A Knowledge Management Methodology for Studying Health Science Students' Development of Misconceptions

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***Abstract*- Development of misconceptions by health care students and providers can be deadly to patients during health care planning and delivery. However, ongoing research of methodologies for knowledge management and knowledge discovery has provided ways to study and then remediate misconceptions. Effective use of data warehousing coupled to automated data mining has been successfully integrated to around complex learning objects. Such integrations allow for monitoring and analysis of students' and practicing healthcare providers' processes of learning and decision making. In this paper, we describe how such coupling enables new types of methodologies which can lead to a better understanding of misconception development.**

Keywords-complex correlations; misconception development; navigational pathways; pattern recognition process mining.

I. INTRODUCTION

The research literature does not provide a definitive understanding of how students and professional practitioners in healthcare develop misconceptions [1][2]. This deficiency in the literature is found across all academic and training levels. Yet, development of misconceptions are dangerous both to the individual who has a misconception as well as to others who may depend on that individual to use their knowledge and skills when making life and death decisions. For example, many health sciences students train to become nurses, doctors, and other allied health professionals. In their professional lives, these practitioners are frequently in situations requiring accurate pattern recognition of emerging signs and symptoms of a patient's disease-injury state and then make decisions about appropriate treatment for the patient.

Importantly, few evidence-based frameworks for education have been broadly deployed during the ongoing transformation of education in which there has been increased use of digital media and e-learning modalities [1-3]. Of course few evidence-based frameworks were deployed for education prior to this transformation. However, the enormous pressure on faculty to deploy e-learning solutions for courses and curricula, as well as increased use of digital media and simulations as teaching-learning resources, has resulted in a plethora of educational methods and materials that have little empirical foundation supporting their actual effectiveness in improving learning and knowledge transfer. We found no broadly-based, generalizable studies probing how and why misconceptions are formed. Consequently, we have both an opportunity and an obligation to study how misconceptions are developed and how to mitigate or at least minimize development of misconceptions that impair clinical judgment during health care planning and delivery.

Tashiro, *et al*. [1] studied the critical issues outlined by the US National Research Council. A more recent literature review identified critical gaps in our knowledge, some identified in the National Research Council analysis, but others not identified. We found the development of misconceptions was one of 10 gaps in knowledge about how educational materials "really work" to change an individual's learning outcomes and willingness as well as ability to sustain behaviours related to learning [1][2][4][5]: (1) How does an educational environment impact disposition to engage in a learning process? (2) What are the relationships between the level of realism in an educational environment and learning outcomes? (3) How do you define the threshold of experience within an educational environment that leads to measurable learning outcomes? (4) What are the knowledge domains being developed during learning? (5) In which knowledge domain is learning being retained and how stable is the retention? (6) What is the disposition to act on the knowledge gained during work within an educational environment? (7) How well can the knowledge be transferred? (8) What learning outcomes (conceptual and performance competencies) are developed during the learning process while working within an educational environment? (9) How are misconceptions developed during and sustained after working within an educational environment? (10) How do teacher-student and student-student social networks or e-communities impact learning. Interestingly, initial work indicated that development of misconceptions was the gap that was most difficult to study. However, as we conducted research on how to study misconception development, we began to test a methodology that allowed study of all 10 gaps. We report this newly developed methodology in this paper, using the study of misconceptions as a detailed example.

As a starting point, a study of diverse research literature bases and interviews with educators led us to pose the following definition for the dynamic condition of a "misconception" [1][5-7]: The state of being unaware that your own knowledge domains and cognitive processing are

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incomplete or incorrect." In this context, we are using knowledge domains and cognitive processing in the sense of Bloom's Revised Cognitive Taxonomy [1][5][6][8][9], wherein knowledge domains include facts, concepts, procedures, and metacognition, while cognitive processing includes remembering, understanding, applying, utilizing, evaluating, and creating. While some researchers might choose a different taxonomy, the key point is that whatever taxonomy might be chosen it can be used to build a knowledge management system to study how people learn. Furthermore, a knowledge management system based on a cognitive taxonomy can be coupled to a second knowledge management system that contains multiple frameworks, each framework based a theory of cognition and theory of behaviour change [11][15]. Our research team worked through the integration of these two knowledge management systems and coupling them to a knowledge discovery system to study how misconceptions are developed during a learning process. Together, these systems can be used to create new types of research platforms that could be used to study misconceptions in concept development and how such misconceptions could be expressed during knowledge transfer into behaviors expressed through knowledge-skills transfers based on prior learning [19].

