

Assessing Interdisciplinary Competency in the Disaster Resilience and Risk Management Graduate Program using Concept Maps: A Pilot Study

Introduction

In recent years, an increasing number of natural and human-made disasters, like Hurricane Maria and the Fukushima Daiichi nuclear disaster, have impacted vulnerable populations across the globe. The Disaster Resilience and Risk Management (DRRM) graduate program, housed at Virginia Tech, aims to educate interdisciplinary scholars who can help address these disasters both before and after they happen in order to increase community resilience. Our overall project goal is to improve understanding and support proactive decision-making relative to DRRM by establishing a sustainable and transferrable transdisciplinary graduate education and research program to produce the next generation of researchers, educators, and decision makers focused on dynamic collaborations across not only academic disciplines, but also among stakeholders. We are particularly interested in bringing together researchers, policy makers, and community stakeholders in ways that foster mutual respect and value, and that adhere to the needs, goals, and engagement of the individuals most impacted by disasters.

Previous work on disaster resilience demonstrates the importance of interdisciplinary teams in developing resilient solutions and effectively managing risk [1]. Disasters are complex problems that require solutions and collaboration from a wide-range of disciplines. Training scholars to think and work across disciplinary boundaries can enhance disaster preparation and management, which, in turn, can enhance disaster resilience, especially in vulnerable locations and for vulnerable populations. To that end, we have embarked on a cross-university collaboration that brings together scholars in engineering and science with expertise in natural hazards modeling and characterization, scholars in urban planning and policy with expertise in the social impacts of disasters (e.g. housing, economy) as well as in community engagement, and scholars in business information technology with expertise in supply chain management that considers how supplies are allocated and distributed before and after disasters. The disproportionate impact of disasters on vulnerable populations makes collaboration across fields and with local stakeholders particularly critical from a social justice perspective as effective preparation for and response to disaster events requires a complex interplay of systems, structures, and strategies.

At the same time, research suggests that both training interdisciplinary scholars and building interdisciplinary teams in university environments remains persistently challenging. Scholars have noted the ways in which effective interdisciplinary collaboration requires individuals not only to accumulate knowledge in other fields, but also to develop dispositions that value and invite engagement across domains [1-6]. The challenge of developing these capacities in individuals is then compounded by the barriers imposed by the disciplinary structures of universities [6, 7]. Thus, educators and university administrators continue to need to develop strategies to help students, faculty, and universities develop the capacity to work across entrenched boundaries. Equally important, we need measures to enable us to effectively assess this interdisciplinary capacity at both an individual and programmatic level.

Toward that end, in this paper we present preliminary data from the first-year of the DRRM program, using students' pre-course and post-course concept maps, their written explanations of the post-concept maps, and ethnographic observations and field notes from the two core, introductory DRRM courses (described below). Since the program is only in its first year, the data presented here represents a pilot study that tests the use of concept maps to explore changes in students' understandings of disaster resilience and risk management in their first semester. The results not only identify patterns in student learning, but, when combined with the complementary ethnographic data, also provide insights into both the use of concept maps and the structural challenges of such a broad-based interdisciplinary effort.

Course Context

The study context is a pair of foundational, team-taught courses in the interdisciplinary DRRM graduate program. The courses include a 3-hour research course and a 1-hour seminar that aim to build student understanding within and across Business Information Technology, Civil and Environmental Engineering, Geosciences, and Urban Affairs and Planning. Both courses met in person on the Blacksburg campus and had remote online students and faculty members join in via Zoom. The 3-hour course, which students take in their first semester of the program, is designed to introduce core principles of DRRM and relevant research methods in these disciplines, driving students to understand the intersections of these disciplines in the context of planning for and responding to natural and human-made disasters. The major project in the course asks students to work in interdisciplinary teams to analyze a recent major disaster from multiple angles. The course is open not only to students in the doctoral DRRM program or masters and doctoral students pursuing the DRRM graduate certificate, but also to graduate students across the university interested in the topic broadly. It is one of multiple interdisciplinary research courses offered through the Graduate School rather than through individual departments. These Graduate School courses, established a number of years ago, provide an extra-disciplinary home for foundational courses, such as this one, and serve a variety of both national- and university-funded interdisciplinary graduate programs.

The 1-hour seminar is geared specifically toward the DRRM doctoral students to complement and extend the work of the 3-hour course. DRRM students participate in this seminar throughout the program, and it serves as a mechanism to build community among the DRRM scholars (horizontally across disciplines but also, as the program grows, vertically across cohorts), deepen students understanding of one another's research, promote peer feedback, and foster ongoing collaborations. The seminar students collaborate to facilitate an annual workshop for the program's advisory board, bring in guest speakers, develop outreach opportunities, and – every other year – design and host a stakeholder workshop.

Because students took the two courses concurrently in the fall, the resulting concept maps reflect the learning across both courses. The assignment itself was assigned in the 3-hour course, but it would be impossible to isolate the impact of that course alone because all study participants also engaged in the weekly 1-hour seminar.

Following previous studies highlighting the importance of interdisciplinary teaching teams to foster interdisciplinary learning [5, 6, 8, 9], both courses were taught by six faculty members (including Authors 2, 3, and 4) representing engineering, the sciences, business, and urban affairs

and planning. (Note that to avoid concerns about influence over grades, Author 2 helped organize the course, but did not participate in any grading of student work, in accordance with the IRB-approved research protocol; Authors 3 and 4 did not participate in the research component until the course was completed, and do not have access to participant identities). All faculty members attended each class meeting unless they were out of town. The 3-hour course sessions were typically facilitated by one or two faculty members, depending on the topic, while the seminars functioned more as a collaborative discussion across faculty and students.

Two factors related to physical space and course dynamics are also worth noting here. First, one faculty member works at one of the university's satellite centers and thus participated in all course sessions remotely. Second, while the 1-credit seminar occurred in a room with all participants gathered around a long table to facilitate discussion, the 3-credit course was set up with tables in a U-shape to create dialogue among the students; however, the room was not large enough for both the faculty and the students to literally sit at the table. As a result, the course faculty typically sat along the wall (behind some of the students), with the individual leading the class at the center of the U.

While the depth of faculty members brought a breadth of multi-disciplinary knowledge into the courses, it also created challenges in organizing both within and across courses sessions to create a coherent experience. Course observations and ethnographic field notes conducted during each class meeting illuminate these challenges in organization and provide an additional lens through which to interpret the results.

Currently, only data from the first cohort is available. Future studies will include additional longitudinal data from the first and subsequent cohorts, as well as interview data from participants. All participants in this paper are doctoral students in the DRRM program and represent a range of both academic disciplines and research interests. The research itself was approved by the Institutional Review Board at Virginia Tech. Nine current students consented to the research.

Purpose and Research Questions

To explore students' understanding of DRRM, we used pre- and post-course concept maps. Researchers in engineering education have demonstrated the value of concept maps for tracking undergraduate students' disciplinary understanding [10], interdisciplinary understanding of sustainability-related concepts within undergraduate engineering courses [11], design knowledge [12], and conceptual understanding [13]. We build on this prior work to use concept maps to assess interdisciplinary knowledge integration in a graduate course that spans not only engineering and science, but also business and social science. To understand graduate student growth from disciplinary to interdisciplinary scholars, we pose the **research questions**:

RQ1: In what ways do graduate students' understandings of DRRM change as a result of their introduction to an interdisciplinary graduate research program?

