SUPPORTING POST-SECONDARY EDUCATIONAL DATA USAGE IN THE ASSESSMENT PROCESS WITH INFORMATION VISUALIZATION

by

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Abstract

Programs, institutions, and governments are increasingly looking at data about student learning for both accountability and program improvement activities. Faculties at post-secondary institutions have employed systems to gather vast amounts of assessment data in recent years with the ultimate goal of using the data to improve the student learning experience. Unfortunately, faculty members responsible for this data are unfamiliar with analyzing data sets of this magnitude or complexity and therefore cannot extract actionable insight from the data to inform their program improvement decisions. Approaches to support this process are still developing, referred to largely as Educational Data Mining. Information Visualization is one technique that has shown promise in facilitating the extraction of meaningful information, though there has been little research conducted into where and how visualizations are utilised at a post-secondary level. The ultimate goal of this research is to build a support that encourages the usage of educational data through visualizations. To build one that is effective, a research study was conducted to discover the factors surrounding how educational data was used in this setting.

The research was a three-phase qualitative study aimed at determining the attitudes around data usage as well as what aspects of assessment data usage are currently challenging education staff and faculty members in achieving their program improvement goals. The study included interviews, a focus group, and an open-response survey created using an emergent design methodology. Participants were from institutions in Canada, focused largely at Queen’s University. The outcome of the research findings was a model of four major stakeholders in the process of educational data usage and some of the important factors that surround the usage and the interaction between stakeholders. The resulting support tool built from this research aims to support those interactions and specifically identified challenges by bringing the principles from the broader field of information visualization into an accessible form for staff and faculty at post-secondary institutions trying to work with educational data.
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Glossary of Terms

**Educational Data:** Data that is created and collected by an educational institution, as primarily related to teaching practices. In this report, educational data refers to one of two types: assessment data or curriculum data.

**Assessment Data:** Data collected from assessments of student performance as well as demographic data about students.

**Curriculum Data:** Data created by departments and faculties at educational institutions that describe their programs. This could include how their program and courses are structured as well as how learning outcomes

**Program Improvement:** Describes the broad process of making decisions to improve an educational program. In this report, the term is used describe changes at the instructor, course, or department level.
Chapter 1

Introduction

Post-secondary faculties have employed systems to gather vast amounts of educational data in recent years with the ultimate goal of using the data to improve the student learning experience [1]. Pressures internally and externally are pushing departments and faculties to collect and analyze this data for program improvement and accountability reasons [2]. However, currently, using this data to guide program improvement decisions at any level is inhibited by a lack of familiarity among program coordinators and assessment practitioners to extract actionable information effectively [3].

While there are many techniques in development that are trying to solve this problem [4], Information Visualization is one that looks especially promising for its ability to “take advantage of the human eye’s broad bandwidth pathway into the mind to allow users to see, explore, and understand large amounts” of data [5, pp. 604]. Unlike other methods for data interpretation, information visualization does not require that the users have a background in statistics or be adept at a particular software to gain insights into their programs or classrooms. To be useful, however, the visualizations need to be purpose built for the field they are being applied toward [6]. In this case, that purpose is using educational data toward improving the student learning experience, both directly and indirectly.

Unfortunately, someone attempting to make visualizations for that purpose currently has no direction or supports as to how to go about that, and would have to synthesize knowledge from the wide field of visualization to design an effective analysis tool. There have been a number of efforts to create visualizations in the post-secondary field that have had successes [7]–[9], but they all target extremely specific research goals and cannot easily be generalized to other needs. What would be helpful for faculty members and support staff working in the assessment is a
support that can readily take advantage of the field of information visualization to help with the hurdles they are facing in their pursuit for data-driven improvement.

There are general principles and frameworks for representing and visualizing large datasets, including a need-driven workflow design [6], and Tufte’s principles for visualizing quantitative information [10], and even full textbooks in the area [11]. These stress clarity and utility and effective design to convey complex ideas and information in the least amount of time. Applying these principles to assessment data would streamline the decision making process and enhance the quality of data-driven program improvement.

The overall goal for the thesis presented here was to support the use of educational data for program improvement by helping educators handle large, complex sets of data. The aim of the thesis was to achieve this through a two-stage process: First, by conducting a qualitative study to find out what role educational data currently plays in the practice of university educators. The findings from this can facilitate the discovery of where visualizations could play a role in supporting that current practice. The second stage is then designing a visualization support tool that educators can use to overcome the discovered challenges with educational data.