The research platform can be conceptually described as a multi-tiered array of knowledge management and knowledge discovery systems. A researcher engages at on tier and selects a theory of cognition and a theory of behavior change. At this tier, the knowledge management system algorithms select templates for instructional design consistent with the theories of cognition and behavior that were chosen by the researcher. The template is then mapped to learning activities, learning resources, learning assessments for each activity, and diagnostic feedback for each assessment.

The next tier of the research platform then loads the learning activities, resources, assessments, and diagnostic feedback into the template so that the template becomes a suite of learning objects that together comprise an educational environment. The educational environment can then be loaded into a Web-based stand-alone simulation or into a module nested within a learning management system. The educational environment then is integrated with a knowledge discovery system. The knowledge discovery system has two subsystems. First there is a subsystem comprised of monitoring and reporting algorithms that can track all of a student's' choices within the educational environments and how much time is spent in each choice of learning activity, resources, assessment, and diagnostic area loaded into that environment. The tracking-timing data are loaded to arrays collated by a set of reporting algorithms. The second subsystem then receives data arrays from the reporting algorithms and loads these arrays into data analysis options that can be selected by the researcher. Such data analysis options include a variety of data mining techniques.

These types of multi-tiered educational environments designed as research platforms can then be opened to access and be used by students in classes or healthcare providers as part of professional development training. Such research platforms are critical to development of empirical frameworks for studying what really works in education, a challenge first posed in 1997 by Tashiro and Rowland [20][21]. However, even as digital media uses within all levels of academia and training has increased dramatically [22], there still are few evidence-based practice frameworks for education.

Importantly, diverse learning environments based on digital media are becoming embedded in health care education and training at multiple levels ranging from all levels of academia, job training, and professional development and enhancement [1][2]. Do such educational digital media really work to improve learning and to reduce misconception development? In 2005, Aldrich stated that use of web-based learning as pedagogy has erupted so quickly it is comparable to the delivery of fast food. Just as fast food chains produce food that compromises nutritional value and increases health risks, educational interventions without substantive evidence for effectiveness may increase learners' development of misconception. Since Aldrich's paper was published, software companies and academic publishers have been flooding the educational and training markets with a variety of digital media and e-learning environments designed to serve diverse audiences in many disciplines. However, lack of a substantive empirical foundation for how effective such environments are in improving educational outcomes may actually lead to ineffective educational practices and dangerous misconceptions in health care education [23].

The digital media transformation of education still has too few well-developed frameworks for evidence-based learning that might provide guidance for development of educational methods and materials that ***really work*** to improve educational outcomes in health care education [1][2]. We now turn to describing how misconception development can be analyzed by the multi-tiered research platform we have described.

The remainder of this paper is organized as follows; Section II discusses the significance of this study while Section III describes our methodology. Results and discussion are provided in Section IV.

II. SIGNIFICANCE OF STUDY

The significance and primary outcome of the research has been a methodology of building systems for knowledge discovery that could be applied to analyzing the cognitive and behavioural paths leading to misconception development in health science students and practitioners. In addition, we were able to evaluate specific types of research platforms in which we had embedded digital media and e-learning environments. Studies of these platforms and their capacity for collecting and analyzing data within teaching-learning environments led to sensible and logistically feasible capacities for improved data analysis of large educational data sets. Such data sets from our educational research platform allow automated data collection, management, database construction, and data analysis with appropriate data mining methods that had to be applied and evaluated.