RQ2: To what extent and in what ways do concept maps serve as a tool to capture interdisciplinary learning in this context?

In addition to serving as an assessment tool, concept maps can help foster meaningful learning by encouraging students to connect their knowledge, thus offering pedagogical benefits as well as assessment and research data. Further, we extend the use of the concept maps themselves by incorporating participants' written explanations of their post-course maps. Research on writing to learn (WTL) suggests that such reflective practice can help deepen students' conceptual understanding [14-16]; these written explanations, like the concept maps themselves, thus both support student learning and enrich the data set.

Methods

As noted above, to assess graduate students' understanding of both disciplinary concepts and connections across disciplines, we use pre- and post-concept maps, administered at the beginning and end of the semester in the 3-hour course. Ethnographic field notes from both courses complement and contextualize the concept-map data.

Concept Map Data Collection

The data presented in this paper were collected during the first semester of the DRRM program and include pre/post concept maps, a one-page explanation of the post-concept maps, and ethnographic observations and field notes of both courses. Pre-concept maps were completed in-class on the first day of the 3-hour class, and post-concept maps were collected as a final course assignment in that class (and thus were completed out of class at the students' own pace).

On the first day of the 3-hour course, Author 2 explained concept maps to the students and led them through an example, in order to ensure the students knew *how* to complete the assessment [16]. Students had about 15 minutes to complete the assignment in class by hand and did not develop complementary explanations. We chose this approach because it enabled us to assess students' initial understanding of the domain (i.e. before any formal instruction) without the added complexity of downloading and installing software during class. Author 1 digitalized the hand-written concept maps in order to provide a consistent, anonymized format for scorers.

Post-concept maps were completed outside of class using concept map software; the online tool CMAP (<https://cmap.ihmc.us/>) was recommended, but not required. We recognize that the difference in medium (by hand versus electronically) introduces a limitation because students may feel more able to go into detail in one medium over the other. In addition, as noted above, students were also asked to submit a one-page explanation of their post-concept map, explaining the concepts they chose to include and the ways in which the concepts are linked.

Ethnographic Data Collection

Author 1 served as an embedded ethnographic researcher in both courses and in faculty meetings, recording extensive field notes that captured faculty practices and general student responses. Author 2 also kept limited field notes throughout the semester. Field notes were recorded electronically during class and meetings on a live Google Doc, with time stamps noted for changes in activity. The notes captured the practices of not only the faculty members leading the course, but the other faculty present who participated in the discussions.

Data Analysis

To analyze the concept maps, we use holistic scoring combined with a review of students' one-page explanation to allow for a comprehensive assessment of students' interdisciplinary knowledge. Holistic scoring provides insight into the concept map's comprehensiveness, as measured through knowledge breadth, depth and connectedness; organization; and correctness [12]. We adapted this holistic scoring method to fit our context.

Table 1: Holistic Criteria for Concept Map Scoring

	Complexity	Density	Connectedness & Organization
Construct	Depth of demonstrated knowledge	Breadth of demonstrated knowledge	Sophistication of organization
Measurement	Number of hierarchies included in the map	Number of concepts included in the map	Sophistication of cross-links

Authors 1 and 2 (a graduate student in engineering education and an experienced engineering education researcher) conducted the initial scoring. The pre- and post-concept maps were mixed and anonymized. The scorers then sorted the concept maps into groups and found that the following categories emerged: complexity, density, and connectedness/organization (Table 1). In this paper,

- the **complexity** of the map (low, medium, high) measures knowledge depth, i.e., the number of hierarchies included in the map;
- the **density** of the map (low, medium, high) measures knowledge breadth, i.e., the number of concepts included in the map.
- **connectedness** and **organization** are measured in terms of how topical the map is, i.e., does the map focus mostly on identifying keywords (topical), organizing those keywords into a structure with some cross-links between concepts (structured topical), or organizing those keywords in a way that is complex and readable and includes cross-links between concepts (functional).

Authors 3, 4, and 5—all faculty members in the DRRM program and each from a different disciplinary background—conducted secondary scorings facilitated by Author 1. Each faculty member brought a different disciplinary perspective to the scoring: one faculty member is based in Civil and Environmental Engineering, another in Business Information Technology, and the third in Urban Affairs and Planning. Given the pilot, exploratory nature of this study, this secondary scoring helped validate the initial scoring categories and illuminate potential differences in both assessment of student learning and understanding of DRRM across disciplinary boundaries. Note, however, that because both the sample size (9 participants) and the scorers (1 from each discipline) are small, the analysis cannot support conclusions by discipline; instead, it highlights potential differences that merit further exploration in subsequent larger studies.

For this second round, Author 1 met individually with each co-author and led them through the scoring process. The pre- and post- concept maps were mixed and anonymized. Again, the scorers were asked to sort the concept maps into groups. Because these faculty are experts in DRRM, Author 1 also encouraged them to identify which maps fell on the ‘low end’ and ‘high end,’ and to describe the categories that they used to sort the concept maps. Generally speaking, connectedness and complexity emerged as categories, where density was captured in complexity. Overall, the results of the secondary scoring align with the categories defined during the initial scoring. However, the scores of three concept maps (students G, H, and J) varied by scorer, as explained in the Results section.

Limitations

The study has several notable limitations. First, the sample size is small and thus prohibits any statistical analysis of changes in students’ development. Moreover, a single semester may be too short a time period to measure significant growth, particularly for a topic as complex as disaster resilience and risk management that draws on so many different and epistemologically diverse fields. Finally, the scoring of concept maps is a complex process with a range of possible foci and outcomes [10, 13], and we consider the scoring approach developed here to be emergent, particularly since the number of available maps for this domain is still relatively small.

Given these limitations and the lack of prior work on using concept maps in this particular domain, we treat this analysis an exploratory pilot study that enables us to 1) identify characteristics useful in scoring the maps, and 2) identify challenges and limitations in the concept map methodology. Secondly, the study helps identify structural areas for programmatic improvement to guide future practice. As the program grows, we plan to scale-up this study to include analysis of more concept maps across cohorts. Future studies can be expanded to cover the full curriculum of the program, thus allowing a more comprehensive pre/post assessment.

Results

We first present the overall results, drawing out specific examples of students who showed significant growth, average growth, and negative growth. We then discuss the outlying concept maps for which the scorers did not reach consensus.

Concept Maps and One-Page Explanations

Figure 1 summarizes participants scores on their pre- and post-concept maps and Figure 2 summarizes the differences in scores across scorers for students G, H, and J. The pre-concept maps tended to have a lower level of complexity than the post-concept maps (i.e., a limited number of concepts, typically only one level of hierarchy, and a limited number of links across concepts). While some pre-concept maps displayed higher density (i.e., more concepts included in the maps), the links between those concepts were limited. Additionally, all of the pre-concept maps were either topical or structured topical, meaning that students did not organize or connect concepts in a functional way. For example, student A’s pre-concept map uses topics that were discussed during the first-class meeting (response to disaster, resiliency, preparation, etc.) to organize their knowledge, while student G uses more fixed categories (actions, organizations,

stakeholders, etc.) to organize their map. Examples of pre- and post- concept maps for students A, C, and G are given in Appendix A.

