Leveraging heuristic reasoning for scaffolding student's understanding in HCI classrooms

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This paper demonstrates the evidence of heuristic reasoning by novice students during a concept mapping activity in an HCI classroom and how it changed after multiple iterations of the activity. Backed up by literature and research analysis from one of the class activities of HCI for Educational Technology, this paper shows how pedagogical tools help facilitate interactions and activities in student groups in improving their disciplinary engagement. The paper then suggests some important strategies to include in introductory classes of HCI classrooms for novice learners to help them engage in better cognitive understanding and participation.

CCS CONCEPTS • Human-centered computing → Human-computer interaction (HCI);

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1 INTRODUCTION

1.1 Heuristic reasoning and its relevance in HCI

Human beings inherently reason intuitively and tend to use shortcut reasoning techniques when put in a cognitively demanding situation or on a time-bound assignment. There are multiple definitions of heuristics in the literature but heuristics in this study is considered to be a shortcut reasoning method of using fewer cues while taking a decision to

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reduce the cognitive load, generally employed by students during their decision-making process [1]. Heuristic reasoning is typically filled with biases and incorrect information [3]. The disciplinary skills of novice students in a new but familiar topic are limited and underdeveloped. When faced with cognitively challenging or time-sensitive decisions pertaining to the content, novice students forcefully create inferences and reasoning techniques within the given time and resource constraint [4]. Prior research shows that novices typically use three types of heuristics while making decisions - representative heuristic i.e., assuming commonalities between the object at focus and the prototypical instance of the class [8], the recognition heuristic i.e., when one thing is recognized and other is not, the recognized thing is given a higher value in the decision making [13], and the one-reason decision heuristic i.e., making decisions based only on a single reason [14]. It has been suggested that heuristic reasoning can be leveraged for promoting effective problem-solving and learning amongst novices. Prior research into leveraging heuristics has shown positive results in the field of science education [9,18], engineering education [19], and design [20]. Heuristics are often employed by designers as a mechanism to explore the problem and generate creative solutions [21].

A few studies involving human-computer interaction have highlighted the importance of different reasoning strategies that users or students use while interacting with the system. For example, researchers have alluded to benefit of heuristic reasoning by suggesting how the human mind overcomes its working memory's limited capacity by working heuristically i.e., through analogies, certain shortcut strategies, or principles [5]. The use of such heuristic reasoning and transferring that knowledge into human-computer interactive platforms while also using formal methods have been strongly suggested by Abowd [6]. A cost-value analysis with Keyboard Issued Commands was done by (Peres, 2005) which investigated the two types of underlying reasoning strategies that computer users take, ie., the systematic (analytical) and the heuristic reasoning that determined their use of efficient keyboard strategies [7]. These research studies suggest the potential benefit of heuristic reasoning in the context of human-computer interaction. Building on these prior works, we decided to explore how to leverage heuristic reasoning during group projects in a semester-introductory HCI course designed for graduate students pursuing a degree in Educational Technology – Introduction to HCI for Educational Technology. This course was taught in an emergency remote teaching mode due to the Covid pandemic [22].

1.2 Concept mapping in HCI

Support cards have been used in HCI courses to help students align, support, and integrate the learned concepts. Apart from helping the students recall and make connections between different topics taught in HCI, it also increases their engagement in the HCI course [11]. Concept mapping has been considered as one of the better visualization tools that help in conceptual understanding instead of the traditional lecturing, reading, and note-taking [12]. Building on this prior work, we used concept mapping in our HCI course to help novice graduate students understand introductory HCI concepts.

1.3 Online collaborative tools

With the onset of the pandemic in the year 2020, the regular classrooms saw a complete shift from teaching in a physical setting to a virtual setting. Various online meeting platforms and collaboration tools were adopted in the virtual classrooms as a result of this transition. For our introductory course, we used Microsoft Teams and Miro board for conducting the class and facilitating concept mapping. Our choice for using MS Teams was driven by the license made available by our institute for conducting online classes. MS Teams emerged as the popular choice for online classrooms due to various social networking facilities such as video-conferencing, chat options, in-built whiteboard, and breakout room facilities within a single platform. It also gives the learners the freedom to personally message or call anyone via the platform. All the chats during a breakout room session and classrooms are saved in the chat option to be accessible anytime by the learners. Class recordings are also uploaded on the same platform enabling learners to easily access them. While some of these features supporting live discussion and group work were easy to use, collaboration tools such as the whiteboard were found to be clunky for this course. Hence, we used the Miro board as another pedagogical tool for a virtual whiteboard as it allowed students to collaboratively create and share their ideas easily. Different features of Miro such as available templates, large canvas space, ease of navigation, and real-time location of other users proved to be helpful for teamwork and online collaborative learning.