Data mining and knowledge discovery have emerged as an important field of research with growing usage in educational research [24]. Data mining in education is an extension of the broader data mining research field. Common educational data mining applications include, but are not limited to, student models [29], educational software [23], collaborative learning environments [7], web logging [28], and factors associated with student development of misconceptions [1][7]. We have chosen to focus on the study of processes for collecting, managing, analyzing and interpreting data for investigating health science students and practitioner's development of misconceptions. Reduction of misconception development in healthcare education and professional development will improve patient care and safety.

III. METHODOLOGY

The methodology developed to study processes of misconception formation evolved through four phases of research.

Phase 1.—Teaching-Learning Simulative Environment

The first tier of the research platform was simplified so that research tested a constructivist model consistent with one cognitive theory (Situative Learning Theory) and one theory of behavioural change (Planned Behaviour). This choice of a constructivist model was studied in the context of ways to improve healthcare education in the area of interprofessional care, which resulted in a template for interprofessional education instructional design. The template was then mapped to learning activities, learning resources for each activity, learning assessments, and diagnostic feedback for each assessment item.

The second tier of the research platform was then built as a virtual world with multiple healthcare settings, each containing a complex patient (funding from HealthForceOntario in Canada). Using the instructional design template and learning objet mapping, we then developed a simulative teaching-learning environment that had instructional design attributes based on prior evidence-based educational research [1-3][25]. This environment was called IPSims, an abbreviation for Interprofessional Simulations. As mentioned above, IPSims was developed to improve interprofessional care among healthcare students and providers and designed as a Web-delivered Flex-based set of patient simulations. The initial target audience was undergraduate health sciences students and the educational goal was to improve students' development and demonstration of skills in interprofessional care of complex patients.

IPSims was substantially derived from earlier work building and studying virtual hospital simulations for nursing students, a virtual medical office for medical assistant students, and virtual patient encounters simulations for paramedic training (funded by the United National Science Foundation and the United Sates National Institute of Nursing Research). As described by Tashiro and colleagues [25], the interprofessional care simulations were developed from a learning map of interprofessional core competencies that all health care providers should be able to demonstrate. The simulations were developed by teams of clinical experts, educational researchers, and software architects, with iterative review by expert panels. These experts provided evidence of construct validity in the patient cases and realism of the simulative teaching-learning environment of IPSims.

The usability of components of the simulations was studied within focus groups of Canadian health care providers. This research was part of a second grant funded by HealthForceOntario that supported a project for improving interprofessional care planning and delivery by health care providers in Southern Ontario, Canada. Components of the simulations were demonstrated in the situated context of how they might be used for interprofessional care education of health care providers. Project researchers recorded comments within a qualitative phenomenological approach. Information from these studies was passed to software architects as the simulations were built.

Phase 2.—Monitoring-Timing System

After three iterations of qualitative probes of usability and construct validity studies, a software architecture and engineering team created the third tier of the research platform. We integrated a set of algorithms that identified each place within the IPSims a student visited, and started a timer for that place. Consequently, we had place-time data that were extracted and saved to data arrays as a student navigated through IPSims and engaged in any or the "places" within the simulation, which were basically learning activities, learning resources, assessments, or feedback systems. This monitoring-timing set of algorithms was derived from a patent by Vargas Martin, Hung, and Tashiro, providing a systematic method for studying learning processes and outcomes of health care students and practicing professionals [19].

This set of algorithms was named PathFinder and was designed to expand our understanding of a student's navigational decisions and time spent in simulation compartments while they were immersed in the online learning environment. The coupling of the second tier knowledge management system of IPSims with the third tier monitoring-timing system provided an automated, systematic teaching-learning environment that could be monitored and timed a student's choices and engagements within the simulation, streaming data to a data warehouse to create a database of choices made by students and times of engagement with each choice. Such databases could then be called into data mining frameworks, e.g., to analyze possible associations with student learning outcomes. In particular, these types of data were tracks of students learning process and allowed us now study relationships between learning processes and learning outcomes indicative of misconceptions in knowledge or skills domains.

