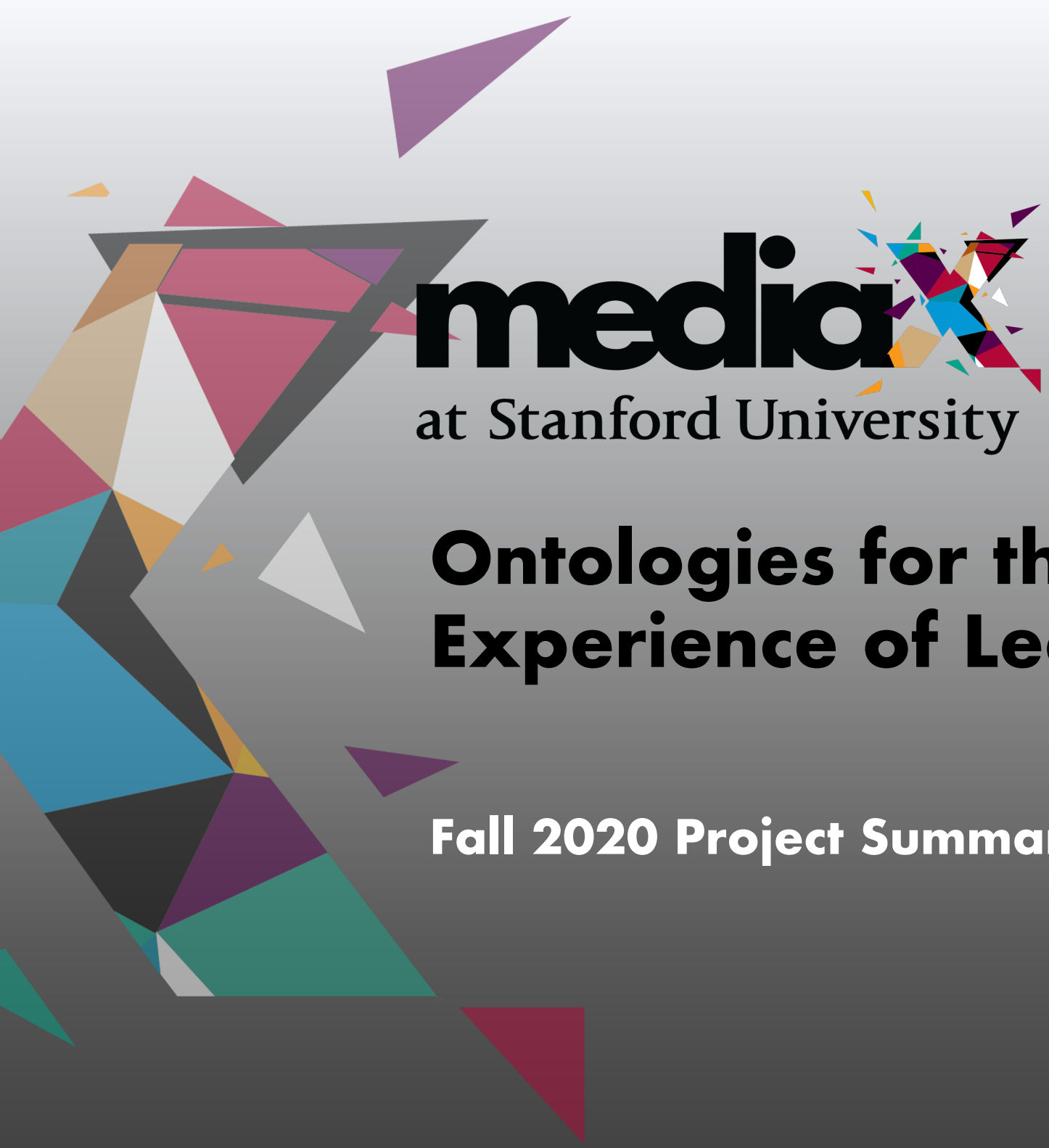

media X at Stanford University

Ontologies for the Human Experience of Learning

Fall 2020 Project Summaries

Background

Ontologies play an important role in enabling knowledge sharing within domains, and they can facilitate collaboration across domains. An ontology creates a formal framework that describes something by establishing the classes, relationships, and constraints that act on concepts and entities within a given system. An ontology is the system of classes and relationships that defines what exists and describes the structure of that data - the rules, if you will, that prescribe how a new category or entity is created, how attributes are defined, and how constraints are established.

