Implementing Guided Inquiry Learning and Measuring Engagement Using an Electronic Health Record System in an Online Setting

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Abstract: In many courses, practical hands-on experience is critical for knowledge construction. In the traditional lab setting, this construction is easy to observe through student engagement. But in an online virtual lab, there are some challenges to track student engagement. Given the continuing trend of increased enrollment in online courses, learning sciences need to address these challenges soon. To measure student engagement and actualize a social constructivist approach to team-based learning in the virtual lab setting, we developed a novel monitoring tool in an open-source electronic health records system (EHR). The Process Oriented Guided Inquiry Learning (POGIL) approach is used to engage students in learning. In this paper, we present the practice of POGIL and how the monitoring tool measures student engagement in two online courses in the interdisciplinary field of Health Information Management. To the best of our knowledge, this is the first attempt at integrating POGIL to improve learning sciences in the EHR clinical practice. While clinicians spend over 52% of a patient visit time on computers (called desktop medicine), there is very little focus on learning sciences and pedagogy to train clinicians. Our findings provide an approach to implement learning sciences theory to eHealth use training.

Keywords: inquiry learning, POGIL, online education, health sciences, student engagement

1. Introduction

In 2016, the number of students enrolled in online education at institutions of higher education grew to 5.8 million in the US, continuing the trend of robust growth over the last 13 years. 28% of the higher education students are enrolled in at least one online course. So as online education has gone mainstream, fewer academic leaders have expressed that online education is critical to their long-term strategies, shown by a 7.5% drop from 70.8% to 63.3% (Allen & Seaman, 2016). Many attributes this drop to the observation that many students enrolled in online education were less engaged compared to their peers from face-to-face classes (Dixson et al., 2017; Friðriksdóttir, 2018). Researchers have found that reconstruction of knowledge through team-based learning, particularly in a social constructivist view (Mingfei and Jie, 2010), is harder to achieve in online courses, where space-time factors separate learners. The 66-year old, now fully online, Health Information Management (HIM) undergraduate program at Indiana University-Purdue University Indianapolis (IUPUI) is in a similar dilemma. HIM and Health Informatics is an interdisciplinary field integrating biomedical sciences, information sciences, and computer science, and brings together learners with different backgrounds and disciplines into the same course. We have employed a multitude of online engagement techniques: project-based learning and active learning strategies using virtual labs to engage students, but low engagement and lack of skills, observed when students enroll into graduate education, continues to be a serious issue. In health systems, where these students will be employed, technology use is nearly in every activity. Recent research has shown that over 52% of physician time is spent on recording, reviewing and managing information, which is now referred to as "desktop medicine" (Tai-Seale et al., 2017). The ever-increasing time spent on desktop medicine is frustrating to many healthcare providers because they are not trained in this practice, as much as they are trained on other types of medical practices.

To solve the new challenges of engaging students in an online setting, particularly in interdisciplinary health information management learning, we designed a novel monitoring tool called Student Team-Based Learning Monitor (STLM) on OpenMRS, an open-source electronic health record (EHR) system. In this paper, we start by describing a more nuanced approach to measure student engagement. We then compare the differences in measuring engagement in face-to-face and online courses. We present a review of educational literature related to student engagement, its applicability to the HIM field and then justify our choice to implement a constructivist approach called POGIL. In section 5, we describe our software development methodology used to develop the STLM tool, which tracks user activities in the EHR system. We then describe the features of the STLM tool that helps to measure engagement in team-based knowledge construction, which is central to the POGIL approach.

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2. A more nuanced approach to student engagement

Student engagement is one of the primary elements of effective teaching and learning and hence it is important to measure it accurately. It is also a key element to ensure that students are involved in learning (Dixson, 2012). Engagement in online courses, particularly in MOOC (Massive open online courses) is often measured using registration rates, participation rates, and completion rates. Educational psychologists consider these measures too simplistic because engagement in learning sciences is considered to be a multidimensional construct. Engagement in education literature is commonly divided into four constructs – cognitive (regulation), behavioral (effort, participation, rule-following), emotional or affective (positive attitude, interest) and social (Daniels, Adams & McCaffrey, 2016).