The model for this type of research platform evolved from analyses of earlier work on misconception development. These earlier studies led us to conclude that sequences of choices by students during learning and expression of skills based on learning were critically important to exploring the complex associations among decisions made while learning, learning outcomes, and expression of learning as conceptual and performance competencies. These earlier studies led to research focused on navigational pathways which we termed decisional sequelae. We believed the research literature supported the idea that decisional sequelae are the key traces of cognitive and behavioral choices leading to learning, including learning in ways that lead to the development of misconceptions.

The three tiers of the research platform provided us with the model system for studying health care students' development of misconceptions. This is possible due to the PathFinder tracking mechanism within IPSims of student navigational pathways or decisional sequelae. We feel these navigational patterns or choices are an expression of cognitive processes that lead to effective metacognitive pattern recognition that is imperative for knowledge transfer within the health care domain [1]. Student misconceptions can occur prior to engaging in the learning environment, while immersed in the learning environment, and after the student has completed the learning activities. Consequently, misconceptions can lead to erroneous concepts in conceptual and performance competencies [26]. We believe misconceptions are defined as a state of being unaware of cognitive and behavioural deficits. As previously stated, misconceptions developed by health care students can lead to negative patient outcomes and we felt strongly that there should be a sense of urgency and responsibility to implement research on the development of health care students' misconception development within teaching-learning environments like IPSims and other educational digital media learning environment.

Phase 3.—Testing in Health Sciences Courses

When the IPSims environment was completed, the patient simulations were introduced into courses within the Health Sciences Faculty of the University of Ontario Institute of Technology. Student usage patterns were evaluated by reviewing discussion board threaded comments as well as emails to the faculty member teaching the courses. While being principally a qualitative phenomenological study, the results indicated the simulations were easily accessible from the BlackBoard learning management system used for the courses and that the navigational schema and content were usable by diverse students. These students were part of the Bachelor of Applied Health Sciences program that provided a baccalaureate curriculum to practicing heath care providers who had been initially trained in two-year undergraduate college programs.

Phase 4.—Pre-processing Data for the Data Mining Analytical Tool

Although we could easily record decisional sequelae and time spent in any part of an educational environment, we still had to solve issues related to preparing the data for a database to apply data mining methods to our data from the IPSims. We simplify a bit here, but the basic model conceptualizes the learning environment as a multidimensional array of "places" in which a student can engage in learning activities, using learning resources, and take learning assessments that are coupled to diagnostic feedback arrays related to each assessment activity. Within the multidimensional array, navigation from a graphic user interface allows the student to "move" from place to place and in each place engage in some type of learning. The PathFinder engine follows students as they move from place to place and starts a time clock at the entry to each place. The clock is stopped when the student exits that place. Through time, PathFinder records the places visited, which becomes the decisional sequela for each student. That is, the decisional sequela is the sequence of places visited within the educational environment. With the clock function always coupled to the place, the decisional sequela of a place within the multidimensional educational environment has concomitant time spent in each place visited. These data are collected and stored in a database that captures multidimensional data arrays for each student that reflects that student's journey within an educational environment, such as IPSims. The data from the database is then configured, normalized, and transformed as necessary for the appropriate data mining methodology to which it has been coupled.

Consequently, we have been able to track the development of health science students' misconceptions by tracking their cognitive processes and behaviours within IPSims learning environment. With such data, we can ask fundamental questions related to misconception formation, such as, "What are the complex relationships between an individual students learning and skills outcomes and the processes they expressed while learning?" Such questions are suitable for analysis and interpretation by data mining techniques. In this current work, we look at Association Rule mining for our data analysis method. This choice is based on the types of data we have, the assumptions of the Association Rule model, and our need to delineate processes of cognitive processing and behaviours in the context of what students can demonstrate they have learned and how they transfer that knowledge.