2 HCI CLASSROOM AND STUDY DETAILS

The HCI class consisted of 15 graduate students (6 males, 9 females) from different parts of India aged between 23 and 40 years (Mean=27.34, S. D. =5.04). The students had a prior background in engineering, architecture, sciences, and management. The students did not have any prior training in HCI methods and concepts. The class was held twice a week (Wednesday and Friday) for 1.5 hours each day. This study reports on 13 weeks of online teaching. The HCI course was designed to be a project-based course where students were introduced to their final project in the first class. The prompt for the project was open-ended and was as follows - Design an inclusive online library. All the HCI concepts were taught to help students make progress toward this final project. Group recordings, semi-structured post-activity interviews, and saved versions of multiple iterations of concept maps were collected as part of the data for the study.

Since this course was designed for introducing graduate students to HCI principles and practices in the context of technology-enhanced learning and education, the readings assigned to the students consisted of topics covering concepts related to how people learn as well as how to design technologies following HCI principles for promoting teaching and learning. The major concepts/readings covered under these topics were 'What is human-centered design',' What designers do',' Learning Experience Design - The Most Valuable Lessons',' Learning: From Speculation to Science. Students were provided with the readings a few days before the online class on Wednesday and they were expected to read and participate in various class activities based on their understanding of the content given. The class was divided into teams of 4 to facilitate group interaction and each team had a mix of Ph.D. and M.Tech. students. We reasoned that this arrangement may help foster diversity of opinions and experience within a group. Groups were assigned different breakout rooms on Microsoft teams. One member of team A dropped this course after a week leaving the team with 3 members. Each team was given a slightly different template of the concept map on the Miro board as constraints. Team B and Team D were just given the head of the concept map and blank nodes, Team A was given the head of the concept map and three correct nodes as constraints while Team C was given the head of the concept map and three wrong nodes as constraints. This was done to see the effect of different prompts/constraints in the use of heuristics while building the concept maps. The teams were asked to disperse to their respective breakout rooms on the MS teams and to discuss and complete the concept map on the Miro board. For the first attempt on Day 1, the students were given approximately 45 minutes to work on their concept map to represent their understanding of the assigned readings. At the end of the activity, each team was asked to present in front of all the teams. On Day 2 and Day 3, the students were given 20 minutes to refine their concept maps based on the class discussion post-presentation.

2.1 Identification of heuristics

To identify the type of heuristics used by students during their collaboration, the class group recordings of the four teams were transcribed. Episodes of heuristic were identified along with the type of heuristic that a student was using during that episode. An episode here is considered to be a conversation between two or more members of the group for at least more than a minute. Three common types of heuristics were evident in the group recordings - representative, recognition, and one reason decision making. Examples of each type of identified heuristic in the study have been presented in Table 1. All four teams have been analyzed for the types of frequency of heuristics used. Each heuristic episode has been circled.

Table 1: Type of heuristics identified along with examples from the study

Type of heuristic	Definition	Example from the study
Representative	Assuming commonalities between the object at focus and the prototypical instance of the class	Student1:"..This is kind of resembling something that I learnt in an entrepreneurship workshop. Like you should actually go and check if people liked your product.." Student2:" right. So I think it is also called in management a need recognition. So we need to first recognize what the need is.."
Recognition	When one thing is recognized and another is not, the recognized thing is given a higher value in the decision making	Student1:" Let us start with sensory input?" Student2: "Could be audio visual, like we know it as a very classic thing ? In the lectures you hear in the classroom or something, or like things you see on videos and boards and everything. So anything audio visual input, so I suppose like we are maybe.."
One-reason decision	Making decisions based only on a single reason	Student1:"…from the history of learning like how human beings learn as that of the behaviorist approach, the definition is that it is a process of forming a connection between the stimulus and response,we get stimuli then we think about it and then we do response. So the process in between that or the connection between that is learning.."

An example of a heuristic episode is as follows: Student A uses a basic form of representative heuristics where she concludes that learning is all about stimuli and response. Student B then quickly acknowledges it saying that it is more valid than what she had said and asked her to put it on the concept map. Student A's heuristic has now influenced Student B's thinking. Student C has written the concept that he recognizes (recognition heuristic) Says that he did not read the materials because they were about neuroscience and he couldn't comprehend those. This has been represented in Fig.1 (Team B, at 15 mins)

Team A showed the maximum number of heuristic episodes of eight in their first attempt of making the concept map with recognition heuristic to be the most used type of heuristic in the team. Team B displayed a total of 8 heuristic episodes with the use of representative heuristic as the most used type of heuristic for the team (Fig 1). In figure 1, the manifestation of the heuristic episodes along with the different types are represented along the x-axis on a time scale of minutes. The time represents the time from the start of the activity. Different students have been represented using different colored circles. Team C showed only single evidence of heuristic reasoning as there was a lack of interaction between students to bring about such discussions. No clear evidence of heuristic was observed in Team D.