Cognitive engagement begins when the learner demonstrates cognitive presence by making an inquiry, which might manifest internally as a structure that the learner creates or externally through discussion. This inquiry results in awareness about new ideas, concepts or problems, and thereby leads to discovering new information, integrating ideas, and eventually to resolving the problem (Akyol & Garrison, 2011). Thus, problem-solving, coping, desire to learn are intrinsic motivations that learner should ideally demonstrate when cognitively engaged with the material and thereby demonstrate self-regulated learning.

Behavioral engagement most commonly includes three ways. (1) Positive conduct, like following the rules, regular attendance and adhering to classroom norms; or negative conduct and undisciplined behaviors, like skipping school and getting in trouble (Appleton, Christenson, & Furlong, 2008). (2) While performing academic tasks demonstrating behaviors, like concentration, persistence, paying attention and asking questions (Birch & Ladd, 1997). (3) Involvement in governance such as participating in student bodies, extra-curricular activities, etc. So behavioral engagement can be seen as a range from simply getting the work done, cooperative participation, and other self-directed academic behaviors. Behavioral engagement is important for achieving academic success or positive outcomes and reducing drop-out rates (Appleton et al., 2008).

Emotional engagement is when learners can express or experience their affective reactions, including interest, boredom, happiness, sadness, and anxiety (Skinner & Belmont, 1993). Emotional engagement in a way is the manifestation of learner's attitudes towards learning and student interest and values (Appleton et al., 2008). For instance, if a learner appears excited about the content, it is considered a positive emotional engagement.

Social engagement can be seen when learners share more than just the facts, but also feel that they can communicate (Kehrwald, 2008). Researchers have stated that social engagement is the effectiveness of using collaborative activities, group discussions, and other forms of student-student interaction (Gaytan & McEwen, 2007). The social constructivism epistemological lens emphasizes the role of constructing knowledge through social interactions. Therefore, when learners can express their social presence, they are emotionally and interpersonally communicating and connecting with others (Garrison & Arbaugh, 2007).

Yet, very little of these well-known engagement metrics have been applied to online education in biomedicine or health/nursing informatics, due to the effort required for such analysis (Gray & Tobin, 2010) or lack of tools that can give quantitative metrics (Russel et al., 2006). It is only recently, that patient engagement with online health information and health portals has caught attention. These concepts of engagement in learning can also be similarly applied to patient's who gain information about their illness and participate in their own care. Thus, the impact of our research can be beyond coursework pedagogy.

3. Measuring the four constructs of engagement in face-to-face or online

In traditional classroom settings, we might observe that when a student asks a question in class (cognitive), completes assignment (behavioral), appears excited about the content (emotional) and shares information with their peers (social) as useful measures for engagement. In an online setting, when a student starts a debate or asks a question (cognitive), regularly logs in and watches full video segments (behavioral), expresses that the content is useful (emotional) and participates in discussions and collaboration with other students (social), as some points to measure engagement. So, it is easy to see how engagement can be measured and possibly compared to the classroom and online settings.

In the face-to-face classroom, when teachers observe low engagement among students, they often use pop quizzes, case studies or example situations to create an inquiry structure within the learner. However, in the case of online learning environments, replicating pop quizzes or other inquiry methods might not yield the same engagement due to space-time differences. In particular, observing, assessing and measuring the inquiry structure is harder, since the teacher will never know for sure about the sources that were used by the learner to create the inquiry structure if they came from the teacher's instructions or elsewhere.

Social engagement in face-to-face or online settings is often measured by the quantity and quality of the interactions. The differences between verbal and written communication are well known, and with modern e-learning technology, the space-time synchronicity provides rich and lifelike experiences. Yet, where the online and face-to-face learning environments vastly differ are in the experiences of the learner. The experience mainly depends on technology affordance, which might be a function of how much or how often technology is used or is available. Often this technology affordance is simplistically correlated to the age of the learner. Instead, we suggest that more granular measurements be made by using structured observations of behavior within the e-learning technology. For example, students can complete an assignment either by paying attention and staying on-task or using superficial learning strategies to memorize, rather than deeper strategies to understand what is being taught. This difference in student behavior can be measured by observing the steps that a learner takes to complete the assignment. This is done quite often in the case of viva voce in medical education, but rarely in e-learning environments (Purkayastha et al., 2015). Many studies demonstrate a link between behavioral engagement and achievement (Connell & Wellborn, 1991).