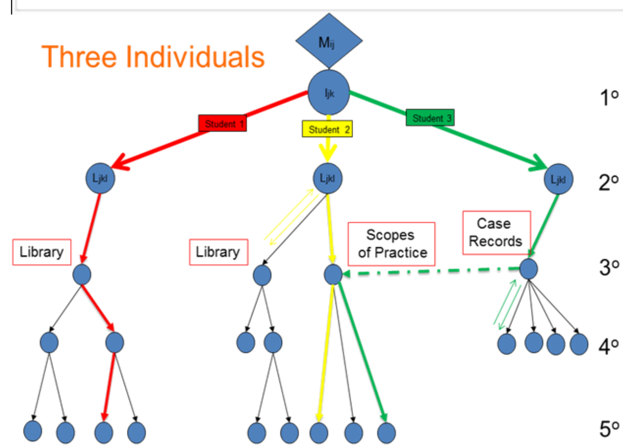
IV. RESULTS AND DISCUSSION

We have now completed the first major study using our research platform,, with the first tier allowing choices of cognitive and behavioral theories to express instructional design templates, with the second tier being a virtual world for active engagement by the student, and the third tier being the monitoring-timing system we call PathFinder. The research platform was used to conduct a study at the University of Ontario Institute of Technology (UOIT). In this paper, we have focused on the methodology for building knowledge management systems into research platforms to study misconception development.

The IPSims-PathFinder research platform was built by an interdisciplinary collaboration of researchers. The first tier emerged from researchers conducting studies of theories of cognition and behavior change that looked at how instructional templates could be generated from grounded theory. The second tier emerged from a research team who built simulations based on instructional templates. This team included content experts who assembled case studies of complex patients and the realistic scenarios in which such patients would be found within heath care settings. Additionally, this team included educational researcher who took these scenarios and mapped them to the instructional design template for a particular combination of theories of cognition and behavioral change. Such mapping was based on a target audience of undergraduate Health Sciences students who would need the kind of interprofessional training for which IPSims was being designed. Together, the content experts and educational researchers created a learning map for the simulations that delineated the places within the virtual world that patients would exist at each moment in time as their simulation unfolded. Within each place, educators and researchers selected a set of learning activities, learning resources, learning assessments, and diagnostic feedback for students for each learning assessment. The Learning Map was then provided to a software design-engineering team, which had the responsibility of translating the Learning Maps into the designs of each immersive learning experience in the IPSims teaching-learning-assessment system. The designs were translated into immersive environments so that each environment becomes a functioning portion of Flex-based IPSims simulations. The design was prototyped and passed through usability tests. An important intermediate step was creating a prototype that allowed iterative use case analyses. Finally, the software design-engineering team integrated the PathFinder monitoring-timing system.

In Figure 1, we show an interface from the IPSims system. Again, IPSims was developed as the prototype for an immersive experience in which undergraduate health sciences students could develop and demonstrate competencies in interprofessional planning and delivery of health care services. The IPSims system shown in Figure 1 allowed researchers to express every pathway that a student might take in an immersive environment. In the case of IPSims, there were three scenarios developed by clinical experts to portray different facets for the care of each patient, with six patients in total. Figure 1 shows a graphic user interface (GUI) for a simulation of an elderly male patient. On the Figure 1 GUI, you can see three buttons on a top navigational bar Scenario1-Scenario3, which allow a researcher to quickly shift scenarios. In this case of elder care, the GUI shows Scenario1 selected, in which we can explore possible interprofessional health team interactions in a hospital emergency room after the man fell and injured himself. Scenario 2 portrays the elder man's in his home and the interactions during a home health visit as a follow-up to hospital discharge. Scenario 3 portrays a meeting in the elder man's home involving him, his daughter, and a mental health team. The GUI also shows a top navigational bar for Library, Scopes of Practice, and IP Competencies. These are Learning Resources that would be available within the immersive environment for every scenario of every immersive environment for improving competencies related to elder care in this simulation.