Students varied in their growth from the pre- to post-concept map. Figure 1 shows the pre- and post-concept map scores by student. Some students, like G and H, show no growth based on the scoring system. Other students, like B and C, whose pre-concept maps were already towards the top of the group, submitted functional, high-complexity, and high-density post-concept maps. Some, like student A and student F, show linear growth, completing more structured, complex, and dense post-concept maps. Finally, some students lost ground in a category. For example, student J's post-concept map is more complex and structured, but less dense, and student E's post-concept map is the same in density, but less complex and less structured. We offer an in-depth discussion of a student who falls into each category, with data from participants' one-page explanations used to clarify and deepen the findings.

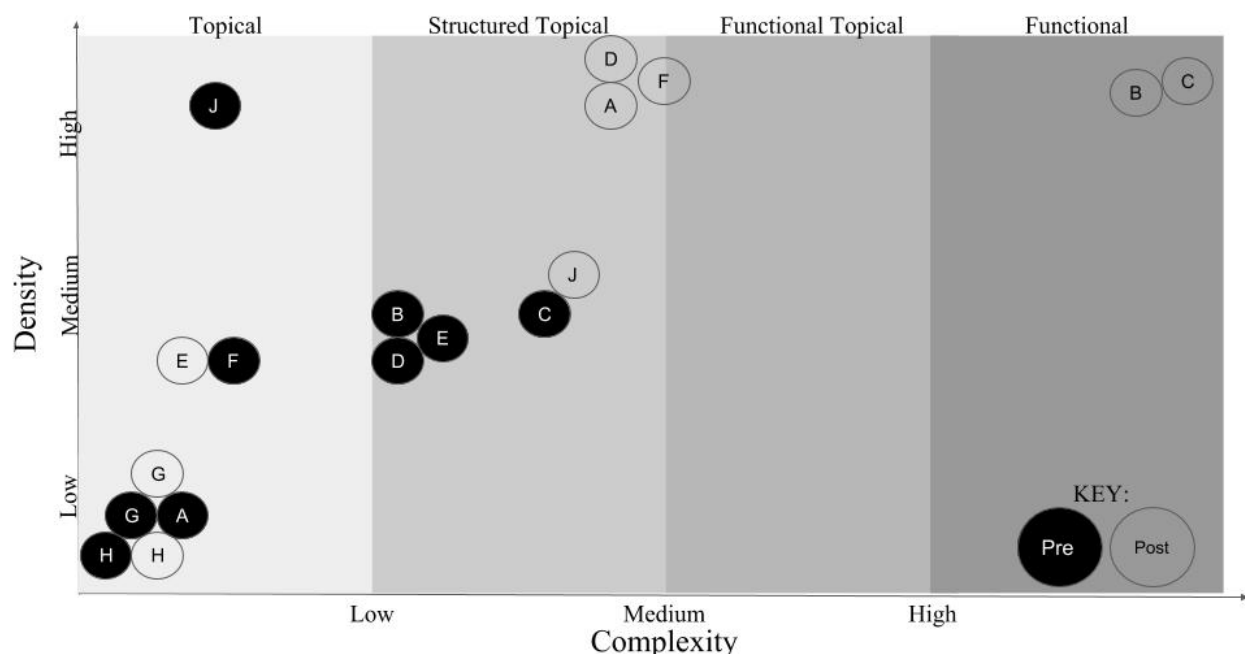


Figure 1: Summary of pre-post concept map scores. Letters correspond to students.

Significant Growth

Student C produced a pre-concept map that scored well compared to other students and produced a post-concept map that scored significantly higher than the other students. Student C's post-concept map reads like an essay: "Disaster resilience and risk management deals with disasters, [which] vary according to time, location, sudden/slow-onset, magnitude, and type, [which] could be manmade or natural..." Student C covers several topics, includes multiple levels, and organizes knowledge in terms of how concepts and actions interact to both understand the impacts of hazards and increase the effectiveness of risk management and resilience efforts. In Student C's one-page explanation, they say their map "points out the complexity and importance of DRRM" and claims that their map "does not include the whole list of items" because that would make the map "very dense and crowded."

Average Growth

Student A exhibits average, linear growth, moving from a low-density and low-complexity pre-concept map to a high-density, medium-complexity post-concept map. Student A's pre-concept map breaks down DRRM into topics: costs, resiliency, response to disaster, preparation, losses, etc. Under each topic is only one level, which describes the topic. For example, under preparation, the student notes that forecasting and hindcasting are important for planning. As a result, student A's pre-concept map scored low in all categories. On the other hand, student A's post-concept map shows significant growth in density, moderate growth in complexity, and moderate growth in how topical it was. Student A's final map still breaks down DRRM into topics, but each topic has significantly more levels, branches, and interconnections. For example, "resilience" connects to two different clusters, and some clusters complete a full loop back to DRRM. This pattern is consistent with Student A's explanation, where they describe resiliency as a "cyclic event." However, student A's post-concept map is slightly less sophisticated and functional than student C's. Where student C's post-concept map reads like an essay, student A's is more phrasal or clipped: "Disaster Resilience and Risk Management [has] types of the disaster [like] hurricanes, landslides, tornado, ...". Accordingly, student A's post-concept map only reaches structured topical organization rather than functional organization.

Negative Growth

One student, student E, showed negative growth between their pre- and post-concept maps. Student E describes their post-concept map as a "high-level overview" of how they view DRRM, explaining that their post-concept map includes the first concepts they think about when considering a disaster: disaster, community, recovery, and management. Similar to student G, student E seems to be aiming for a different audience than the rest of the students, and, as a result, scored lower. However, very similar concepts are included on student E's pre- and post-concept maps. For example, the pre-map has sub-categories: types of disasters, preparations, and post-disaster steps. The post-map has subcategories: impetus (i.e., type of disaster), planning, and recovery. The post-map scored lower because it was less complex and contained less nodes and sub-nodes than the pre-concept map.

Outliers: Discrepancies in Scores

While the scorers largely agreed on the scores for the majority of concept maps, they disagreed on the scores for students G, H, and J. Based on the original scoring system, students G and H shows no growth between their pre- and post-concept map and student J shows average growth. We will discuss each case and offer insight into how and why the scores varied.

Both of student G's concept maps have a low-density of concepts and low-complexity. However, scorer 3 ranked student G's pre-map in the middle range of scores, and scorer 4 ranked student G's post-map in the middle-high range of scores (see Figure 2). Notably, scorer 4 described student G's post-map as an outlier, saying that while it was less visually complex, it did have meaningful connections between the concepts. Moreover, student G's explanation of their post-concept map explains the lack of growth. Student G explains that their map is designed for a

general audience, saying “stakeholders are the everyday, average Joe.” As a result, student G’s post-concept map is low in density and complexity but is intended to be readable by a general audience, as scorer 4 noted. We note here, that as recorded in the field notes, stakeholder communication was a recurrent topic in the 3-hour course; thus, while the concept is not present as on the map itself, it is shaping this student’s decisions about how to represent the field.

Similarly, student H showed little to no growth in terms of density, complexity, or structure based on the original scoring system, but this result varied across scorers. Scorers 2, 3, and 4 each ranked at least one of student H’s concept maps in the middle range of scores. While, scorers 2 agreed that the student showed no growth, scorer 3 believed the student showed negative growth and scorer 4 believed the student showed positive, linear growth.