Emotional engagement is often the hardest to measure or capture in both face-to-face or online settings because it depends on whether the learner expresses or experiences those emotions. Much of the emotional response to a subject or topic might also be outside the face-to-face classroom. Thus, we need to use surveys and interviews to measure emotional engagement.

4. Review of pedagogical approaches to engage students

As part of our HIM program, multiple approaches have been taken to involve the undergraduate students in the learning process - using active learning, problem-based learning, experiential learning and inquiry learning. All these teaching and learning methods try to move away from didactic learning and engage students in their own learning process.

Experiential learning requires self-initiative, an intention to learn and an active phase of learning (Moon, 2013). David Kolb's 4-step experiential learning model (ELM) that built on the work of Dewey, Lewin, and Piaget is probably the most popular model to explain experiential learning (Dixon, Adams, & Cullins, 1997). But with the challenge of self-initiative, particularly in the undergraduate and online classroom, we saw limited approaches to implement ELM. Problem-based learning (PBL) is another approach commonly used in STEM education, due to the constructivist philosophy and positivist epistemological base of many natural sciences. Wood et al. (2010) expressed that utilization of resources and tutor facilitation are the main problems of PBL methods. Students have also reported information overload and unable to determine the amount of study required to be able to solve a problem. On the other hand, another method influenced by constructivist teaching philosophy called inquiry learning can be applied to active learning and group-based learning strategies without student overload. In the 1960s, Schwab articulated 4-levels of inquiry – confirmation inquiry, structured inquiry, guided inquiry and open/true inquiry (Schwab, 1960). These levels of learning might be thought of as hierarchical and form a chain of discovery where student traverses the different levels of inquiry. For undergraduate education, guided inquiry learning has been founded to be appropriate, given the amount of work that students need to put in a traditional, single semester course (Kuhlthau, Maniotes, & Caspari, 2015). Furthermore, to facilitate early or introductory courses, making students walk through a process also helps in inquiry learning. This is what is referred to as process oriented guided inquiry learning (POGIL) (Brown, 2010). Although POGIL started in chemistry, it has been customized to other fields such as Computer Science, Nursing, Medicine, and Pharmacology. POGIL has been shown to improve student engagement, improved performance in assessments, particularly among women, minority and low-income student groups (H. Hu & Avery, 2015). Thus, POGIL is the theory that we have put into practice using STLM in the two HIM courses.

5. Our implementation context and methodology

Our intervention is based on a practical application of the theory of Process Oriented Guided Inquiry Learning (POGIL). We selected two courses from the HIM program for implementation, M200 - Database Design for HIM and M220 – Health informatics for Decision Support. The main learning outcomes of the two courses are for students to acquire process skills in the use of technologies such as electronic health record systems and health databases. POGIL practices, which we describe in the next paragraph, were integrated into the curriculum redesign of these HIM courses. We implemented the core philosophy of POGIL in the two courses - students learn through the process of performing activities that aid in developing critical thinking skills, as in such scenarios, learning is by doing, and the teacher does not instruct, he/she facilitates guided learning. Before our modifications, the courses used active learning strategies such as group discussion on database-related work, and virtual labs, where students critically review decision support tools in an EHR system. Based on the HIM plan of study, these courses are taken by students in the 2nd year of their BS in HIM. The HIM M200 is a general education course, which can be taken by students from different programs. Approximately 40 students enroll in these courses each semester.

We currently use OpenMRS, an open-source electronic health records system in the Health Information Management and the graduate Health Informatics program at IUPUI. OpenMRS is widely deployed in more than 350 sites in over 42 countries, mainly in clinics in low-and-middle income countries, but also in some academic sites such as medical schools and schools of informatics in high-income countries. Students enrolled in the online program are given lecture material (slides, documentation or videos) suited for POGIL pedagogy. We divided the students into small groups of 3-4, which is the appropriate size for the tasks from these courses. As part of the POGIL implementation, each student of a group can play two roles - iTrainee and rTrainee. The "inquiring student" called the iTrainee is asked to create a set of tasks based on the concept that was explained in the lecture material and instructions from the teacher. The iTrainee is not aware of the most efficient way to perform the task but tries to perform the task on their own, based on the concepts explained in the lecture slides. See Figure 1 below for an example. After performing the task, the iTrainee requests the other students of their group (rTrainees) to perform the same task.