The research questions that guided the qualitative portion of the thesis are as follows:

1. What are the most common motivations to use educational and learning outcomes data?
2. What kinds of data are currently available to and/or collected by faculties?
3. What barriers have been the biggest hindrance to an efficacious use of the data?
4. Are there supports that have helped in illuminating information from large sets of data?
5. What are the attitudes and beliefs from faculty surrounding data collection and usage?
6. What key characteristics of visualizations maximize the provided insight pertinent to each of the common motivations for data usage?

The qualitative study was divided into three phases. After conducting the literature review, as described in Chapter 2, the first phase was an exploratory phase that used long form
interviews to gain preliminary insight around the research questions. After an initial round of analysis, the second phase of the study used a focus group as a way to member check the findings from the interview data, focusing primarily on the third and fifth research questions. With a better understanding of the participant needs, an initial version of the support was designed, built, and tested with an open response survey. The details of the methods for all three phases can be found in Chapter 3. The result of the member-checked findings from the phases one and two can be found in Chapter 4, while Chapter 5 describes the creation and details of the final support. This document concludes with a discussion of the thesis’s limitations in Chapter 6, and conclusions and future work in Chapter 7.

Note, for certain chapters of this thesis, the report uses a first-person perspective in the writing. Findings from a qualitative approach are influenced heavily by the researcher’s own experience and biases. A first-person perspective was chosen for those sections to emphasize the researcher’s self in the analysis and moves further away from reporting the methodology or analysis as a purely objective endeavor. In these cases, “I” refers to myself, while mentions of “we” refer to refer to myself, my supervisor and other members of our engineering education team who were consulted during the study.
Chapter 2

Literature Review

Visualization of educational data for the purpose of program improvement is informed by literature in three key areas: institutional assessment, change management, and visualization. The three areas are reviewed here. Additionally, literature used to inform the design of the qualitative methodology are also discussed.

2.1 Assessment Data

The assessment data cycle is a process by which educational data gathered from student activities, department administration and educational design are used to inform improvement of the overall student learning experience. The assessment process is often described as a cycle that begins with setting goals for improvement, acquiring the appropriate data, interpreting that data, and using it to support decisions about program improvement, which then forms the basis for the next set of goals [12]. Each of these stages has their own set of challenges for which there are dedicated research fields. For example, the process of acquiring the appropriate data can be troubled when educators are not knowledgeable with measurement tools gathering the data, or are ‘assessment illiterate’ [13]. While assessment literacy is an area researched largely outside of the realm of higher education, there are those suggesting that promoting assessment literacy be a higher priority among higher education institutions [14]. This thesis however, focuses on the stage of interpreting data and the literature in this section detail the kinds of challenges that have been identified in the area of higher education.

Of particular importance in the assessment cycle is student learning outcomes assessment process which measures and assesses the degree to which students demonstrate learning outcomes on an assigned task. The outcomes-based assessment movement has slowly been adopted by
universities and colleges over the last few decades [2]. As we show here, a focus on outcomes-based assessment is seemingly widespread among institutions now but there are still some major roadblocks that are impeding this process from completing the cycle.

Banta and Blaich [3] identified a common weakness when commissioned by journal Change to do an article on assessment practices. They set out to find “examples of the ways in which the results of student learning outcomes assessments, particularly those derived from standardized tests, had been used to stimulate improvements in teaching, learning, and student services such as advising,” [3, pp. 22]. However, they found that out of 146 examples of good practice submitted by their peers from campuses across the United States, only 6% of the profiles contained any evidence that student learning had improved. They point the source of the problem to be that “Too few faculty are closing the loop—that is, studying assessment findings to see what improvements might be suggested and taking the appropriate steps to make them,” [3, pp. 22]. They suggest that a large step in overcoming this issue is focusing on faculty engagement. While assessment data is commonly disseminated through lectures and reports, Banta and Blaich argue that it needs to be more conversational; whereby assessment data is provided to faculty and then the faculty respond with possible reasons for the results and suggestions for improvement. The article is not a study based in empirical evidence, but an editorial with suggestions from experts in the field.