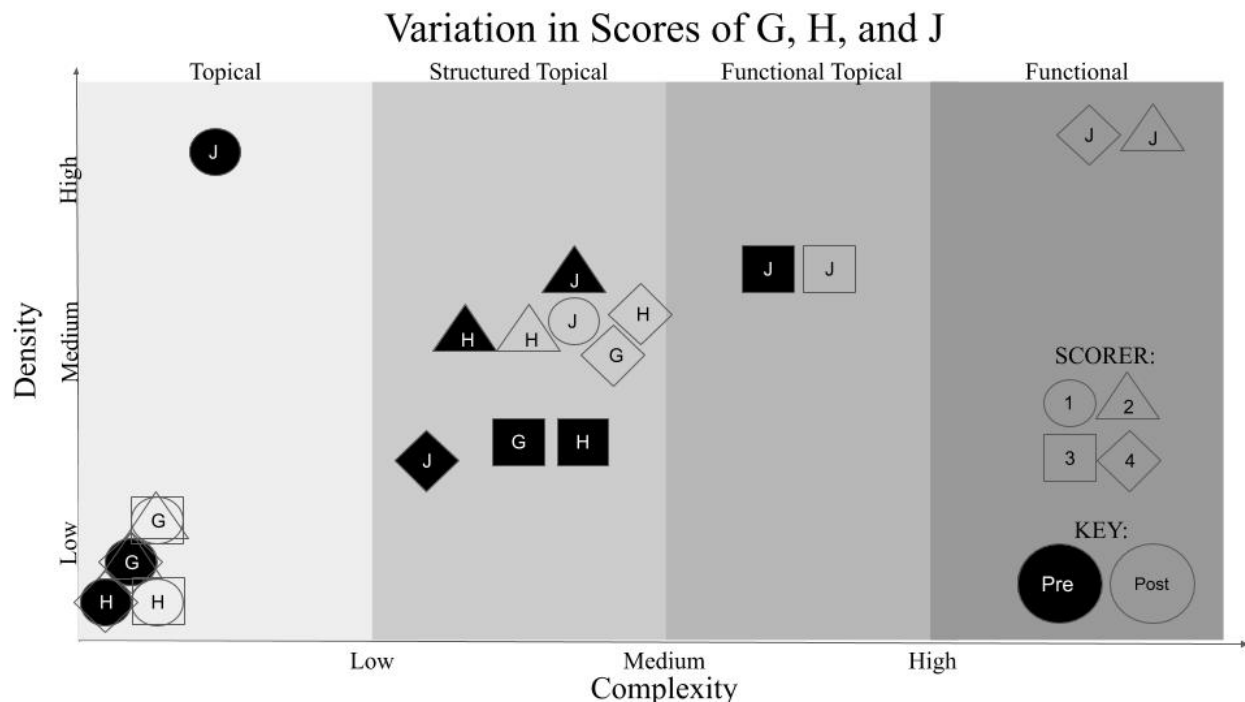


Figure 2: Variation in scores of Students G, H, and J across scorers. Scorer 1 represents the original score shown in Figure 1. Note that overlapping shapes indicate that scorers agreed on that score. (Scorers 1, 2, and 4 agreed on the pre-map score for Student G. Scorers 1 and 4 agreed on the pre-map score for Student H. Scorers 1, 2, and 3 agreed on the post-map score for Student G. Scorers 1 and 3 agreed on the post-map score for student H.)

Student H’s explanation provides context to help understand the scoring discrepancies. Student H described their pre-concept map as focusing on “key terms” and their post-concept map as focusing on “broad concepts.” They also describe learning that DRRM is “much larger than a specific event or type of disaster.” Rather, it is about larger concepts like “community, communication, compassion, and understanding.” However, while student H’s post-concept map does include larger topics like community and compassion, there is no elaboration on any one concept. That is, the ‘large concept’ is the final node, with no further connections or examples. Had student H elaborated more in their post-concept map, it likely would have received higher scores from scorers 1, 2, and 3.

At the same time, while the concept maps ostensibly show “no growth” according to some scorers, both students either explained their intended audience or demonstrated a richer and more complex understanding in their explanation, supporting the importance of asking students to complete an explanation to supplement their concept map. Note that for these students, traditional quantitative approaches to concept map scoring [13] would fail to capture the growth in student development because those methods typically rely on both the number of concepts and the depth of the hierarchies represented on the map.

Finally, student J showed average growth based on original scoring system (Figure 1) but their score varied across scorers. Scorers 2 and 4 ranked student J’s post-map in the highest category, while scorer 3 ranked both the pre- and post-map as average. Scorer 4 remarked that the student’s post-map has a different organization system that is not as connected or complex at first glance. However, scorer 4 gave the post-map a high score because the concepts are thoughtfully connected in a circle. (Student J did not submit an explanation with their post-concept map.)

Discussion

RQ1: Student Learning

Not surprisingly, the comparison of students’ pre- and post-concept maps, albeit across a relatively small population, does reflect an overall pattern of growth in participants’ topical knowledge relative to DRRM (i.e., the post-concept maps generally include more topics than the pre-maps, with more levels of hierarchy) as well as growth in their understanding of connections among topics (i.e., more cross links). As the post-maps of students’ A and C illustrate, the introductory courses, in general, substantially expanded students’ knowledge of both concepts and links among concepts associated with disaster resilience.

At the same time, even among this small cohort, the findings highlight the very different ways in which students organize their knowledge of DRRM and conceptualize the required processes and practices. As the results suggested, we noted multiple distinct organizational patterns, and even participants who used the same overarching pattern (e.g., structured topical) selected different concrete ways of organizing. Moreover, while there is some evidence of growth in terms of cross-disciplinary links in the maps themselves, the maps do not necessarily fully capture the complexity of those links. Given the small sample size, with only one or at most two students from each discipline in this initial cohort, we have refrained from attempting to analyze these variations by discipline, though such analysis is planned for future work.

We also note that while issues of social justice and vulnerable populations were discussed several times during both the 3-hour research course and 1-hour seminar and were often a major focal point in students’ course projects, these issues did not emerge as a major theme across the post-course concept maps. Some students included vulnerable populations on their concept maps as something needing attention, and others noted it in their explanations, but its limited appearance raises new questions for both the research team and the program about strategies to help students more effectively integrate these ethical concerns into their conceptual understanding. In part, as suggested by the results, concept maps alone may not be a sufficient tool to capture students’ understanding of a domain as complex as DRRM. At the same time, it is

possible that some students saw these populations as *targets of* DRRM, but not necessarily *participants in* the process; additional data collection would be needed to better understand this gap.

Finally, a review of the ethnographic field notes suggests that one source of the limitations in student growth may be the result of the course structure itself, particularly in the 3-hour course. The number of faculty involved, though they represented disciplinary richness, may also have contributed to a sense of disorganization and confusion as the course had no clear center and discussions ranged widely back and forth among the faculty. At the same time, while some cross-disciplinary connections emerged from the faculty conversations, and some faculty explicitly linked across boundaries when they led class or joined discussion, more often faculty tended to focus on their areas of specialization in both leading and participating in discussions. Moreover, the lectures themselves tended to be primarily topical, focusing on a specific issue (e.g., disaster impact mapping, hazard prediction), with less attention to the intersections across issues. Such intersections were not entirely absent from the course – either in the lectures or in the interdisciplinary team project – but they were often embedded parts of the conversation rather than focal points.