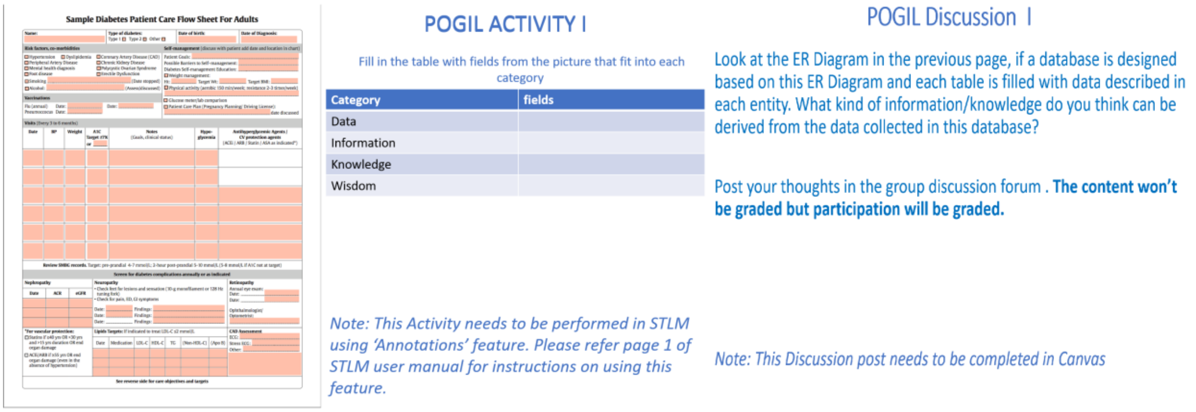

Figure 1: A comparison of slide material (right), STLM (left), and the Canvas discussion

This is written by the student on the Canvas learning management system used at IUPUI. The rest of the group members are notified of this request. Other "responding students" called rTrainee now attempt to complete the task that is put forth by the question of the iTrainee. The rTrainees attempt to complete the task, without knowing the way in which the iTrainee completed or could not complete the task. After completion of the given task, the rTrainees and iTrainee will be able to compare their work with other members of the group. The iTrainee will also similarly have to play the role of a rTrainee when other members of his/her group make inquiries and propose new tasks to the group. We found that with each attempt as a rTrainee, there is improved student learning of the concept, followed by knowledge reconstruction that occurs by observing the comparison of the tasks performed by different students.

Let us look at the example POGIL activity from Figure 1. The HIM M220 course has an assignment, which requires all the students to identify data/metadata, information, and knowledge from the EHR data, shown in the patient dashboard, such that they can be used to create clinical decision support rules. We modified the assignment in such a way, where iTrainee is given a set of instructions to search for a patient in the EHR system and tag the elements and values as data or information or knowledge. The STLM tool enables selecting or typing text in the EHR forms and tag them as data/metadata, information or knowledge. Figure 2. shows how this task is performed by the student in the EHR and monitored by the STLM. The iTrainee then posts instructions in the discussion forum for other members of the group, who will now have to play the role of rTrainees. The iTrainee instructs the rTrainees with the specific name of the patient to search, the form that needs to be opened and the type of concept or form that should be filled to complete the task. After completion of the task, students can compare their methods to attempt the task with other members of the group, this is facilitated by the STLM tool, which is discussed in the next section. Our implementation involves students in the learning process, through inquiry and activities of the constructivist learning cycle. Due to the use of the POGIL approach, students discover different ways to complete the tasks in the EHR system. This is difficult in a didactic setting since all possible ways to solve the problem are hard to demonstrate. Whereas in a POGIL approach environment, the students will work with/against (in a competitive way) to solve the problem and discover efficient ways to complete a task.

