, A., Prasetya, D.D., Hayashi, Y., Hirashima, T.: Design and development of semi-automatic concept map authoring support tool. Research and Practice in Technology Enhanced Learning **16**(1), 1–19 (2021)
21. Porter-O'Donnell, C.: Beyond the yellow highlighter: Teaching annotation skills to improve reading comprehension. The English Journal **93**(5), 82–89 (2004)
22. Sein, M.K., Henfridsson, O., Purao, S., Rossi, M., Lindgren, R.: Action design research. MIS quarterly pp. 37–56 (2011)
23. Shuell, T.J.: Learning theory and instructional design: Engaging the learner in meaningful ways. Singapore Journal of Education (1992)
24. Sweller, J.: Cognitive load theory, learning difficulty, and instructional design. Learning and instruction **4**(4), 295–312 (1994)
25. Viberg, O., Hatakka, M., Bälter, O., Mavroudi, A.: The current landscape of learning analytics in higher education. Computers in human behavior **89**, 98–110 (2018)
26. Vom Brocke, J., Fettke, P., Gau, M., Houy, C., Maedche, A., Morana, S., Seidel, S.: Tool-support for design science research: Design principles and instantiation. Available at SSRN 2972803 (2017)
27. Wilson, M., Howell, C., Martin-Morales, K., Park, S.: Concept mapping and reading comprehension. Journal of Political Science Education pp. 1–24 (2023)
28. Zuber-Skerritt, O.: Helping postgraduate research students learn. Higher Education **16**(1), 75–94 (1987)