RQ2: Concept Maps as Tools for Assessing Interdisciplinary Growth

While the concept maps have yielded useful insights into students' learning around DRRM and highlighted an overall expansion of students' awareness of core concepts, the scoring, particularly across faculty disciplines, highlighted several challenges with the tool.

First, several of the student cases, including students G and H, point to a possible weakness in using concept maps alone for highly complex, interdisciplinary topics. Students were effectively gathering knowledge from four fields with distinct epistemological and methodological orientations, each with its own knowledge base and research methodologies. The resulting concept maps, as illustrated by the post-concept maps of students A and C, can be quite dense in terms of the number of concepts and levels of hierarchy. In part as a result of that density, students G and H adopted a different approach, simplifying their maps ways that, as suggested by their explanations, may actually represent a potentially higher and more sophisticated level of abstraction – and thus perhaps a greater degree of synthesis across concepts. As students' depth of knowledge grows, a domain like DRRM may simply become too large or too complex, with too many different disciplines involved to capture meaningfully in a two-dimensional concept map, and simplified concept maps may represent deeper learning. The results from this study suggest that pairing concept maps with textual explanations may be one approach to better capture students' full understanding of the domains.

Second, while all students received the same explanation of the concept maps, different students considered different audiences when creating the map – a result that could have stemmed in part from course discussions around stakeholder communication and the need to create accessible information around DRRM to help support meaningful community engagement. Certainly, student G's explanation highlights this possibility as they reference the need to communicate with "the average Joe." Alternatively, this approach could reflect the students disciplinary background.

Finally, the scoring differences across the authors highlights the potential for differences in disciplinary perspective to shape the scoring process, though substantially more work is needed to confirm and delineate those differences. Since each author is from a different discipline, it is impossible to determine whether differences in our approaches reflect disciplinary epistemologies, personal perspectives on teaching and learning, or other factors.

Implications

The sample size of this pilot study is small, which limits the ability to generalize or transfer findings to a larger population. However, the results are useful in informing program development and future studies. In addition, one semester may not be enough time to assess conceptual change. Future studies can follow a cohort to track their progression across years.

For Interdisciplinary Programs

While the results of this pilot study showed notable growth in students' awareness of core constructs, they also highlighted potential areas of improvement for both the specific program at hand and complex interdisciplinary graduate programs broadly.

First, while previous studies indicate that interdisciplinary faculty teams are a key component in building students' interdisciplinary capacity [5, 6, 8], our experiences in this course suggest that too many faculty can potentially counter those gains by creating a sense of fracturing rather than integrating – particularly in the 3-credit course, which, as noted earlier, was open to a wider audience. Too many faculty members may create unmanageable complexity. Programs such as ours that involve a broad and epistemologically diverse array of disciplines likely need to carefully and intentionally plan how best to model interdisciplinary work for students. Diverse faculty teams can support a shared workload, but the line between diverse and diffuse may be easy to cross.

As a result, for our program in particular we have opted to reduce the teaching team for the 3-hour course to two faculty, each from a different domain (1 from social sciences/business and 1 from STEM) and bring in the larger team for more structured panel sessions that can promote accessible discussions of disciplinary interactions around planning for and recovering from disasters. Other faculty (and guest lecturers) will be invited to join periodically throughout the semester. At the same time, the 1-hour seminar will function predominantly as a research group for the whole cohort, and all faculty will continue to attend that weekly meeting, with an increased focus on cross-disciplinary research initiatives among students and faculty. Reframing the seminar as a research group meeting will allow the faculty members to focus more on providing opportunities to grow as a researcher and develop professionally. For example, faculty members have explored hosting a session to discuss how to become an interdisciplinary scholar, and students are now regularly bringing work (grant proposals, abstracts, talks) to share with one another for feedback – and consequently deepening their awareness of one another's fields. By explicitly discussing with students how to think interdisciplinarily and how to conduct research across disciplines, students will be more likely to develop a functional understanding of the interdisciplinary space.

We anticipate that this structure will build more opportunities to explore intersections across disciplines and increase coherence, while still maintaining a model of interdisciplinary work and

engaging students in working across boundaries. In addition, as noted above, this approach will help mitigate faculty time until better institutional structures can be created to support interdisciplinary teaching.

Second, our field notes also raise questions about the role of space. As noted earlier, in the 3-credit course, the faculty not leading a given class session typically sat along one wall, outside the center of the class discussion. Further research is needed to explore how this dynamic may have impacted students' perceptions and experiences; at this point we simply note it as an area that warrants attention in course design. While classroom space is always a factor in teaching and learning, it may be particularly important in creating interdisciplinary spaces that can promote dialogic engagement among stakeholders.

Finally, and perhaps specific to DRRM, the students' concept maps showed less attention to issues of social justice than the team had hoped. As a result, we are focusing on ways to make social justice an explicit conversation in the program. A student-planned and -led stakeholder workshop is scheduled for summer 2020, where students will engage with stakeholders from a given area as they work to develop a disaster resiliency plan. As students prepare to host that workshop, faculty will develop lessons and workshops for the students to ensure they view vulnerable populations as *participants* in the process and to ensure that members of vulnerable populations are well-represented and included at the stakeholder workshop.

For Researchers and Evaluators

The findings here also have implications for the ways in which concept maps are used to assess and explore students' understanding of complex domains. The data set for this project highlights the challenges of creating concept maps for complex interdisciplinary tasks, particularly above the undergraduate level. As individuals' knowledge grows deeper and richer, paradoxically, as with Student G, their maps may grow superficially simpler, but cognitively more complex as they develop a higher-order abstract understanding of the domain. Pairing concept maps with other tools such as the written explanation used here provides one alternative; others may include using layered or hyperlinked maps that allow individuals to map in three rather than only two dimensions.

Conclusion

This study sought to understand how graduate students' understandings of both disciplinary concepts and interdisciplinary connections related to DRRM change as the result of their introduction to an interdisciplinary graduate program and to test concept maps as an assessment tool. While the sample size for this pilot study is limited, we can draw conclusions that inform future program efforts and future, larger-scale studies. Overall, most students demonstrated a denser, more complex understanding of the interdisciplinary concepts of DRRM at the end of their first semester in the program.

The results presented in this paper support the inclusion of an explanation component to concept maps and also suggest that concept maps alone may not be the best measure of student understanding of concepts within and across disciplines in this specific context. If similar programs wish to use concept maps as an assessment method, we suggest the inclusion of an

explanation component and suggest providing explicit instructions that specify the intended audience. We also suggest using a holistic scoring method, as it is more likely to capture nuances in the concept maps than traditional scoring methods, which focus solely on counting factors like hierarchies and number of cross-links. We are in the process of making program improvements in accordance with these results, including restructuring the 3-hour and 1-hour courses and making connections to ethics and social justice a more explicit piece of the program.