Recognizing the complexity of these structures, mediaX invited Stanford thought leaders and research groups across all disciplines to develop projects that would establish an ontological model of human learning and education. Proposals were requested to establish or contribute to an ontological framework that would allow scholars and practitioners to go beyond sequence definition models for content mastery to guided flows for exploration and adaptive learning environments.

Three projects were selected to receive funding, with research beginning in September 2019.

Funded Projects

Creating an Ontology for Human Motion and Psychomotor Performance: A Look at Surgical Skill as a Use Case
Principal Investigator: Carla Pugh

An Ontology of Choice-Based Learning
Principal Investigator: Daniel L. Schwartz

Screenomics: A Venue for Developing an Ontology of Informal Learning through Everyday Digital Media
Principal Investigators: Thomas Robinson, Nilam Ram, Byron Reeves

Research Continues

University research enables the generation of new knowledge, advances in fundamental concepts, and the development of a network of questions and answers. Each research project, often as part of a larger research agenda, both builds upon previous research as well as forges new pathways for inquiry. As such, research is an ongoing process, with opportunities to learn from each step along the way. Like a stream, an explorer can dip his or her cup into this knowledge flow at varying points, learning something different at each stage of the research journey.

The three projects in this report have each made significant strides in their areas of investigation, resulting in the initial findings shared here. The research has also generated new questions, validated the need to refine tools and measurement capabilities, and ignited the researchers' desire to continue pursuits inspired by this Research Theme. While this report provides an endpoint for this specific round of funding, there are still significant opportunities for continued research; and we look forward to learning from the developments that grow out of each of these projects.

Project Overview

Creating an Ontology for Human Motion and Psychomotor Performance: A Look at Surgical Skill as a Use Case

Principal Investigator: Carla Pugh

The most common implementation and use of an ontology in surgery is the use of standardized checklists. When evaluating surgical performance and learning, checklists enable structured feedback and a standardized approach to communicating the most important learning points within a surgical procedure.

This project focused on the development of an ontology for a surgical training process and the exploration of machine learning to facilitate the development of that ontology.

The dataset used in this project was collected from 255 surgeons (practicing surgeons = 201, residents = 40, retired =14) at the American College of Surgeon's annual Clinical Congress in 2019. In this study, we focused on the breakdown of a simulated bowel repair to address 5 mastery areas and the use of Artificial Intelligence (AI) to facilitate this process. This resulted in the development of the first ontology for surgical bowel repair. The process for creating this ontology is extendable to other surgeries and to instructional activities.

What We Found

Creating an Ontology for Human Motion and Psychomotor Performance: A Look at Surgical Skill as a Use Case

Principal Investigator: Carla Pugh

We developed an ontology of the bowel repair through annotating videos and defining surgical actions and sub-actions. Two major phases have been defined: 1) Visualization and 2) Suture Repair.

In the 'Suture Repair' phase, two major approaches were defined: 1) 'Primary Repair' and 2) 'Resection & Re-anastomosis'. In the first approach, there are 2 methods: 1) 'Joining Injuries & Repair them Together' and 2) 'Repairing Injuries Individually'.

In the method, 'Joining Injuries & Repair them Together', the development of the logical actions of the participants we recorded were: suture type (Silk, Nylon, Prolene, PDS, Vicryl); stitch type (interrupted, running, or inverted); and repair direction (Horizontal, Longitudinal).

What We Found

Creating an Ontology for Human Motion and Psychomotor Performance: A Look at Surgical Skill as a Use Case

Principal Investigator: Carla Pugh

In the second method, 'Repairing Injuries Individually', there are two actions: 1) 'Repair Small Injury' and 2) 'Repair Large Injury'. Each of these repairs has 2 possible techniques: 1) 'Single Layer' and 2) 'Double Layer'.

In the breakdown of the visualization phase, it is observed that participants generally used three distinct inspection techniques to locate injuries: 1) Hands-Only, 2) Hand and Tool, 3) Tools Only. All three techniques are acceptable and there were no significant differences in the success rates between them.

In our ontology development process using AI, we implemented a state of the art object detection algorithm called 'You Only Look Once – Version 3'. This algorithm is capable of localizing and identifying objects (e.g., Hand, Tissue, Tool). The findings illustrated that hands-on visualization techniques can be identified automatically using Artificial Intelligence. AI helped to segment a large dataset into visualization components.