More evidence of a lack of ‘closing the loop’ can be found in data from national studies. The Center of Inquiry at Wabash College conducts the Wabash National Study, a longitudinal research and assessment project across 79 colleges and universities in the United States. During the analysis and dissemination of their work, Blaich and Wise [1] found some surprising results that did not originate from the assessment data collected, but rather from the data about the its collection and dissemination. In this supplementary paper, their findings suggest that “most institutions have routinized data collection, but they have little experience in reviewing and
making sense of data” [1, pp. 10]. The authors talk about how the governmental pressure for accountability has pushed institutions to create systems by which to acquire assessment data, a part of the assessment process at which the institutions now excel. However, when the authors provided the institutions with reports on actionable changes based on that assessment data, they were able to see through the report access data that the vast majority of these institutions did little to nothing with the information. The authors outline a number of ways that assessment programs could be modeled to nurture improvement. One of particular relevance is about the efficacy of prioritization efforts. They discuss that when assessment projects are “prioritized on one, two, or maybe three specific outcomes, institutions can sift through their typically vast piles of assessment evidence to focus on specific elements that relate to their chosen outcomes,” [1, pp.14]. This indicates that programs looking to make evidence-based improvements should create specific goals that they are looking to achieve from the assessment process. Through their findings, it is clear that educators looking to take advantage of the assessment process are in need of resources that help them make this data more actionable to their needs. We see that to achieve program improvement, there are additional processes that still need to be developed beyond simply collecting the data.

In a study at one university, Schoepp and Benson [15] conducted a meta-assessment on the university’s current assessment process. Their findings echo what is described by Blaich and Wise [1], that only a small amount of collected data results in action taken, and an even smaller amount leads to measured increase in student performance. Equally interesting however, is their survey of faculty perceptions of the assessment process. The survey results indicate that the faculty members are quite willing to participate in the assessment process and that they do believe there is value in it, but find that the current process is still very much in need of work. They do not see results of the assessment process communicated effectively and they responded that there is a lack of professional development around learning outcomes assessment. This illustrates that
the problem is not necessarily with a lack of willingness on the part of the faculty, but instead that the problem lies in a burdened process that fails to convert that willingness into engaged action. This study included just a subset of departments at a single university, but it does allude to some of the concerns one might find with faculty members elsewhere.

Overall, there are signs that there is an upward trend with regards to the adoption of learning outcomes and assessment processes. In a survey of 1,202 provosts of American colleges and universities 74% of the institutions reporting that they have adopted plans for student learning outcomes in 2009, which has risen to 84% in 2013 [16], [17] illustrating that there is at least a commitment towards the process at the administration level, whether or not it was driven by previous data. Particularly relevant from the survey results, nearly half the provosts responded ‘technology and analytics’ as an area considered a priority need for advancing assessment work. Among the priority needs, ‘technology and analytics’ ranked fifth of fifteen; with the highest priority, ‘more professional development’, at just over 60%. Specifically among for-profit institutions, ‘technology and analytics’ was tied for first. Technology and analytics being the area in which this research is situated, and this survey clearly shows that administration would like to see more support in the area to move their assessment practices forward.

In their politically minded review of the past three decades of the assessment field, McClellan [2] succinctly summarizes another troubling aspect with assessment initiatives: that there is an implicit paradox with the forces moving for its implementation:

“By providing information about what students are learning through the college experience, institutions are held accountable to the government, accreditors, and public for the results they achieve. The same evidence can help institutions, academic programs, faculty, and staff.” [2, pp. 88]

Unfortunately, these two purposes provide conflicting motivations about how to approach the interpretation of the data. The accountability side of the equation incentivizes institutions to
present only positive evidence, while program improvement requires a critical analysis of what is often not positive looking results. The result is that “complying with accreditor expectations is the most frequently cited use of assessment evidence.” Presenting assessment results in novel ways can assist in shifting the focus from an accountability mindset, towards one of improvement, where less than positive outcomes results are seen as areas for improvement rather than failures from the departments; moving the strategy “from compliance to ownership” [18].

In all of these papers, ‘use’ of assessment data is what they have found to be lacking in the assessment process. However, none define what actions on the part of the faculty constitutes usage. While it might seem obvious, it is important to clearly define what is being measured or otherwise fail to appreciate some of the more nuanced impacts of the process. With regards to assessment data, the transformative impact that having access to student learning evidence can have at varying time scales is often underappreciated. Jonson, Guetterman, and Thompson [12] suggest that closing the loop does not have to involve immediate change to curriculum or program, but that assessment data can have a more subtle influence on the process by which assessment is conducted and the assessment practices of a faculty. They propose a four-dimensional model of influence that captures the more nuanced elements of how assessment evidence can affect perceptions, processes, and communities of practice.