Acknowledgement

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Appendix A: Examples of pre- and post-concept maps for two students (A, C, G, and J)

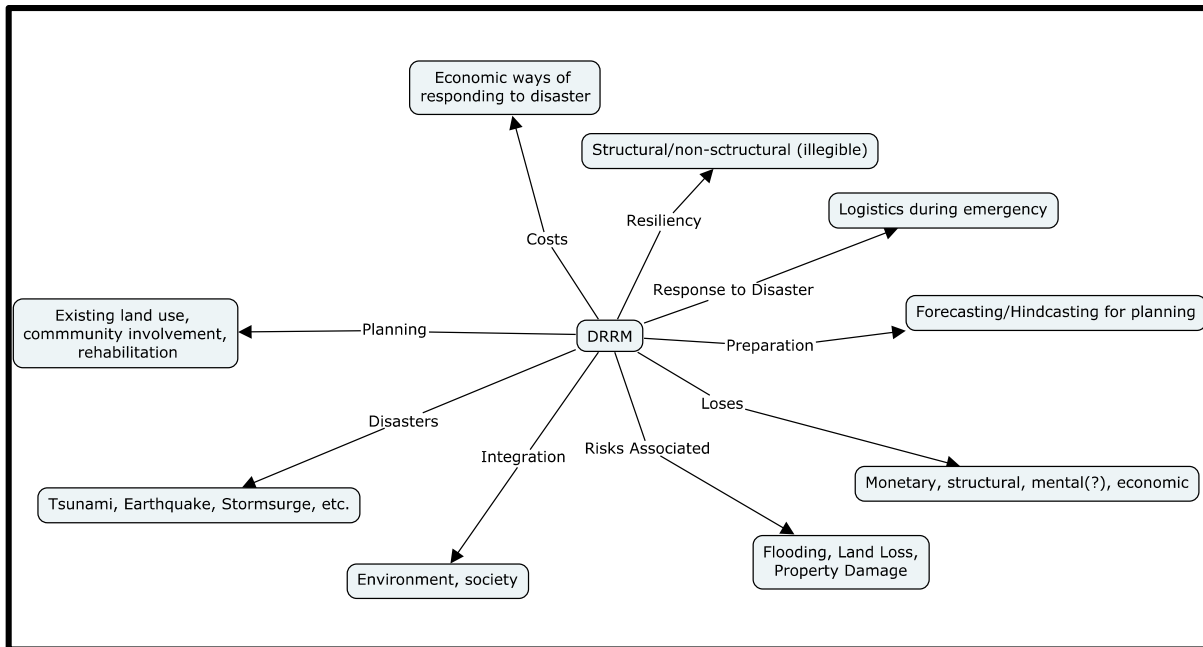


Figure 2: Student A's pre-concept map