What We Found

Creating an Ontology for Human Motion and Psychomotor Performance: A Look at Surgical Skill as a Use Case

Principal Investigator: Carla Pugh

Summary

In summary, we have developed an ontology of a surgical process - bowel repair - using annotated videos of a recently collected dataset from surgeons performing operations in a controlled setting. Furthermore, we showed the capability of AI to facilitate further ontology development by reducing the amount of human work needed to annotate surgical actions. The developed ontology can have a huge impact on instruction and assessment in surgical education, and potentially in other highly-skilled tasks that require consideration and judgment.

Building A Trajectory

Creating an Ontology for Human Motion and Psychomotor Performance: A Look at Surgical Skill as a Use Case

Principal Investigator: Carla Pugh

We have developed a partnership with the American College of Surgeons to create a database of surgical performance metrics that can be used to further develop ontologies of human motion and psychomotor performance.

Together, with the ACS, the Technology Enabled Clinical Improvement (T.E.C.I.) Center has set out to create an anonymous, non-discoverable database of surgical skills (motion, EEG, video & audio) that can be used to answer the following questions: 1) What is the range of decisions surgeons make when faced with a surgical task? 2) How do their decisions and technical approaches affect outcome, such as bowel repair quality? 3) Can this database serve as a benchmarking resource for trainees? 4) Is there an expert strategy or evidence-based approach that can be discovered in the data and shared with participants? 5) Can this database serve as a platform to discuss the possibility of longitudinal, personal assessments in which participants track their performance throughout their careers?

People Behind The Project

Creating an Ontology for Human Motion and Psychomotor Performance: A Look at Surgical Skill as a Use Case

Principal Investigator: Carla Pugh

Carla Pugh, MD, PhD, FACS, Professor of Surgery at Stanford University School of Medicine and Director of the Technology Enabled Clinical Improvement (T.E.C.I.) Center

Hossein Mohamadipanah, PhD, Senior Research Engineer, (T.E.C.I.)

Brett Wise, Researcher, (T.E.C.I.)

Su Yang, Researcher, (T.E.C.I.)

Anna Witt, laboratory manager, (T.E.C.I.)

Cassidi Goll, Administrative Coordinator, (T.E.C.I.)

Project Overview

An Ontology of Choice-Based Learning

Principal Investigator: Daniel L. Schwartz

We proposed to instantiate a framework for a new form of learning ontology. The ontology is an outgrowth of work on choice-based assessments (Schwartz & Arena, 2013). Choice-based assessments were developed to capture the learning and motivation strategies that prepare people to continue learning on their own when they no longer have the strict guidance of a teacher. The ontology focuses on learning strategies rather than knowledge states. Each entry in the ontology describes a beneficial learning strategy, and importantly, the competing tendency that often pulls people away from the strategy. For instance, rather than having an ontological entry for "critical thinking," the entry might be "critical thinking versus deference to authority."

Success at observing student learning strategies requires closely observing how a student goes about learning, and it requires tasks that support student opportunities to apply strategies conducive to rule induction. It is much easier to observe whether a student is achieving a correct or incorrect answer than to observe the learning strategies.

What We Found

An Ontology of Choice-Based Learning

Principal Investigator: Daniel L. Schwartz

The coronavirus pandemic has highlighted the importance of independent learners to every parent who has a child learning at home instead of school. Independent learners can choose the right strategies for learning, and they do not need to be told everything they need to do. Notably, these learning strategies do not occur by themselves, but they are always in competition.

This project focused on inquiry strategies that one might use in a scientific investigation. Using a novel machine-learning algorithm, we were able to detect three dominant strategies – just try to guess the right answer, explore the phenomena haphazardly, or try to find out the equivalence between different units (e.g., 1 large character = 3 small characters). The use of various strategies correlated with learning from the simulation as well as students' standardized test scores. In a complementary line, we found that teachers have difficulty discerning this level of strategy use, which motivates the value of using choice-based assessments to reveal what is difficult to see with the naked eye.