The authors recommend viewing the ‘use’ of assessment data instead as an influence, and they categorize it in three main dimensions: its source, its effects, and its results. The source of the influence could either be learning data or the assessment process. The effect could be instrumental in making a particular decision or instead simply affirm an existing understanding. The results of the influence could be an improvement in student learning, but it might also be a personal change among faculty members or help to build a community of practice around teaching and learning. Often, influence can be the identification of gaps in learning outcomes. Additionally, their model also acknowledges that this influence can occur over vastly different
time scales, from immediate and during the assessment process to well after an assessment cycle. They looked at 28 case studies of how assessment data was used at institutions, and under their model found that only 25% of the influence would be categorized as the more narrowly defined “use” of assessment data. The model provides an important lens with which to view assessment practice and the breadth of its influence is important to keep in mind so as not to inadvertently ignore some of the impact that disseminating assessment data can have. With regards to visualization, one might quickly disregard discovered information because there is no way for it to affect immediate change, but insight may be able to be provided on a longer scale. That said, Blaich and Wise [1] pointed out that of the institutions they worked with in the study, only 40% of them further disseminated the results to their faculty. Hence, there are still some more pressing issues to address first, no matter how ‘use’ is defined.

It is also important to mention where this research is situated in regards to the attitudes towards assessment, as there are still concerns that the student learning outcomes assessment process does not actually provide value or accurate accountability. In their commentary piece, Gilbert [19] describes their disbelief in the goals of assessment practice and even questions whether it has brought more harm than good. Given these opinions, the research was situated upon the foundational belief that assessment can have value, even if few institutions have made demonstrable improvements from it.

From these studies, it is evident among scholars in the assessment field that there are some key issues with how the assessment cycle is currently carried out at institutions. A lack of experience working with this kind of data, coupled with a desire for increased faculty engagement in the assessment process culminates in data being collected but not being applied toward the purposes of program improvement. A point of entry to begin bridging the gap is delivering supports to help faculty and their departments both make sense of and disseminate their data.
2.2 Change Management

Visualizations can only really be useful if there is some purpose for which it is being used towards. Change Management is the broad field of research that relates to supporting individuals and institutions in making organizational changes smoothly and successfully. In the scope of this thesis, this can largely be seen as program improvement. Also, this report uses the term program improvement to describe the change at the instructor, course, or department level. The field of change management has come up with many change strategies to follow based on the needs and goals of the group seeking change. Henderson, Beach and Finkelstien [20] looked at a large number of publications describing various change strategies in the STEM field and were able to come up with four change strategy categories along two axes. The two axes are ‘What is the primary system that the change seeks to directly impact’ which move from individuals to environments and structures; and the other axis is ‘To what extent the intended outcome is known in advance’, ranging from prescribed to emergent. Each category fills one quadrant of the two axes, as shown in Table 1. The categories are disseminating: curriculum and pedagogy (individual, prescribed); developing: reflective teachers (individual, emergent); enacting: policy (environment, prescribed); and developing: shared vision (environment, emergent).

Table 1 - Adapted table from [20] showing the four categories of change strategies. Highlighted are categories that we are situating our support initiatives in.

<table>
<thead>
<tr>
<th>What is the primary system that change seeks to directly impact?</th>
<th>Individual</th>
<th>Disseminating Curriculum &amp; Pedagogy</th>
<th>Developing Reflective Teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment &amp; Structures</td>
<td>Enacting Policy</td>
<td>Developing Shared Vision</td>
<td></td>
</tr>
<tr>
<td>Prescribed</td>
<td>Emergent</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To what extent the intended outcome is known in advance?
Borrego and Henderson [21] used these four categories as a basis to find eight exemplars of change strategies in higher education STEM programs, two from each category. The strategies were drawn from a wide range of applications with differing goals and functioned as a great guide to direct the selection of visualization approaches. For example, change strategies appropriate to environments and structures that use an emergent approach involve developing shared vision, which would suggest a visualization design that can quickly and easily be interpreted by diverse set of users, rather than a more complex visualization design that could provide richer details at the expense of the user's time investment. Considering the four change categories, the project’s goal is to provide support largely in the emergent side of the framework, highlighted in Table 1. While visualizations can be very helpful in communicating previously known information to stakeholders for which the prescribed change is intended, the initial impetus and focus of the project was to support promote educators improving their own practice by making better sense of the educational data they currently have available.