The left-side navigation bar in the GUI of Figure 1 provides interactions specific to a particular scenario. So, when the Scenario1 button is clicked on the top navigation bar, data are loaded so that the left-hand navigational bar buttons access data relevant only to the emergency room visit that was conceived as the immersive environment of Scenario1. The IPSims environment allows for iterations of use case analyses to probe how and why a student might make choices within an immersive teaching-learning-assessment environment. One example of a use case iteration is provided below in Figure 1. The use case of Figure 3 unfolds in the following manner.



1. Three students enter the teaching-learning-assessment environment. They have been assigned to complete the same learning activity in Scenario 1. Each selects Scenario 1, and selects the Learning Activity button on the left side of the GUI.

2. The Learning Activity functionality opens an instruction page. A sample page is provided below, along with an interprofessional care core competency.

Scenario 1: Emergency Room

Competency 3.1.1 – Respects complementary nature of health team members' scopes of practice.

Learning Activity 1 — You are providing care for an elder man who has fallen in his home and has been transported to the Emergency Department. Your colleagues include an Emergency Department triage nurse and physician, as well as a Geriatric Emergency Management RN. All of you are working together in the Emergency Room to care for this elder man. What should your colleagues' roles be in providing care for this patient? How are these roles complementary? In what ways do these practitioners fulfill their designated roles and in what ways do they not work within their scopes of practice?

3. Each student begins to work on this Learning Activity, but imagine that each of the three students chose a different pathway through the simulation. You can see in Figure 1 that we show a representation of how the three students could have taken different pathways within the IPSims teaching-learning assessment environment.

Indeed, you can see in Figure 1 that Student1 went to the library to review articles on interprofessional care. Student2 also went to the Library but then came back to the Learning Activity, and finally decides to go to the Scopes of Practice resource. Student3 decided first to view the Case Records, but then went back to the Learning Activity and subsequently decided to examine the Scopes of Practice Resource, but went to a different area of that resource than Student2.

The key point of this methodology is that at each of the "places" visited by the student, PathFinder records the location and starts a clock. The clock times the student's presence within the location and when the student navigates out of the location, the time is recorded for that moment of the student's journey through the IPSims learning environment. Figure 1 shows the decisional sequela of each student, that is, the place to place journey within the IPSims environment, and along that decisional sequela is the time spent in each location of the journey. However, the usage of term location needs to be reined here. Some locations are just like a real hospital room in the sense that a student can engage in many interactions with a patient, equipment, electronic health records, and so on.

Figure 1 is a representation of three students' possible excursions into the IPSims learning environment. In this figure, the paths of three different students are described, showing the choices at each level of navigation (1^{st}, 2^{nd}, and so on).

In our usage of "location", we are evoking the multidimensional sense of the database structure mentioned earlier. That is, a student within IPSims can go to locations that are analogous to a room. Within that room, there are locations that allow access too many types of interactions, such as accessing and using as-needed teaching and learning resources. So, Student1 went to the library to review articles on interprofessional care. Student2 also went to the Library but returned to the Learning Activity location before navigating to the Scopes of Practice resource. In contrast, Student3 decided viewed the Case Records, next went back to the Learning Activity, then navigated Scopes of Practice resource, but went into a different area of that resource than Student2. The term "location" has a variety of different meaning. Some locations are analogous to a physical place (e.g., Library, Patient's Room for a Case Encounter, a Web-link resource within the Scopes of Practice functionality. Other locations are analogous to an activity, such as reading a paper in the Library, exploring a Web-site for Scopes of Practice of different types of clinicians, reading one of the different types of patient records within the Case Records functionality.

Consequently, we had to explore how the decisional sequela and time data for each student could be contextualized in semantic and workflow meaning. For example, if a student navigated to the Scopes of Practice location, they would find Web-links to over a hundred different types of health care providers and for each type of provider a description of their respective scope of practice. So PathFinder would record accessing the Scopes of Practice portal and start a clock. If the student accessed a Web-link that location would be recorded and another clock would start. This would be true for any Web-link accessed with the Scopes of Practice location, with each Web-link accessed becoming a new location with a new clock. These types of analyses of students' journeys and work convinced us that the locations within the teaching-learning-assessment environment could be conceptualized as locations within a cognitive process. So, the term "location" was not particularly problematic, despite its usual implication for physical space or something analogous to physical space.