What We Found

An Ontology of Choice-Based Learning

Principal Investigator: Daniel L. Schwartz

Most efforts to use AI in education rely on student accuracy to make inferences about students' knowledge states. There are a few examples that try to use process data (e.g., student moves while trying to figure something out). We developed a novel algorithm that combines both types of data, which led to the discovery of several previously undocumented, yet highly effective, inquiry strategies along with the alternatives strategies that often lure students away. (Topic A)

We explored two strategies for memorizing new words – restudy versus try to generate the word (e.g., house: domicile versus house: d_mic_le). Adult participants experienced both memorization strategies. We then gave feedback to half the participants about which strategy was more effective for them. We had assumed that students would use this performance feedback to change their strategy preferences in the direction of the feedback. Surprisingly, this was not the case.

What We Found

An Ontology of Choice-Based Learning

Principal Investigator: Daniel L. Schwartz

Instead, the most important variable is the cognitive experience of using the strategy. This might be called internal task feedback. The implication is that if you want to affect people's strategies, it is recommended to help them have a positive experience while using the strategy, not afterward. (Topic B)

Based on the discoveries above, we recruited several hundreds of students in Columbia, along with their teachers, and made an objective evaluation of the students' strategy use. We also asked the teachers to evaluate each child by saying which strategies the students are most likely to use. The results showed that teachers had a very difficult time assessing students' strategies and were far off the mark. This makes sense, as it is difficult for teachers to assess their students' process/choices for learning. It makes a clear case for the added-value of choice-based assessments. (Topic C)

What We Found

An Ontology of Choice-Based Learning

Principal Investigator: Daniel L. Schwartz

Summary

This project has identified potential taxonomies for the broad category of inquiry-based learning strategies, which might include:

**Inquiry-based problem-solving strategies: try-to-guess; explore; try-to-find-out*

**Strategy choice approaches*

**Memorization strategies*

**Evaluation techniques for strategy choice*

**Feedback source: internal, external*

**Feedback timing strategies*

**Cognitive strategies for using feedback*

Building A Trajectory

An Ontology of Choice-Based Learning

Principal Investigator: Daniel L. Schwartz

We continue to pursue (Topic A) with the development of a new assessment that attempts to measure similar strategies for inquiry.

We will also pursue (Topic C) by using the findings from (Topic B) to inform an intervention to help students change their strategies.

Finally, we are earnestly trying to make the assessments easily used by teachers. Currently, we have yet to further analyze the data. We plan to automate this so that teachers can run the choice-based assessments and get a quick dashboard of the results.

We are developing a way for teachers to use the choice-based assessments, and we are exploring how these assessments can be best used.

People Behind The Project

An Ontology of Choice-Based Learning

Principal Investigator: Daniel L. Schwartz

Daniel L. Schwartz, I. James Quillen Dean Stanford Graduate School of Education and Nomellini & Olivier Chair of Educational Technology

Rachel Wolf, PhD in Astrophysics and Researcher in the AAA Lab

Tanja Kaiser, Post-doc with a faculty position at EPFL Switzerland. She was responsible for (Topic A).

Katie Cheng, PhD Student about to defend dissertation based on (Topic B).

Ana Saavedra, PhD student, in the process of composing a dissertation proposal based on (Topic C).

Project Overview

Screenomics: A Venue for Developing an Ontology of Informal Learning through Everyday Digital Media

Principal Investigators: Thomas Robinson, Nilam Ram, Byron Reeves

We have developed an end-to-end system for capturing, transforming, storing, visualizing, and analyzing the full record of what individuals view and interact with on smartphone and laptop screens over time, second-by-second, week-by-week, month-by-month – the "screenome" (Reeves et al., 2019). By collecting screenshots every few seconds and sequencing those screenshots into a screenome, we obtained a new "microscope" for studying how, when, and for what purposes individuals use their phones and screens as they go through everyday life. We used the screenomics paradigm to develop an ontology for describing the full range of content, functions, contexts, and time-scales that manifest in individuals' digital lives (smartphone and laptop screens). We used individuals' screenomes, and the fine granularity and temporal resolution of data therein, to develop an ontology for describing individuals' digital lives. We used that ontology to describe the informal learning that occurs as individuals produce and consume information on smartphone and laptop screens.

What We Found

Screenomics: A Venue for Developing an Ontology of Informal Learning through Everyday Digital Media

Principal Investigators: Thomas Robinson, Nilam Ram, Byron Reeves

We completed Phase 1 in December 2019. To facilitate purposeful observation of individuals' screenshot sequences, we developed a variety of compelling visualizations that support display and description of the structure of the screenome and how that differs across persons and time. Versions of these accompanied our recent piece, "Time for the Human Screenome Project", that appeared in the Jan 16 issue of *Nature* (Reeves, Robinson, & Ram, 2020). In Phase 2 we developed, in consultation with colleagues in computer science, a new exploratory machine-learning approach that can both alleviate bottlenecks in labeling and makes efficient use of subject-matter expertise.

