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Learning Through Patient Stories: Fostering Sensemaking in A Technology Enhanced Learning Environment for Clinical Diagnosis

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Abstract: Clinical diagnosis of genetic disorder requires sensemaking based on the symptoms of a patient. Making a diagnosis needs information gathering from the patient, interpreting the information, conducting tests and advice on further treatment. Furthermore, the experience of diagnosis requires developing a personal connect with the patient, which allows immersion in the case being investigated. This has been known to promote learners' attention so that they can better notice relevant information, and minute or unusual details. It can help them recall and relate to their own previous experiences. *Karyotype* learning environment provides learners with an authentic situation of solving video-based cases of patients suffering from genetic disorders . Students perform the clinical diagnosis by building and revising scientific explanations for the given cases while going through a series of learning activities. In this paper, we report a study conducted with 26 bioscience students to understand whether working with karyotype improves students' sensemaking and how the design of karyotype supports students' learning experience.

Keywords: Technology enhanced learning environment, sensemaking, clinical diagnosis, case-based reasoning, empathy

1. Introduction

Clinical diagnosis of genetic disorders caused due to abnormalities such as change in the number or structure of entire chromosomes, or a specific part of the chromosome carrying a particular gene. This requires sensemaking based on the symptoms of a patient, to make decisions regarding the treatment. Students need sensemaking and reasoning skills to build a scientific explanation by analysing the symptoms and connecting it with chromosomal abnormalities. However, students often learn genetics as separate, unrelated concepts, and face difficulty in understanding how they are related (Kılıç and Sağlam, 2014). Due to the lack of experience and not being immersed in the phenomena being investigated, novice learners, when introduced to new concepts, perceive them as an activity of mere memorization of facts and procedures (CTGV,1990). Though sensemaking and reasoning are essential to the way scientists construct knowledge, the majority of science undergraduate students lack these skills (Odden and Russ, 2018). This is partly due to the undergraduate science laboratories being fact-laden, non-inquiry based, with activities that do not support the development of sensemaking and reasoning skills explicitly (Daempfle,2006). Apart from these cognitive aspects, clinical diagnosis also involves affective aspects such as forming a personal connect with the cases. This is important to be immersed and involved in the process of diagnosis. Being empathetic towards patients and their stories helps in relating the given situation to prior knowledge and experiences, to build explanations regarding the new situation encountered. Empathy helps the learner to be more attentive and considerate towards minute details that might be significant for the diagnosis.

Karyotype is a web-based technology enhanced learning environment (TELE) where students are given the task of diagnosing the genetic disorders of patients while assuming the role of a geneticist. It uses a case-based reasoning approach where the students are given a set of symptoms and asked to explain them with the help of given information to suggest a diagnosis. *Karyotype* provides hands-on learning experience of the diagnosis process where students build and revise their explanations while solving cases of genetic disorders through a series of learning activities (Raste, Deep and Murthy, 2021).

In this paper, we describe the findings from a research study conducted with 26 bioscience majors' students interacting with *Karyotype*. The focus of this research study was to understand:

1. Does working with *Karyotype* improve students' sensemaking?
2. How does the design of *Karyotyp*e support students' learning experience?

2. Theoretical basis and design of *Karyotype*

Sensemaking about a phenomenon involves collecting observations, analysing the data and constructing interpretations. In this study, we use the definition of sensemaking as "s*ensemaking* is a dynamic process of building or revising an explanation in order to "figure something out"—to ascertain the mechanism underlying a phenomenon in order to resolve a gap or inconsistency in one's understanding." (Odden &Russ, 2018). Sensemaking and reasoning are closely associated in order to strengthen the interpretations. Learning to make sense of phenomena in the classroom can help the learners by preparing them to make sense of unfamiliar, complex, or seemingly inconsistent scientific phenomena that they may encounter in real life .