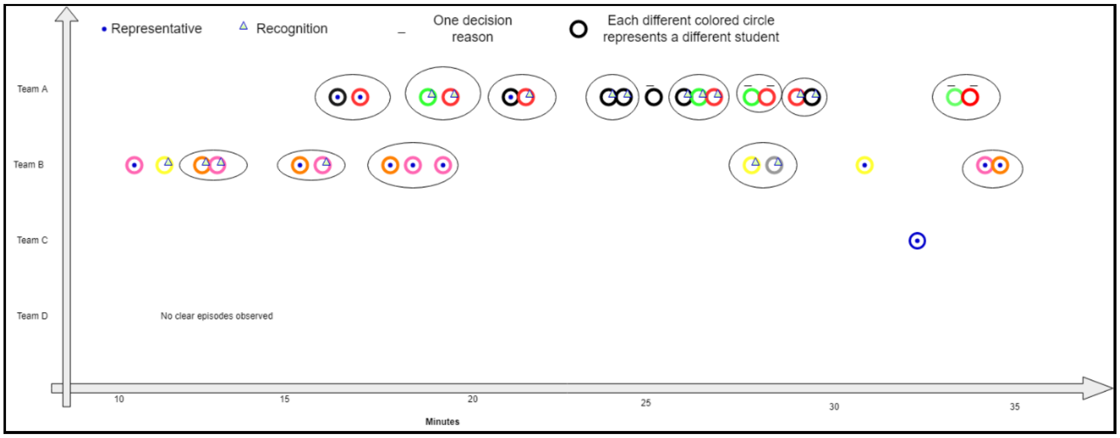
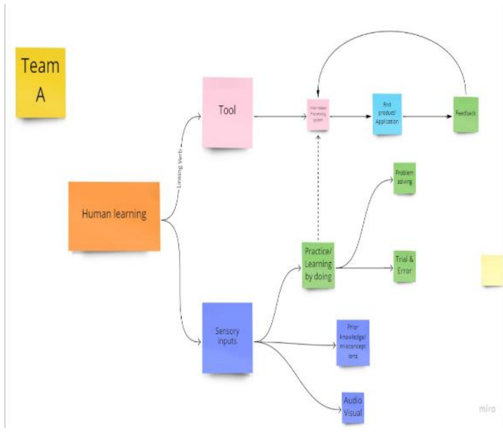


Figure 1. Representation of the manifestation of heuristics in the student teams during the first iteration.

2.2 Using Concept maps to facilitate sharing of heuristics

The above manifestations of heuristics were observed during the concept map creation and refinement process. Concept maps were used as final outcomes to test the change in the trajectory of the student's reasoning. There are many ways that a good concept map can be identified. It can be through the content of the nodes, the number, and quality of linking verbs, or the hierarchy and position of the different nodes [15]. This study focuses on the hierarchy and positioning of a node in the concept map to determine the quality of the concept map. A shift in the spatial positions of the concept nodes in the concept mapping activities was observed. The hierarchical structure of nodes in all the teams improved successively in the 2nd and 3rd attempts. This improvement is illustrated using Team A's concept map Fig 2. The concept map started from the node 'human learning' and was seen hierarchically in the horizontal flow. In the initial attempt (see Fig.2(a)) that showed evidence of the use of heuristics reasoning, the position of the 'tool' node was incorrectly placed at a position of more inclusive and general concept hierarchy in the map of how humans learn. In the subsequent attempts of the team (see Fig.2(b)), it can be seen that the position of the 'tool' node was correctly shifted towards a lower hierarchy in the map.