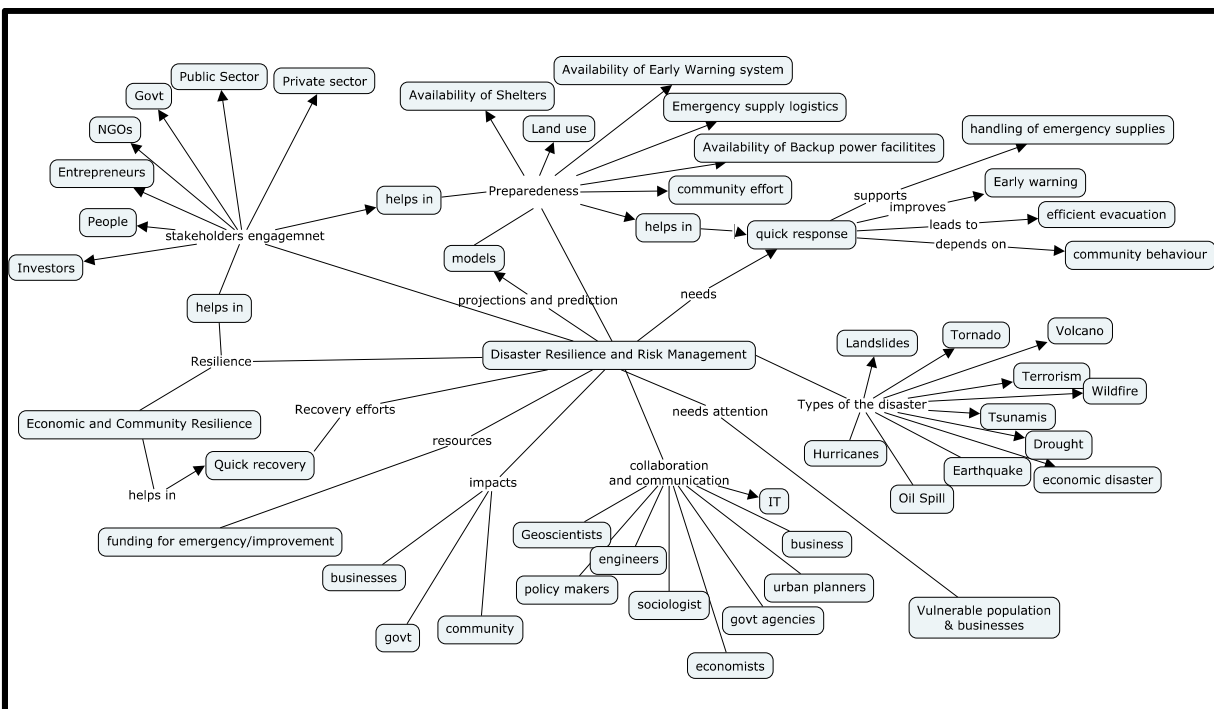


Figure 3: Student A's post-concept map

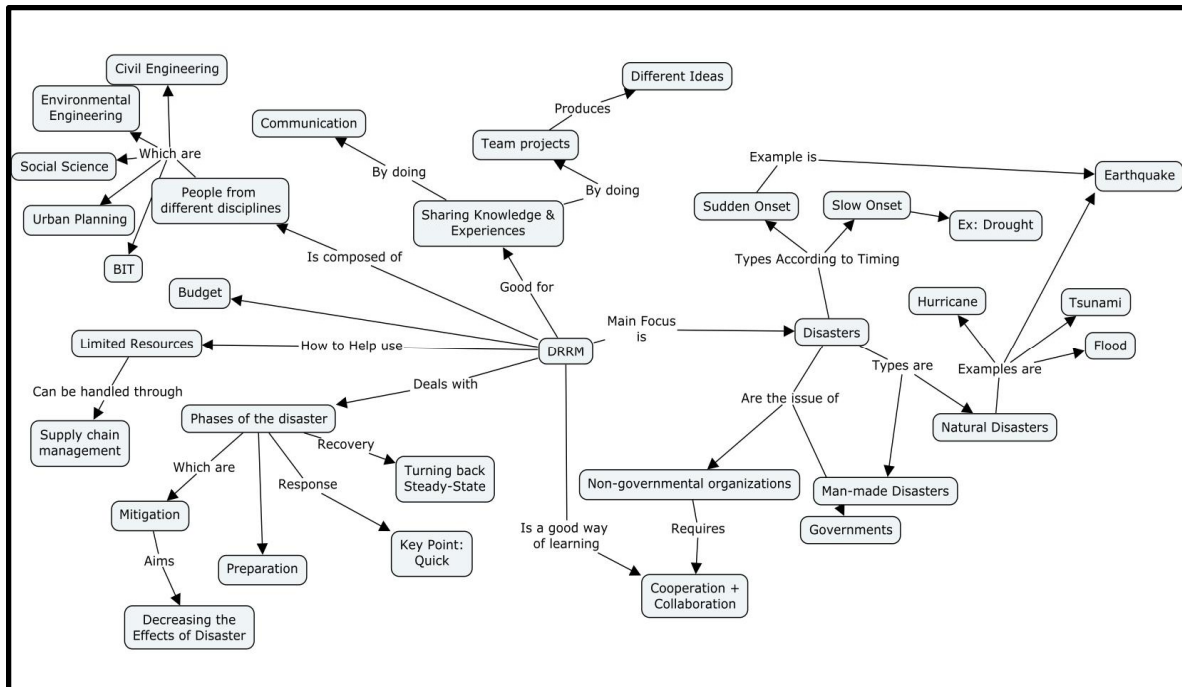


Figure 4: Student C's pre-concept map

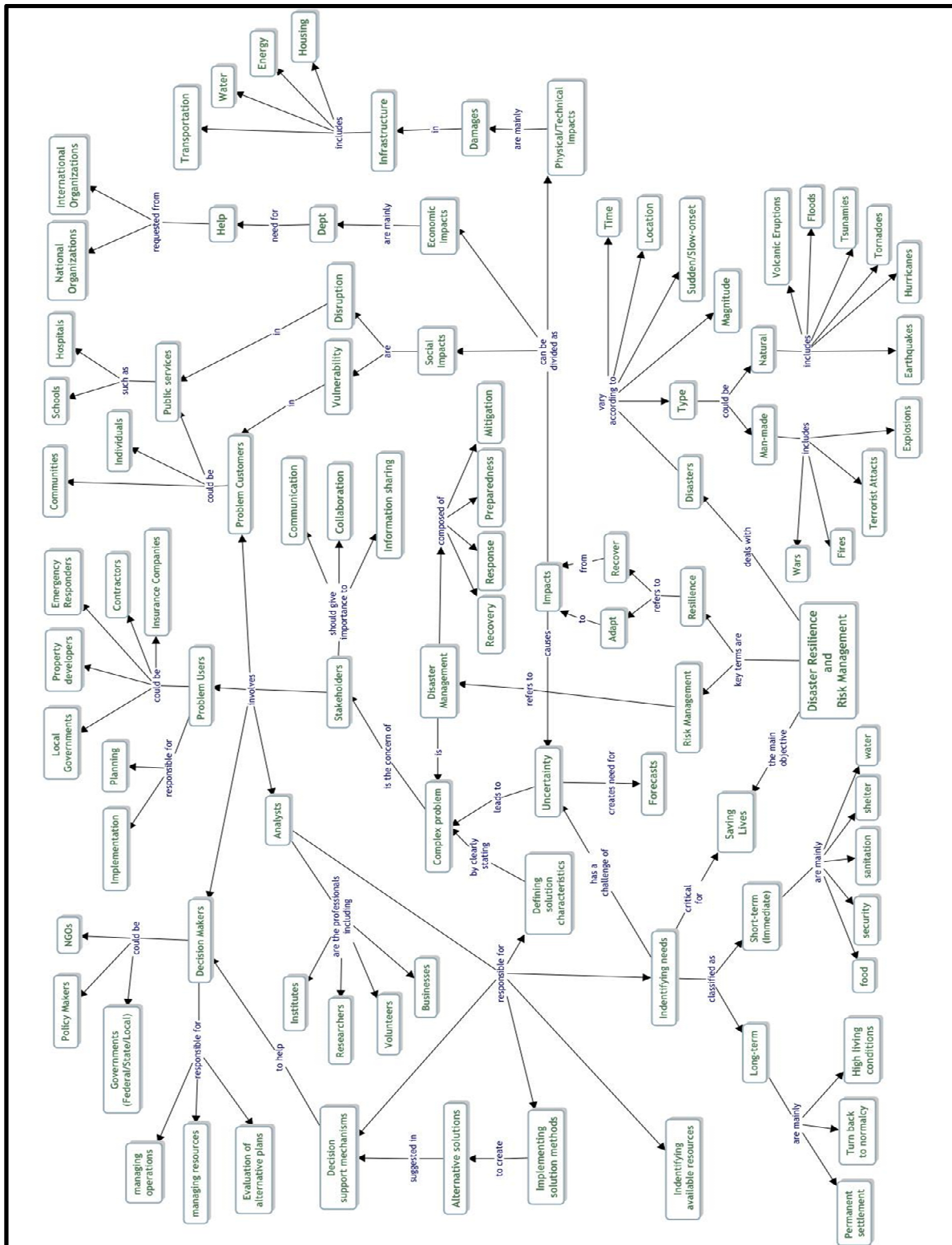


Figure 5: Student C's post-concept map (rotated to increase size)