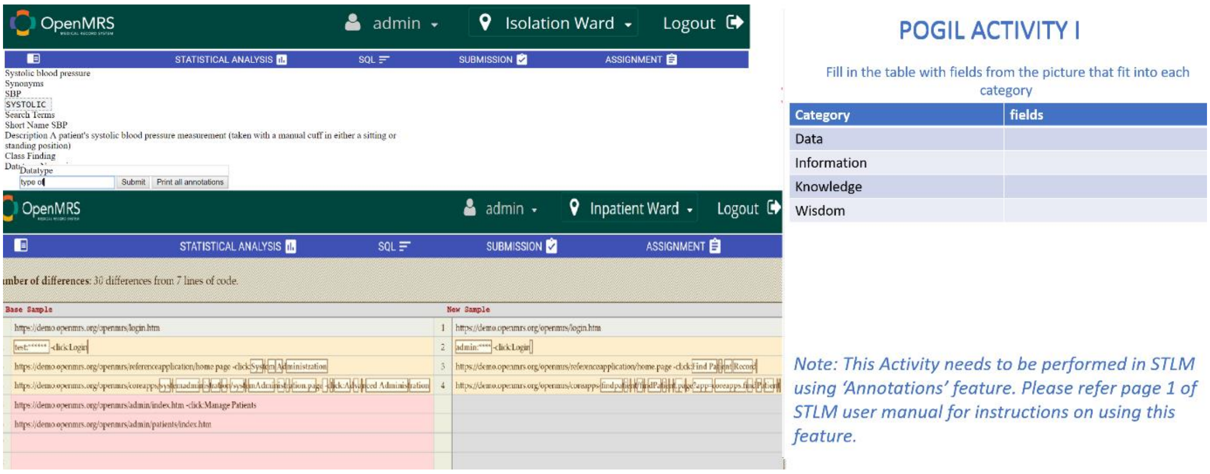

Figure 2: Screenshot showing STLM tool with annotation and compare feature (left) and POGIL task (right)

We measured the student engagement using survey instrument and learning analytics from the Canvas learning management system and the STLM tool. The survey questionnaire is based on the National Survey of Student Engagement (Kuh, 2003) and the Student Engagement Instrument (Appleton, 2012). This survey contained 22 questions related to four engagement components (cognitive, behavioral, emotional and social) and took about 15 minutes to complete. A semi-structured interview was then conducted by an undergraduate researcher (who has already taken the course). The interview lasted between 30-45 minutes and included questions about student's experiences on the POGIL and the STLM tool. The results of the analysis of the survey and interview data have been reported elsewhere.

6. Features of STLM

We developed the STLM tool as a module on the OpenMRS EHR system platform, because it is flexible, and used in many Health Informatics and Health Information Management courses (Purkayastha et al., 2017). Using the role-based permission scheme in OpenMRS, we assigned trainee roles to students. The students are sub-divided as one iTrainee or multiple rTrainee roles in a round-robin fashion for each week's assignments. The teaching assistants or course instructors use the EHR administrator role to manage the trainees, grade and provide answer keys for the tasks that are completed each week in the EHR system, under the observation of the STLM.

The STLM provides a generic assignment task list to be completed by the trainees each week. The iTrainee is the only student who sees this tasklist and creates a specific question out of each task for their student group. Along with creating the question, the iTrainee applies the concepts learned from the slides and attempts to answer the question. As shown in Figure 3, the iTrainee clicks the "Start recording" button to record their answer, navigates through the EHR performing actions to complete the task, and then answer the question that they originally asked. The "Stop recording" button is activated once the recording is started and the iTrainee needs to press it to complete registering the answer. By doing so, the STLM tool has captured all the actions that were performed by the iTrainee. After performing the task, the iTrainee will have to request the other students of their group (rTrainees) to perform the same task. The rest of the group members will be notified of this request. rTrainees will then attempt to complete the task that is put forth by the iTrainee for the given week. As the rTrainees attempt to complete the task, without knowing the way or approach in which the iTrainee completed the task. After completion of the given task, the rTrainees and iTrainee will be able to compare their work with other members of the group using the compare feature in the STLM tool as shown in Figure 3. The STLM tool captures the different types of actions performed on the EHR. The user fully controls the STLM recordings and as such avoids privacy or security issues during deployment. The following are actions captured by STLM:

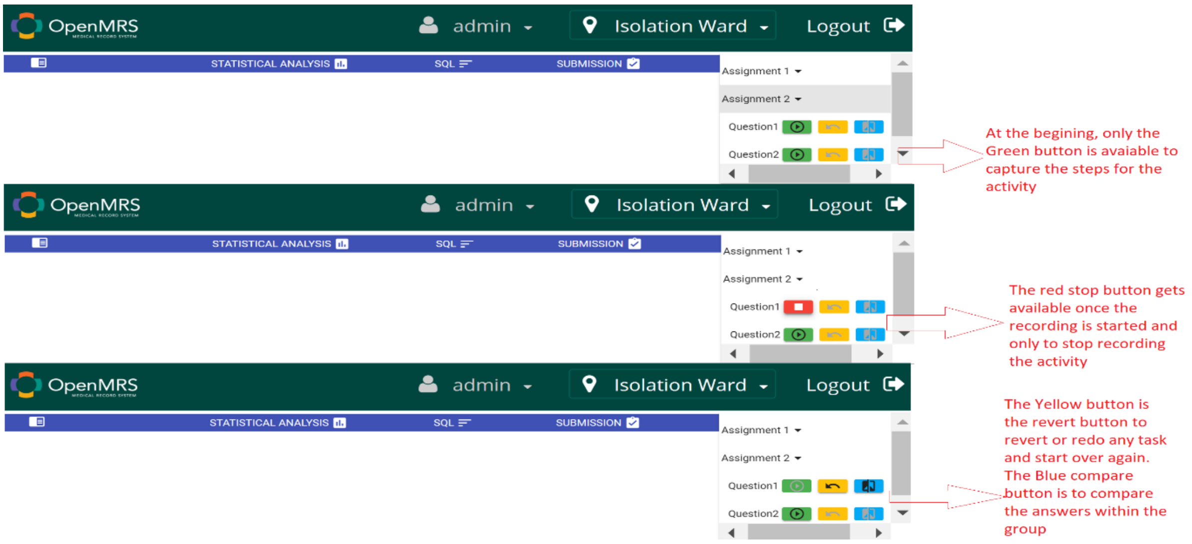

Figure 3: Steps involved in capturing the task performed in STLM

- 1. Page navigation: This is the most basic data captured by the STLM. The STLM captures all the pages where the EHR user (iTrainee or rTrainee) navigates, clicks and types on text fields. The users then have the option to compare the navigation to complete a task with other trainees.
- 2. Onscreen annotations: The user can select parts of the screen text and annotate them with tags. E.g., in M200 course, while studying Database Design for HIM the students are given the task to annotate a few data points based on their slides. This task needs to be completed using the 'Annotation' feature. For better understanding as shown in Figure 2 the students are expected to annotate words or fields based on their understanding from the uploaded patient care sheet, which will be made available to the students by uploading in the tool where they can directly select the field or word that corresponds to 'Data', 'Information', 'Knowledge; or Wisdom' and annotate it. Each step performed to complete this activity will be captured into the STLM tool. In this way, they can perform an information management assignment. The trainees can then compare the annotations with other trainees within the STLM.
- 3. Diagram comparison: Block diagrams, entity diagrams, and workflow design are an important part of information management and for the design of EHR systems. Trainees can create flowcharts, block diagrams using entities as shown in Figure 4. The STLM will compare the diagrams that are created by the trainees. The STLM does not evaluate the exact contents of the diagrams but can compare the number of entities, number of connectors between entities, as well as the layout and arrangement of the entities.