Case-Based Reasoning (CBR) approach allows students to learn by doing problem solving and other activities that pique their interest and apply what they've learned in a way that provides immediate feedback (Kolodner et al, 2003). CBR has been used in medicine for diagnosis as the methodology of CBR systems closely resembles the thought processes of a physician. In CBR, the remembered cases are used as a means of efficient problem-solving. Here elicitation becomes a task of gathering case histories and implementation is reduced to identifying significant features that describe a case (Watson and Marrir, 1994). CBR is typically a cyclical process comprising the four "REs". A new problem is matched against cases in the case base and one or more similar cases are retrieved. A solution suggested by the matching cases is then reused and tested for success. However, the previous diagnoses cannot be applied to new cases as-is, they need to be adapted to fit the new case/situation. Unless the retrieved case is a close match the solution will probably have to be revised producing a new case that can be retained. (Kolodner, 1992; Watson & Marrir, 1994). The cases presented in the form of an authentic and engaging narration can help learners understand and empathize with the patients. Empathy is an emotional experience between an observer and a subject in which the observer, based on visual and auditory cues, identifies and transiently experiences the subject's emotional state (Hirsch, 2007).

Karyotype is designed for the target learners of biology majors students. The learning environment consists of a series of learning activities that helps the learners to get a walkthrough of the process followed for clinical diagnosis of chromosomal abnormalities. The system makes use of interactivity to enhance learners' engagement with the content and provides scaffolds for the learners to help them make progress in the learning activities. A patient narrative is presented in the form of a video case to establish a personal connect with the content. Each case contains in-video questions where learners are being pointed towards details related to the symptoms. This puts an emphasis on relevant observations that help in making a correct diagnosis.

3. Study design

3.1 Participants and context of study

The participants of this study were 26 bioscience majors' students from Kerala, Karnataka and Maharashtra, India. The context of this study was clinical diagnosis of genetic disorders caused due to chromosomal abnormalities. The problems are given in the form cases presented as patients' narrative. Students need to understand the context of the problem, make relevant observations regarding the case, perform basic tests for diagnosis and come up with an explanation that provides reasons and justification for a possible diagnosis associated with the given case. All the participants of this study had basic prior knowledge of the domain as they had undergone an introductory course in genetics during their first/second year of undergraduate studies.

3.2 *Procedure*

This study was conducted as a part of a workshop for bio-science students. A pre-post study design was followed as we intend to check the effectiveness of pedagogy and design elements used in *Karyotype* to support sensemaking. The workshop was conducted online using Google Meet as the video conferencing platform, in the presence of the instructor in a supervised setting. *Karyotype* was accessed as a Google Sites using the standard web browser for capturing data of the learning activities related to the task of clinical diagnosis. The study had five steps and followed a pre-post design. A registration form along with informed consent was floated among bioscience undergraduate and postgraduate students. The registration form included the personal and academic details of the participants. There were 2 close-ended questions to check students' prior knowledge about the topic, and a confidence questionnaire. Participants who have undergone an introductory course on genetics during their bachelors or masters were recruited for this study on the basis of the registrations received. Participants were asked to solve a minimum of 5 cases. 86.5 % participants solved >5 cases (lowest-2, highest-9) spending an approximate of 20 minutes on each case during their interaction with *Karyotype.* For each case solved, participants created a final diagnosis report. After the intervention, participants were given one common case in the post-test where all the scaffolds were removed. A post workshop interview of 20-25 minutes was conducted with each participant.

3.3 Data collection and analysis

Mixed methods approach was used for the data collection. Quantitative data was collected through the diagnosis reports prepared as artifacts by students during the intervention and post-test. Qualitative data was collected through semi-structured interviews with students.