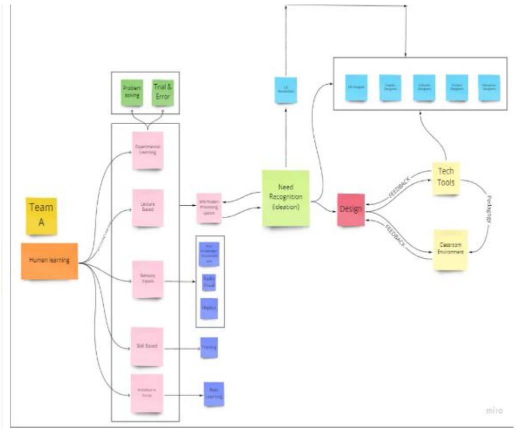


Figure.2(a) Concept map created in Iteration1

Figure.2(b) Concept map created during latter iterations

2.3 Transition from heuristic reasoning to disciplinary engagement

Students can be said to be 'engaged' during group work when more students contribute to the discussion in alignment with each other's contributions, maximum contributions are devoted to related tasks, and less for unrelated tasks, evidence of passionate involvement through the emotional display of voices. When this engagement is done in alignment with the course of content discourse, it is called disciplinary engagement [16] Episodes of disciplinary engagement were analyzed in the group recordings of the teams that showed episodes of heuristics reasoning. An episode of disciplinary engagement here refers to the span in which different students have engaged in the discussion towards the development of the concept maps and engaged in conversations related to the course topic. The distribution of the disciplinary engagement episodes can be seen in Fig.3. An example of one episode of disciplinary engagement is as follows. This episode is depicted in Fig.3 (Team A at 10 mins): *Student A talks about how they need to cover multiple things while talking about informal learning so instead of trying to include all forms of learning, they needed to focus on formal learning. Student B then talks about how that is creating an error in their concept maps as motivation applies to both forms of learning. Student A then suggests having an individual and group division for the learning.*

Team A displayed 8 different episodes of disciplinary engagement of short durations whereas Team B displayed 4 different episodes of longer disciplinary engagement. Team A had also displayed 8 episodes of heuristic reasoning prior to demonstrating disciplinary engagement (See Fig.1.). This shows how the episodes of disciplinary engagement emerged in the later iterations gradually replacing the heuristic reasoning episodes in the initial attempt. We could not identify disciplinary engagement in Team C and Team D.

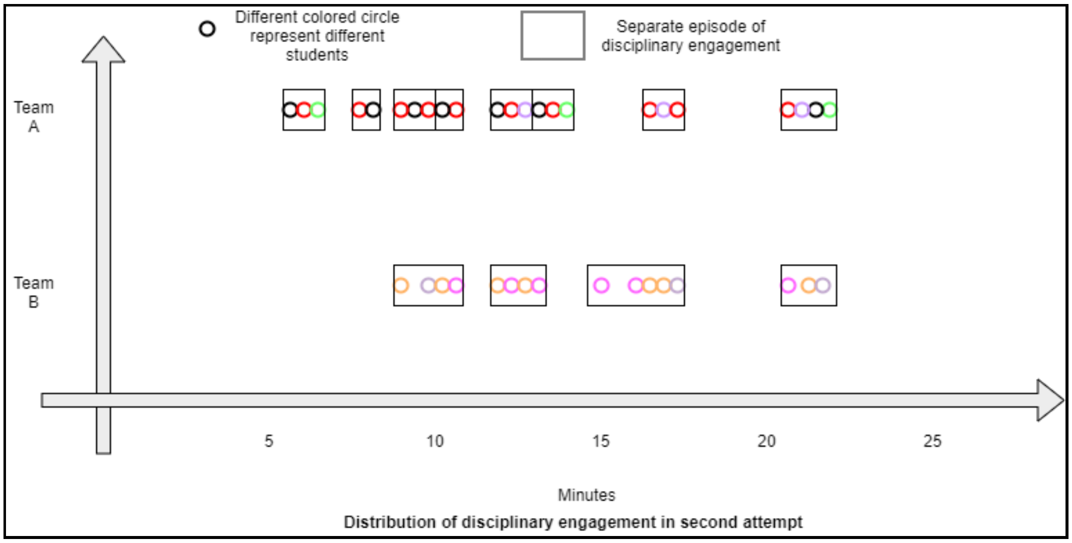


Figure 3. Distribution of disciplinary engagement in the second attempt

3 DISCUSSION

Two teams, Team A and Team B, showed ample evidence of the use of heuristics during their first attempt at the concept mapping activity. Students in both these two teams came prepared to class having done their readings and pre-class activities. However, the other two teams, Team C and Team D, were trying to catch up on the reading during the class. From the group recordings, Team C and Team D indulged in reading the reference materials during the activity and could not participate satisfactorily in the concept mapping activity in the given time. This likely prevented them from engaging in heuristic reasoning during the concept mapping activity. Team D also struggled to get proper group dynamics going due to difficulty in arriving at a shared understanding of what was to be done. Team C was also given the head of the concept map and three wrong nodes as constraints. This may have caused confusion amongst the students as they were trying to understand new concepts. Further research on the differences between these groups should be attempted to claim the exact reason. The constraints given to Team A and Team B seem to have helped elicit heuristic reasoning in these teams.