Kezar proposes another approach to view the change model [22]. In their review of change literature, they argue that planned changes and events are not enough to create lasting change in higher education. Instead, the review uses a social network analysis view to point out how it is the interactions of participants in a social system that move communities to change. These social structures include more than just the organizational structures in higher education. These networks of participants might get ignored, but are often more important in describing the change mechanism than mandated policies. As such, to understand the barriers for change in current assessment practices, it is important to analyze how participants in the change process interact to push change and not just look at the policies they follow.

2.3 Information Visualisation Principles

While modern computing has revolutionized the field of information visualization, it has a long and rich history as a research field and predates many of the other popular data mining
techniques. As such, theory in the field of information visualization has been in development for much longer. Core principles and tenants of how to effectively visualize data have been written and studied about extensively. The economist William Playfair was one of the first to actively work in the field and published his work even as far back as the eighteenth century [23].

In the time since there have been sporadic additions to the field, with the bulk of the seminal work happening in the past few decades which are discussed here. In roughly chronological order, Bertin [24] proposed three main aims behind how one chooses to represent data, moving from high to low-level acts of graphical interpretation. Each aim provided a guide as to which data and how much data can be presented effectively at once. Briefly, the highest aim is concerned with making sure details are visually discriminate, while the second aim is to make sure comparisons of magnitude can be satisfactorily judged, and finally the lowest aim relates to judging value and how well a visual variable’s value can be accurately judged. Tufte [10] discusses the key aspects that one must worry about to promote “graphical excellence”. While some of what is discussed is less relevant with the advent of digital, interactive screens (for example, using ink as a measure of visualized data), there are large principles outlined that still very much hold today. Simple guidelines and techniques are outlined of how to send a clear story to the reader, reducing clutter while also maximizing the information provided. Following the guidelines when creating visualizations lets the user perceive the information provided the visualizations quicker and with more ease. MacKinlay [25] ran empirical studies on Bertin’s lowest aim of judging value when interpreting a visualization. From the studies, MacKinlay provided rankings on the effectiveness to judge values when different visual variables are used based on the kind of data being visualized; showing for example, that values shown with ‘position’ can be perceived much more accurately when visualizing categorical data than ‘shape’. MacKinlay did this for over a dozen different visual variables over the different kinds of data that can be visualized. Additionally, Plaisant [26] outlines tests to measure these technical aspects of a
visualization. The steps to administer these tests on visualization users are outlined in a procedural way and provide an avenue to measure and then maximize a visualization’s utility towards its intended task. There is a lot of foundational work with which to build visualizations to ensure maximum usability and usefulness.

More recently, with the advent of technology and the ability to create visualizations more readily there has been additions to the literature to ease the process of creating novel visualizations. For example, Börner and Polley [6] operationalized the process of visualization creation in their version of a workflow to build a workflow for almost any scenario, starting with the stakeholder needs and making decisions based on the type of data (ie. categorical, ordinal, numerical) and the kind of relationship being visualized (when, what, where, with whom). While they use their process to create visualizations for a variety of applications in a variety of fields, the one workflow details the ways in which to think about building a visualization for your needs. Schneiderman [27] has created another workflow that has its basis in interactivity, an aspect of visualizations that was not an option prior the digital age. The design philosophy relies heavily on the visual information seeking mantra, which boils down to three statements: overview first, zoom and filter, and details-on-demand. Schneiderman provides a taxonomy that helps with how to handle different types of data. Following the mantra allows for visualizations that can illustrate large trends while not losing the ability to drill-down into the original data. Both of these workflows are very useful for reference since the eventual goal of this research is to build some kind of support that will work as a workflow to move from data to visualization to insight. While the deliverables of this thesis will not be quite as general as either of these resources, the deliverables will probably borrow a few aspects.

Of the more recent attempts to provide guidance to information visualization, by far the most comprehensive was Visualization Analysis and Design by Munzner [11]. Much like Börner and Polley, Munzner provides a workflow for how to design a visualization depending on the
type of data available and the task at hand. However, while Börner and Polley structure their book around the specific visualization tool that they prefer to use, Munzner’s approach works regardless of tool and any limitations or structure that a tool would impose. The result is much broader in scope of the kinds of visualizations that are output from the workflow. The book is sectioned by the variety of design choices that one can make with a visualization.

Munzner’s workflow is divided into three large steps, labelled ‘What’, ‘Why’, and ‘How’. The first two are abstraction steps that categorize domain specific data and tasks, respectively, into common, abstracted ideas that can be much more easily designed for. The ‘What’ step looks at the data being visualized and categorizes the data by type like Börner and Polley (categorical, ordinal, quantitative) and also the data set by its type (tabular, network, spatial, etc.) and availability. The ‘Why’ step is largely independent and provides a similar set of categories to abstract the task you are hoping to achieve with the visualization. Once abstracted, these choices provide an easier way to make design decisions.