3.3.1 *Quantitative data*

The diagnosis reports included notes and observations made for the respective cases. The pre-test consisted of two questions which asked the learners to analyse the given problem and interpret it in the context of a chromosomal disorder. The purpose of these pre-test questions was to understand how learners make sense of the given problem and the role of providing an authentic context. Student artifacts (diagnosis reports) for the pre-test, intervention and post-test were evaluated using a 4-point rubric scale (0-missing, 1-needs work, 2-adequate and 3-target. Three criteria corresponding to the disciplinary practices involved in the process of clinical diagnosis were used to check if students are able to:

1. Make explicit and relevant clinical observations
2. Connect the observable clinical symptoms with the chromosomal condition
3. Explain how chromosomal changes lead to clinical symptoms

These criteria are consistent with the disciplinary practices of making relevant observations (R1), making connections across concepts (R2) and giving a scientific explanation respectively (R3).
R1 checks if learners have pointed out relevant symptoms and noted specific observations, while R2 checks if a clear connection has been stated between the observed symptoms and the chromosomal condition identified. R3 checks for reasoning that explains and justifies the diagnosis by pointing out the cause-effect relationship between the observed symptom and the chromosomal condition. To ensure the consistency of the rubric used for evaluation of students' responses, we carried out an inter-rater reliability test with 2 independent raters. The raters were given information about *Karyotype*, the problem context and the learning activities. They were provided with the rubric that explained the target level descriptor corresponding to each score on the 4-point scale of 0 (missing) to 3 (Target). The raters were also provided with an exemplar sample response for their reference. Each rater was first asked to individually rate 6 sample reports on the 3 criteria mentioned in the rubric (Ref. Table 1). The researcher had separate meetings with the raters to clarify their doubts regarding the rubric and TELE, if any. After one round of individual rating, the two raters discussed their scores with each other to resolve the discrepancies and reach a consensus. Both raters submitted their revised scores based on the discussion, which were then used to calculate the percentage agreement and Cohen's kappa. A percentage

agreement of 83.33 % was observed between the two raters, giving a kappa value of 0.66 indicating substantial agreement.

3.3.2 *Qualitative data*

Semi-structured interviews were conducted with 22 students based on their availability and willingness to participate in the interviews. The conversations were recorded and transcribed to obtain the verbatim. The intended purpose of these interviews was to get insights regarding students' experience of interacting with *Karyotype*. Students were probed about the procedure they followed to solve the given cases, what features of the TELE helped them in the process of diagnosis and how? Students were also asked about their prior knowledge of the topic, their prior classroom learning experience and how it is similar or different from the learning activities in *Karyotype*. Each interview lasted for about 15-20 minutes. These interview conversations were coded and analyzed using a thematic analysis approach. The unit of analysis was one sentence/series of sentences related to a broad theme of questions asked by the researcher. The broad themes included questions related to the prior knowledge, features of TELE, procedure followed for diagnosis and how did they build a plausible explanation about the case.

4. Findings

4.1 Students' performance on sensemaking criteria

We compared students' pre and post test scores to see the difference in their performance on each criterion. The paired t-test result shows significant difference for all 3 criteria suggesting that the intervention did help the students in sensemaking. Table 2 summarizes the results from the paired t test between the pre-test and post-test scores, represented graphically in figure 2 to indicate students' learning gains.

Table 2*: Students' learning gain*

Criteria	Pre-test	Post-test	Paired t test	Interpretation
			T value	
R1: Making relevant observations	0.27	1.27	5.70	Significant
R2: Making connections across concepts	0.35	1.04	3.49	Significant
R3: Giving a scientific explanation	0.00	0.54	4.24	Significant

4.2 Affordances of the TELE supporting sensemaking.

Thematic analysis of the interview transcripts gave us insights about how the features of *Karyotype* support students to engage in sensemaking while performing the clinical diagnosis. We present excerpts from the interviews where students were seen to engage in the cognitive and affective processes involved in clinical diagnosis. The excerpts indicate how the design features of *Karyotype* aided this process. As sensemaking requires prior knowledge, students' interaction with *Karyotype* builds on their existing knowledge through a set of activities that are different from the regular classroom activities and enhance the learning experience. Sharing her experience with *Karyotype S21* was quoted saying*: "Many of the syndromes which I have not studied in my graduation. We did a theoretical experiment about karyotype. I have studied during my MSc, regarding mutations and chromosomal abnormalities. In this activity I have engaged myself in doing the diagnosis, looking for what are the symptoms and what are the causes."*