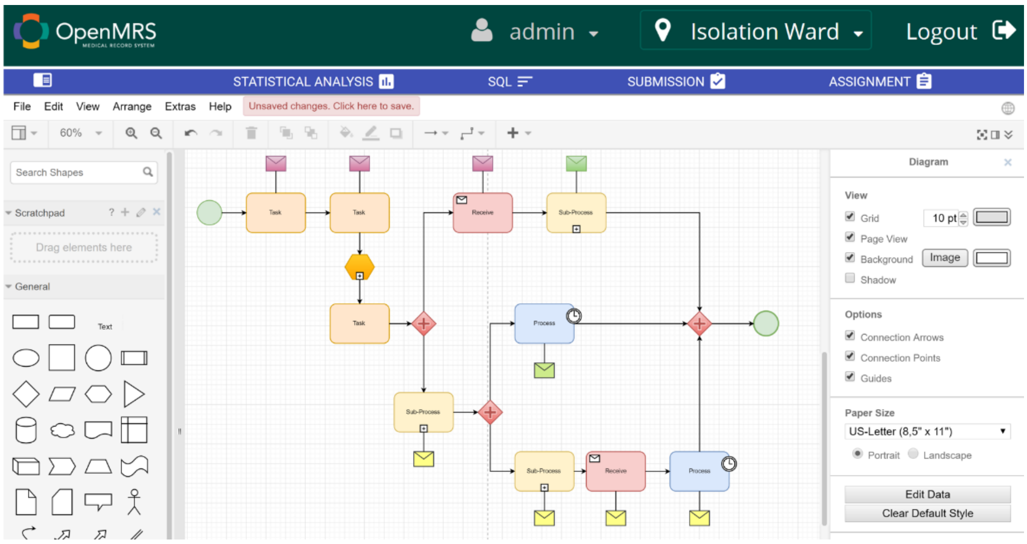

Figure 4: Screenshot showing drawing feature to capture various steps

- 4. SQL execution: This allows the user to execute SELECT queries on the database to retrieve data from the EHR and compare those between students, this feature can be referred in Figure 5. The STLM can compare the text of the queries themselves, as well as the output that is generated from it.
- 5. Cohort export: As shown in Figure 5, while the SQL execution results in some data that is shown on screen, it can be combined with previous run queries and trainees can compare the exported cohort between their extracted data and data that is extracted by other trainees.

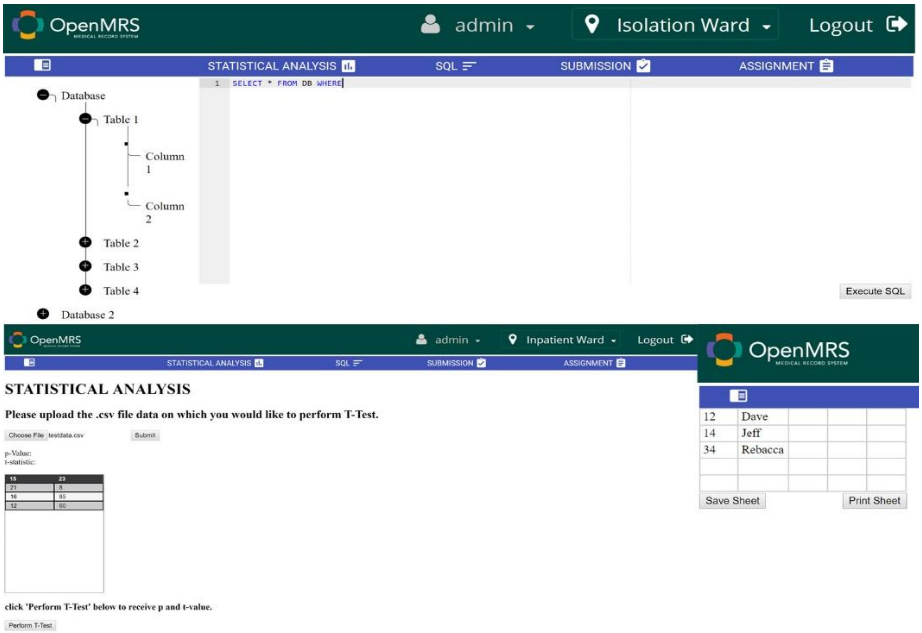

Figure 5: Screenshot showing feature for SQL query execution (top) and Cohort export (bottom)

STLM supports inter-disciplinary learning by involving trainees with different skills in groups. Health informatics and health information management are inherently interdisciplinary fields where individuals with a background in biomedical sciences, information sciences, and computer science collaborate with each other. The STLM use-cases support interdisciplinary collaboration, as trainees with different backgrounds can observe how each person from their group performs the same action in different ways and can engage in learning from each other.

7. Conclusion

Through our study and development of the STLM module, we can capture more granular information about student engagement, instead of just time spent on a task, which is what is usually available in learning management systems. Using STLM, instructors, learning science researchers, clinic administrators and students can review more detailed information about how students perform tasks and how they convert conceptual learning into practical implementation of process-oriented inquiry learning, particularly in interdisciplinary settings and e-learning environments.

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