Munzner uses the term ‘idiom’ to refer to a specific set of visualization design choices for a given data set and task. Making these design choices for a given idiom is the ‘How’ step and is where Munzner spends the bulk of the book. For each design choice, Munzner provides alternatives and any extra ideas to keep in mind when making those decisions. A particularly useful aspect of Munzner’s work is how comprehensive it is in covering the field of information visualization. Much of the novel work in the book is the synthesis of literature from the other seminal work in the field. For each of the design choices that Munzner describes, the book cites larger empirical research or design principles behind them. Almost all the authors mentioned in this review find a place in the book. For instance, when discussing how to choose how to visualize a specific data point, they point to McKinlay’s work and the reasoning behind it. This comprehensiveness works to build confidence in Munzner’s recommendations as they are based in well reviewed literature.
One shortfall of the book is that it does not explicitly connect the results of the ‘What’ and ‘Why’ steps to the ‘How’ stage, though the connections can be inferred during application. Overall, the book provides a thorough dissection of the aspects to consider when approaching the information visualization field and was a crucial component to how I approached the end results of the research. More details on how I used the book can be found in Chapter 5.

There are many libraries and taxonomies that allow a user to browse various visualizations in a user-friendly manner and read descriptions for where they can be used. However, while most describe where a visualization might be useful they generally do not guide a user to a visualization if they have a task in mind. They also tend to use language that might not be familiar to those not already in the field of data statistics. These are often generic visualizations that are designed to be independent of domain. While there is often a reason why specific visualization idioms have become prolific, these libraries cannot provide guidance on where more custom visualizations can be more appropriate for a given task. Part of this study’s goal is to fill that gap in the domain of higher education by providing guidance in terms that are familiar to educators to visualizations that may or may not be exclusive to this domain. We provide a list of these visualization libraries with short description as to their intended use in Appendix E.

Clearly, visualisation of assessment data can be a valuable tool to highlight useful information and support decision making among faculty and course administrators. Of particular note is how in all the examples, the visualizations provide an avenue to the data that does not require intricate experience of data manipulation to be able to extract insight from the data. However, there is a dearth of resources for faculties to use to inform them about how best to take advantage of these techniques as they apply to assessment data. When the goals of a faculty do not fall under one of the available tools”, they are left to come up with their own methods to extract the information specific to those desired goals. Thankfully there are plenty of resources
available in the field of information visualization with which to build a more all-encompassing framework. With it, hopefully faculty members can better use the available data for the purposes of program improvement.

2.4 Information Visualisation in Education

Educational Data Mining (EDM) is the larger field that educational information visualization fits into. It is an emerging research area focusing on the development of methods of information extraction from large sets of education data. The general goal of this extraction is to resolve educational research issues, examples of which include measuring a program’s constructive alignment or identifying barriers for student achievement. New techniques and collection methods are providing a large number of stakeholders, from instructors to institution-wide units, access to substantive bodies of rich data that may open up entirely new avenues for evidence-driven improvement, through the insights that in the past were otherwise inaccessible.

In their exhaustive survey of 304 publications in current EDM techniques, Romero and Ventura [5] highlight Information Visualisation as a useful way to help people understand and analyze data, by means of graphical techniques. In their words, it takes advantage “of the human eye’s broad bandwidth pathway into the mind to allow users to see, explore, and understand large amounts of information at once,” [5, pp. 604]. While most other data mining techniques require that the user have a background in statistics and a familiarity with the software, information visualization bridges that gap by instead relying on the user’s own expertise in their respective research field; education in this case. The authors present 18 studies that have had success with visualisation to present their educational data. The bulk of the studies however, do not focus on the visualisations themselves, but merely use them as a means of presenting their own research findings in a way that most clearly illustrates their research goals. Here however, I am looking at publications primarily focused on visualizations in education, rather than the larger body of work that utilized one or more visualizations as part of their larger research interests. This particular
selection of papers provides insights into visualizations that are larger in scope than any particular educational research’s specific data-mining goals.

Of note is that the majority of these visualizations focus largely on data acquired from students through means of technology. This kind of data can include assessment data such as quiz and assignment scores, but also interactional data such as click-streams and forum posts found from learning management systems (LMS) like Moodle and Brightspace by Desire2Learn. By contrast, few focus on data created and collected outside of the technology like curriculum data including learning outcomes or course maps.