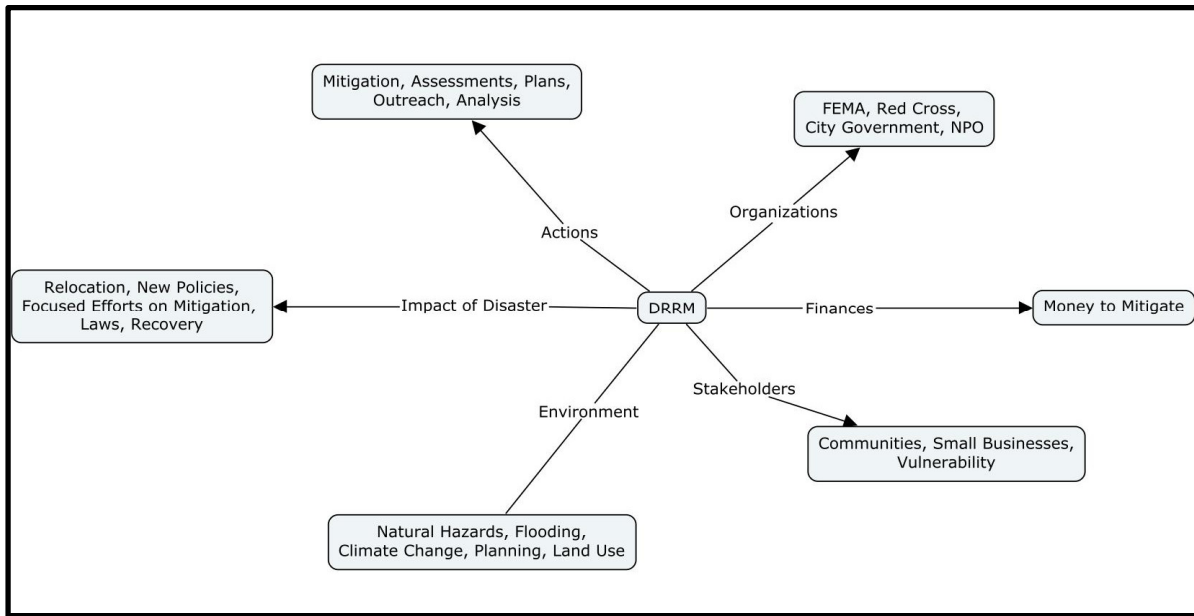


Figure 6: Student G's pre-concept map

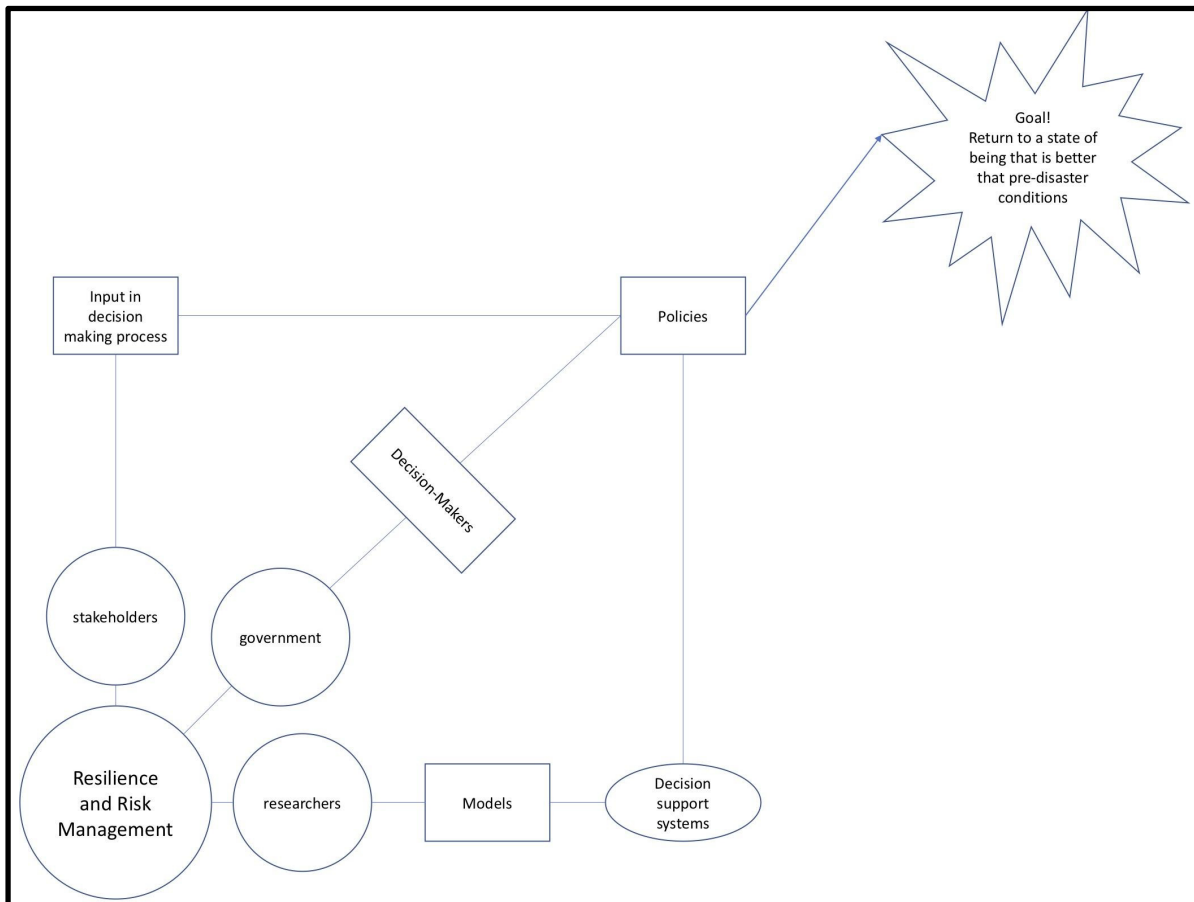


Figure 7: Student G's Post-Concept Map

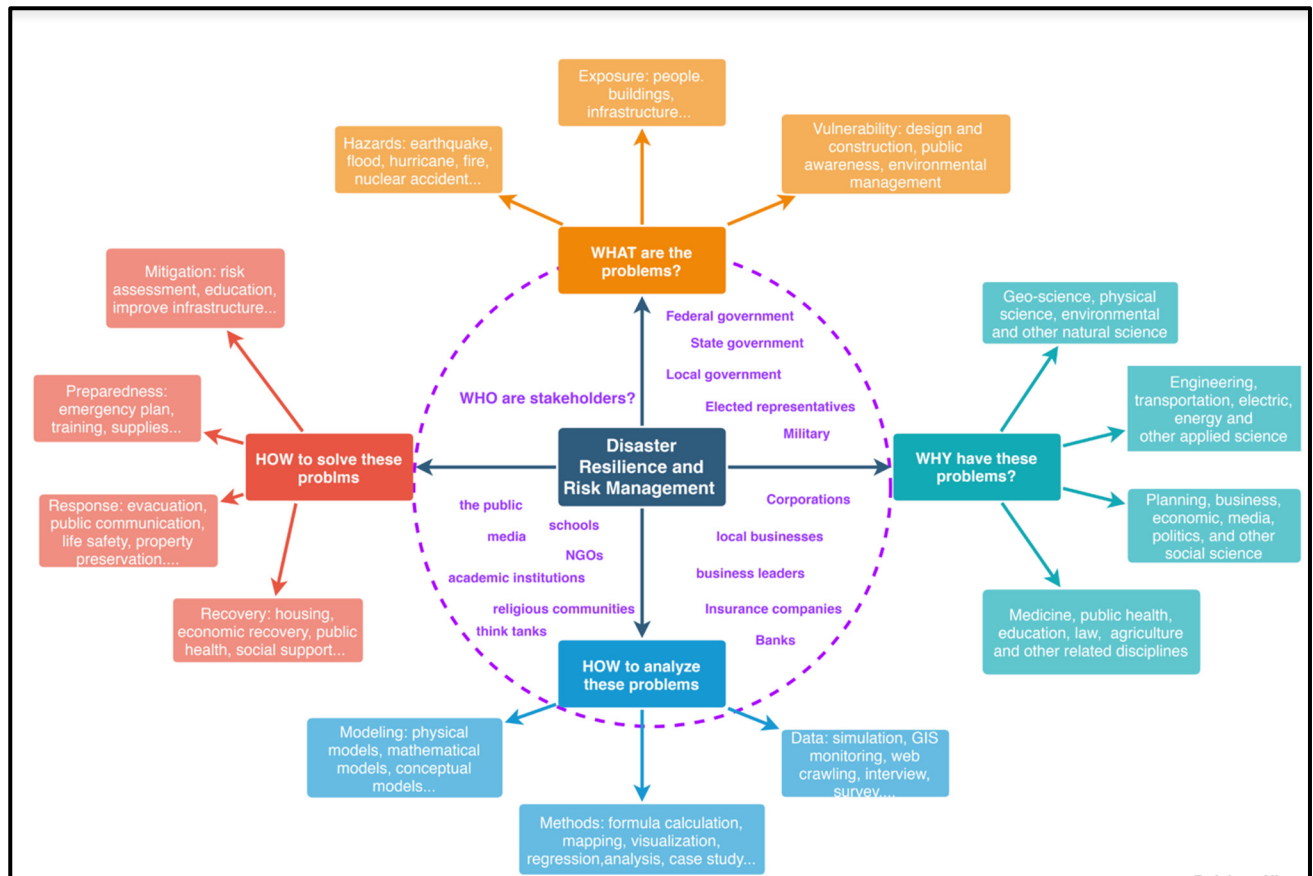


Figure 8: Student J's Post-Concept Map