As a way of thinking about science, sensemaking is a cognitive process, and a type of discourse (Odden and Russ, 2018). *Karyotype* learning activities are designed to support this cognitive process. Students were seen engaging in sensemaking while performing diagnosis. *S14:"Also, in cri-du-chat one portion of the chromosome was broken, the P arm. And given that it could affect the voice and speech that could have definitely been a reason for the symptoms that appear. The genes that could have been* *deleted or affected in other patients that directly connect to the symptoms that they have."*

Students were seen relating the cases in *Karyotype* with their real-life experiences (if any) and empathizing with the people who were a part of the case narrative. An example of one such instance, *S10: "In the common diseases, there was this one Nora baby and it showed the cleft lip. I know one man like that. So, I just remember that guy. Yeah in my experience, what is happening, I used to go there because the surgery was going, he was explaining the experience. He was trying to understand why it was happening, at that time I also didn't know. Yesterday I came to know, ok it is because of this reason.''*The process of clinical diagnosis involves not only the cognitive aspect but also the affective aspects as it concerns the lives of patients. Having an empathic approach helps the students to get involved in the diagnosis by being more careful and observant about the given cases.

During sensemaking, experts can spot meaningful patterns that may not be apparent to novices. Thus, students being novices require assistance in mapping their understanding of the concepts. *Karyotype* provides scaffolds for students to complete the diagnosis process. Students found these scaffolds useful and pointed out how it helped them navigate through the process. *S24: "The video gives you a brief idea about the patient's history. So it is better to understand and to judge the karyotype, because visually you can understand what is going on with the patient. The interactive questions, if it is wrong, you will get that there is some mistake or something is missing. So, you have to go back and read and listen carefully."*

5. Conclusion

Making links to the real world or lived experience, coordinating different representations, analyzing the rationality of solutions, and perceiving the problem as a reasonable one to address are all behaviors connected with sensemaking (Chen, Irvin and Syre, 2013). In the efforts to answer RQ1, we observed that students' sensemaking improved after interacting with *Karyotype*. We believe that design of the learning environment has led to this positive change. *Karyotype* is novel in terms of the use of instructional strategy and interactivity introduced to support learners' empathy. The technological affordances provide a more immersive experience of the diagnosis process. A personal connection established between the patients shown in the cases and the learners solving the cases is something that can not be achieved with the traditional pen and paper activity. Further, thematic analysis of student interviews show evidence regarding RQ2 i.e how the design of *Karyotype* supports students' learning experience. The design and pedagogical decision of using video-based cases including patient narrative provided veridical representation of the events which led to the improvement of students observation skills. The use of real-life cases to provide authentic learning scenarios, explores both cognitive and affective aspects of the diagnosis process. In our context, the visual representation of issues faced by patients proved to be more effective over the mere textual representation of facts. It got the learners more involved in the diagnosis process rather than reading and imagining a list of symptoms. Use of scaffolds have shown some significant change in students' abilities to perform tasks related to sensemaking. Design elements such as look-up table, reflection spots, Hints and feedback, prompts scaffolded students' sensemaking while navigating through the learning activities in *Karyotype*.

The focus of this current study was to highlight the design of *Karyotype* in supporting students' sensemaking during the process of clinical diagnosis. Thus, we used pre-post study design to evaluate their performance on certain sensemaking criteria before and after the interaction with *Karyotype*. Since there was no prior exposure to the TELE, the difference observed in the pre-post comparison can be attributed to learning activities in *Karyotype*. However, we acknowledge that the observed positive effect maintained post the withdrawal of scaffolds could be due to the post-test being conducted immediately after the intervention. Going further, to evaluate the effectiveness of *Karyotype* in improving sensemaking, a quasi-experimental study will be conducted along with a delayed post-test to account for the retention of acquired skills. *Karyotype* being aligned with the curriculum, it can be deployed in classrooms as a bridge between the theory classes and laboratory sessions. Instructors can also use it for assessment purposes.

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