In one study, three novel visualisations were proposed as a way of externalizing group activity and interaction [28]. The study tested the usefulness of the visualisations by using them on data acquired from a semester long group project. Through the project, the students had to use certain tools, and the log data that was produced was used as the data for the test visualisations. From these visualizations, the authors were able to gain insight into a number of group dynamics. One example was the ability of a team leader: “The Interaction Network [one of the visualisations] clearly distinguished successful leaders because it showed that they interacted with all group members. For less successful groups, there are clear indications of problems: for example, a nominal group leader had absolutely no interactions with anyone on any medium,” [28, pp. 204].

These judgements were validated by using reflective statements from the groups which found that many of the insights gained from the visualisations could be corroborated by group experiences. Without a visualisation, this kind of log data would be extremely difficult to perceive. It would require knowing exactly what question needed to be answered, and extracting information only pertaining to that answer. With the visualisation however, through just one snapshot, people inside and outside the group are able to determine if a team is functioning in an
effective manner. Mirroring this information either back to the team or a supervisor would allow them to take action accordingly.

In another example of effective uses of education visualizations, Vaitsis, Nilsson, and Nary [29] visualized the teaching methods of a course in a medical school program by mapping them to the course’s expected learning outcomes. They used a subset of information visualisation called Visual Analytics, that combines the visualisations with quantitative data analysis to give more detailed summary of the data. The authors created a visualisation that used student data from a particular exam in conjunction with their learning outcomes plan to give a more granular picture of which learning outcomes for the course were and were not being achieved. It let them identify gaps in the course’s current curriculum, where expected learning outcomes were not being adequately taught. The authors also mention that there is little previous work in the field of visualizing curriculum based data: “there are no scientifically-validated [Visual Analytics] techniques or reported appropriate tools for the analysis and visualization and representation of curriculum data.” [29, pp. 10]. This was consistent with the results of this literature search in the area.

Other notable examples of information visualization tools that are available include VisMod [30], [31], InVis [7], SNAPP [32], and Gismo [8]. ViSMo (Visualization of Bayesian Student Model) is a tool that externalizes the internal student model of an intelligent tutoring system in the form of an interactive visualization. This model is what the system builds based on a student’s prior performance. The papers [30], [31] suggest that by letting students understand, explore, inspect, and modify their Bayesian models, it empowers them to take more control of their learning. Additionally, teachers can compare student models to see where students are struggling and excelling. InVis is a tool for exploring student-interaction networks, providing interactive visualizations that show how students are interacting with an advanced intelligent tutoring system. When the students are given a sequential set of problems, the tool allows
instructors to gain insights as to what the pathways are that students take to a correct or incorrect solution. SNAPP uses data from online discussion forums to provide instructors with real-time interaction patterns between students, which can be used to evaluate the impact of an intervention on student engagement. CourseVis [33], [34], whose second iteration, GISMO is an implementation of a visualization strategy for LMSs created to increase retention rates of distance courses. They create visualizations from log data to provide insight as to how and when resources on the LMS are being accessed, while comparing it to student scores. This allows instructors to quickly see which students are engaged with the course, and plan interventions accordingly. Instructors also gain insight as to which resources on the LMS are popular among students as well as which ones have an effect on student achievement.

The teams behind CourseVis, InVis, and ViSMoD used similar techniques to evaluate their visualization. With CourseVis, the team conducted a study with 6 participants, giving them the tool with data from a mock course [34]. The InVis team performed a similar study, providing 15 participants with mock visualizations and asking them to answer a set of questions which asked them discern certain details of the visualizations [7]. Both studies [30], [31] included a qualitative portion that let the users provide more open feedback. The ViSMoD team used this approach as well and asked 15 students to try interacting with their visualizations, change the settings, and provide feedback about what they thought worked best [31]. All studies used the feedback to iterate the designs of their visualization tools to make them more readable and user-friendly.

While these three tools do provide possibly useful information, all had a very specific goal in mind and would only work on data from a single source. There is still untapped potential about how data from these separate sources could be used together.

A more in depth look at the other tools in the field can be found from our review of the tools in the area [35].
2.5 Qualitative Literature

This study seeks to identify the current practices, challenges and supports for interpreting data by interviewing assessment practitioners in faculty and staff roles in the effort of creating a support to benefit their practice. Since these practitioners will be the end users of such a support, it is critical to include them in the planning and design stages in a way that maximizes the support’s usefulness. There is currently little foundational research in this area; as such, the study would need to be responsive enough to refocus on the major assessment challenges as this data presents itself.