It was observed that the episodes of heuristic reasoning which were evident in the first iteration were not found during the subsequent iterations. Instead, episodes of disciplinary engagement were identified in the subsequent iterations. Team A had the greatest number of heuristic episodes in their first iterations and then displayed the highest disciplinary episodes in the subsequent iterations. This suggests the possibility of heuristic reasoning acting as an anchor in helping the students build on better disciplinary actions. Team A also talked about the different ways in which the collaborative tools helped them facilitate this change during their concept map building activity. A similar result was seen for Team B. The change in the hierarchical position of different nodes in the concept maps of the teams represents the refinement of their understanding of the concepts involved in creating the concept map. All teams showed improvement in the hierarchical positions of important concept nodes over subsequent iterations while as shown with an example in Fig. 2(a&b).

The disappearance of clear evidence of heuristic reasoning episodes with the appearance of disciplinary engagement episodes suggests that the heuristics that the teams used might have acted as a “driving force” or foundation to direct them into a better conceptualization of the concepts that they were learning. The incomplete or partially correct actions during the initial iterations anchored the teams into developing better concept models with the help of the outcome brought about by the heuristic reasoning. The teams were able to create a conceptually sound concept map at the end of the multiple iterations despite being novices in the given domain. Students were novices in HCI concepts. The design of the class and concept mapping activity gave them an opportunity to connect the new concepts with their prior knowledge with the help of heuristic reasoning in the first iteration. They were soon able to demonstrate disciplinary engagement in the following iterations (Fig 3).

4 INTEGRATION INTO HCI CLASS

Initial classes in a course are crucial to prepare students for the entire course. While teaching HCI in an Educational Technology context, it is essential to bring out and use most of the different reasoning strategies and mental models that students possess about HCI as well as learning. The understanding of basic-introductory topics such as how humans learn and introduction to HCI will be influenced by our prior experiences, knowledge, and reasoning skills in making sense of the readings. We suggest the following steps for leveraging heuristic reason in an HCI course.

1. **Use of concept maps in the initial classes of the HCI course.** Concept maps are advisable to be used in classes as part of the group discussions and clarification of concepts. When students are introduced to a new domain of knowledge, these maps help in bringing out different misconceptions and prior conceptions of students as they try to relate to the readings. These concept maps act as a guiding tool for instructors as well as students where the understanding of the students and gaps in knowledge of the students are quite evident.
2. **Multiple iterations.** It is advisable to encourage multiple iterations of the concept maps created by students. Multiple iterations help refine the concepts of the students while also helping the instructor and student see the trajectory and tangible changes occurring in the student's understanding. This helps the instructor in diagnosing the sense-making strategies of the students while going forward with the course. Evidence of disciplinary engagement becomes more prominent after multiple iterations of the concept maps. Such instances of disciplinary engagement are essential while engaging in collaborative discussions of new HCI topics.
3. **Use of collaborative platforms in group works.** The creation of concept maps in a collaborative group requires the use of online collaborative tools and their features. Miro board is a useful tool to create concept maps where students can collaboratively create as well as look at other teams' maps on the same board. The instructor can also monitor and record the progress and changes that the students make on the collaborative whiteboard.
4. **Use of constraints and attention to Heuristic reasoning.** Giving different groups different sets of constraints will help in evaluating their understanding of the assigned readings. Concept constraints can be helpful or confusing to the groups depending on their competence in understanding the given readings. Students will have to work around the given constraints to create a conceptually correct concept map. Heuristic reasoning will be evident in the students' reasoning strategies while they are trying to reason with different nodes and concepts in the concept map creation. As it is a group activity, the conceptions and perspectives of different group members will influence and trigger the use of heuristic reasoning strategies. Classroom activities are time-constrained so it demands reasoning within the given time frame. But, humans work heuristically during such time-constrained environments and create partially correct or incorrect mental models during the process. These models then stay with them unless refined. Attention to such heuristic reasoning and ways to refine those should be of primary focus during introductory classes of HCI.

5 CONCLUDING REMARKS

Research has shown how the emphasis on particular concepts at the start of a course becomes resistant to change in later parts of the course and determines the conceptual trajectory of the student [17]. Paying attention to novice students' epistemic trajectories during the class is essential to both the instructor and the students themselves. The use of concept mapping activities with different constraints at the start of the course is suggested especially for introductory HCI classes. Refinement of heuristic reasoning strategies and the prominence of disciplinary engagement is seen with multiple iterations of concept mapping activity with the help of group activities and online collaborative tools to help facilitate the reasoning and participation processes.

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