We continued studying the methodology for building and using the IPSims-Pathfinder combined education and research system. Although the delineation of a user's decisional sequelae and associated time coding were robust, the research literature suggests there are other types of data that may be critical to understanding the complexities of cognitive processing and behavioural choices. Therefore, we began building into the IPSims environment a variety of data collection pathways that could complement the data representation of a student's journey through the learning environment of IPSims.

One of our studies built in a data collection process that would provide a student user profile. This profile was a set of variables, with variable values collected when a student entered the IPSims environment for the first time. These variables were taken from the research literature as possible covariates shaping learning processes. Our choice of variables included, age, gender, prior academic knowledge, perceived academic success, discipline major, academic class, and a cluster of variables assessing digital literacy.

A second study examined choices of variables that research literature suggests are important in shaping cognitive processes and behavioural choices. These included

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variable clusters for measuring disposition to engage in higher order reasoning, formal operational reasoning, and value placed on a learning experience, expectations for success in a learning experience, perceptions of and preferences for digital learning objects and online learning modalities, and perceptions of usability of learning objects and simulations with the different situated experiences of a virtual world.

These additional data are now being integrated into the database for automated data collection systems of the coupled IPSims-PathFinder teaching-learning-assessment system. The methodology described in this paper provides a means to study misconception development. We recently completed a study of 67 students in the Health Sciences Faculty of UOIT. A subsequent paper will describe the methodology in action and the detailed analysis of how misconceptions development can be studied and remedied.

V. Conclusions and Future Work

In conclusion, we have developed a methodology that allows us to study learning processes as a sequence of decisions an time spent within learning activities, learning resources, leaning outcomes assessments, and diagnostic feedback for any assessment item. Such activities, resources, and so on, are “places” within an educational environment. We have called these earning processes decisional sequelae in the context of how data related to the processes are collected and analyzed as decisions made by a student to engage and spend time at certain “places” within a learning environment. Importantly, such decisional sequelae now can provide an opportunity to study students’ development of misconceptions. In a subsequent paper we will provide the data analyses of the first set of student research subjects who were undergraduates in the Health Sciences Faculty at UOIT. This next paper will show the efficacy of the methodology for identifying learning processes as decisional sequelae that lead to misconception development.

However, our ongoing work using knowledge management systems to study misconceptions is part of a larger research program to build and evaluate an inclusive and adaptive teaching-learning-assessment-diagnostic system in which we can embed a diverse array of educational environments. Certainly, we believe in the importance of identifying decisions and patterns of learning engagement that lead to misconception development. Nevertheless, difficulties studying misconception development is only part of a larger set of barriers to transforming education into a more evidence-based praxis. Our ongoing research has become increasingly focused on creating human-computer interfaces that are truly inclusive in the way these interfaces engage learners, probe and adjust to their accessibility needs, and identify their preferences for learning. Our model of these interfaces will create a learner profile that can then be used to adapt a computer-based learning environment dynamically in order to meet the learning attributes of the respective learner’s profile. Knowledge management systems can be used to configure a teaching-learning-assessment-diagnostic educational environment based on the learner profile. The methodology for studying student outcomes, including misconception development, can then be integrated into this educational environment.

Furthermore, we already have developed meta-level knowledge management systems that can be used to select theories of cognition and behavioral change, along with their respective associated instructional design templates. These templates can be integrated with the inclusive-adaptive interface to allow instructors or researchers to select combinations of theories of cognition and behavior change. Consequently, a learner’s profile can then be mapped to instructional templates based on a particular combination of theories and the teaching-learning-assessment-diagnostic environment configured to be consistent with that theory combination. The result is a truly inclusive-adaptive educational environment based on grounded theory and nested within a research platform. Such research platforms will allow cross-theory studies that will advance our understanding of how to build evidence-based frameworks for educational methods and materials.

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