What We Found

Screenomics: A Venue for Developing an Ontology of Informal Learning through Everyday Digital Media
Principal Investigators: Thomas Robinson, Nilam Ram, Byron Reeves

In the first step, we use a variety of "off-the-shelf" image processing (Gabor filters) and pre-trained deep learning models (e.g., YOLO model trained on ImageNet) to extract a large number of low-level and high-level features that describe each screenshot image. These features are then used, in a second step, to identify clusters of similar screenshots that are presented to our subject matter experts for labeling. We tested and refined the prototype work-flow; and we will, when buildings can be accessed again, scale the process up to our larger (~10 million) screenshot repository. Moving on to Phase 3 of the project, we developed a new approach for identifying the typology of screen behaviors wherein co-occurrence methods adapted from ecology are used to identify specific screen behaviors that are performed together. Through this process, we were able to develop an initial typology of "user journeys".

What We Found

Screenomics: A Venue for Developing an Ontology of Informal Learning through Everyday Digital Media
Principal Investigators: Thomas Robinson, Nilam Ram, Byron Reeves

For example, the co-occurrence of gaming and YouTube is indicative of a "leveling up" behavior where an individual iteratively consults You-tube videos as they learn how to overcome hurdles faced in gameplay. Co-occurrence of Instagram, Snapchat, and a picture editor is indicative of a "social-media check-in" behavior where an individual iteratively learns about, tests and contributes to their social environment. While waiting for the opportunity to confirm the results (building access needed to review screenshot sequences per our privacy protocols), we are preparing a paper for publication.

What We Found

Screenomics: A Venue for Developing an Ontology of Informal Learning through Everyday Digital Media

Principal Investigators: Thomas Robinson, Nilam Ram, Byron Reeves

Summary

By utilizing the screenome concept, we were able to successfully track individual "user journeys" of adolescents as they moved through a variety of screens and media.

Overall, the project has successfully developed analytic tools needed to identify meaningful patterns in the newly available screenome data and used those tools and data to identify a new typology of screen behavior.

Given that learning is a continuous and contextual activity, this new typology of screen behavior can provide insights into the ways that informal learning occurs through everyday media consumption.

Building A Trajectory

Screenomics: A Venue for Developing an Ontology of Informal Learning through Everyday Digital Media
Principal Investigators: Thomas Robinson, Nilam Ram, Byron Reeves

After we can access screenshot images again (limited during the pandemic due to privacy safeguards) we plan to continue to build upon these methods and expand to data from additional participants.

The methods developed will be incorporated and be expanded upon in future projects. We are hoping to apply some of the methods developed during this mediaX award to new screenshots collected during the pandemic.

People Behind The Project

Screenomics: A Venue for Developing an Ontology of Informal Learning through Everyday Digital Media
Principal Investigators: Thomas Robinson, Nilam Ram, Byron Reeves

Thomas Robinson, MD, MPH, Irving Schulman, MD Endowed Professor in Child Health in the Departments of Pediatrics, Medicine and Health Research and Policy at Stanford University

Byron Reeves, PhD, Paul C. Edwards Professor of Communication and Education at Stanford University

Nilam Ram, PhD, Professor in the Departments of Communication and Psychology at Stanford University

Xiaoran Sun, PhD (postdoc), programming of analysis pipeline testing alternative approaches

mediaX Research Themes

mediaX Research Themes are Stanford open innovation initiatives that are inspired by mediaX corporate members. Awards are made as university seed grants from funds contributed as membership fees, based on proposal competitions, adjudicated by a faculty review committee. The primary objective of mediaX Research Themes is to spark Stanford interest and proof of concept for novel ideas.

Strategic membership in mediaX permits members to make input into the RFP, review the proposals, and have introductions to the PIs who receive awards. These grants are intended to catalyze novel concepts that may lead to new lines of research – and provide inspiration to the members of mediaX at Stanford University.

For further information about membership in mediaX, contact Elizabeth Wilsey, ewilsey@Stanford.edu

For further information about the projects in this Research Theme, Ontologies for the Human Experience of Learning," contact Martha Russell, martha.Russell@Stanford.edu

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