With the current literature in the area, it is clear that there are areas in which educators could use support around assessment data usage. Broadly, administration and faculty would like to see their assessment data play a larger part in their educational practice, partly through increasing faculty engagement and also having better tools with which to interpret that data. Information visualization is a promising avenue that seems like it could provide some support but there is a lack of clear direction as to where in the assessment process it would be most beneficial or what an effective support would look like. Hence, a qualitative research methodology was determined to be best path to creating a visualization support that would best suit the needs of its intended users.

McMillan & Schumacher state that the purpose of qualitative research is to understand a social situation from participants’ perspectives [36]. They posit that there are nine key characteristics of qualitative research, of which two are emergent design and inductive data analysis. The former stems from the idea that the researcher does “not know enough to begin the study with a precise research design,” [36, pp. 323]. Emergent designs therefore need to evolve during the study, with a full account of methods done retrospectively. Inductive Data Analysis dictates how qualitative studies build theory from the “ground up,” not relying on proving a prior hypothesis but instead using inductive reasoning to generate generalizations only after the data is
gathered. Doing so allows the findings “to be open to new ways of understanding,” [36, pp. 323]. While all nine characteristics have some degree of relevance to the study’s purpose, these two are of particular importance considering the exploratory nature of the research and will heavily dictate how the study is designed and conducted.

As McCracken describes in his book The Long Interview, the long-form interview gives the researcher “access to individuals without violating their privacy or testing their patience. [This access] allows [the researcher] to capture the data needed for penetrating qualitative analysis without participant observation, unobtrusive observation, or prolonged contact.” [12, pp. 11] Assessment processes can be long and finding data through other research strategies such as observation would require much larger time scales and would be much more logistically complicated. Additionally, interviews bring forward the attitudes and beliefs that underpin practice that would otherwise be hidden to an observer.

In the book, McCracken outlines the process and best practices for how to conduct design and conduct long-form interviews. Along with principles for researchers to keep in mind, McCracken breaks down the data-gathering and analysis process into four major sequential steps: a Review of Analytical Categories, a Review of Cultural Categories, a Discover of Cultural Categories and finally the Discovery of Analytical Categories. The first two deal with immersing the researcher within the field of study. The Review of Analytical Categories is an exhaustive literature review of the academic area that lets the researcher create assumptions that they can be surprised by through the process. Acquired data that are counterexpectational “are conspicuous, readable, and highly provocative data”. [12, pp. 31] McCracken notes these data are especially relevant since they are the origins for intellectual innovation. This step also provides a guide for how to organize the questionnaire. The Review of Cultural Categories is a process of getting acquainted with all the material relevant to participant pool around the area of study. The goal
being to give “an extraordinarily intimate acquaintance with the object of study.” [12, pp. 32] In
the case of this study, that object would be the assessment data process.

The *Discovery of Cultural Categories* is split into two sections, the process of creating
the questionnaire followed by the process of running the interviews. The discussion of the former
dictates how questions should be posed and written. Specifically, respondents should be allowed
to tell their own story and in their own terms. They should be prompted with Grand Tour
questions to describe their practice with their own key terms, which should then be subsequently
used to elicit further responses. Additionally, there should also be planned prompt questions that
address gaps in the literature that have not been discussed. Even here, the participant’s own terms
should be used unless necessary. With regards to conducting interviews, McCracken provides tips
about common pitfalls to watch out for and how to prompt further responses. Most notably,
McCracken suggests ‘playing dumb’ with the participant. By asking the participant about ideas
the researcher might already be aware of, the participant explains their own understanding of
what might have been assumed common knowledge but where there are inconsistencies.

Finally, the *Discovery of Analytical Categories* is the process for analysis of the collected
interview data. McCracken’s description for the process was somewhat broad and simplistic for
the scope of the study. Instead, the Grounded Theory methodology was used as the conceptual
framework to help guide the analysis. Specifically, Charmaz’s take on grounded theory was used
as the basis for analysis, as detailed in the book *Constructing Grounded Theory: A Practical
Guide Through Qualitative Analysis* [38]. Charmaz’s take on grounded theory is an abductive
approach that stays close to the data throughout the analysis process. This contrasts with other
forms of grounded theory which take an inductive approach, which moves further and further
away from the original data as the analysis proceeds. In these other approaches, data are
summarized into codes that then become the primary source of analysis. The original data is not
looked at again in later stages. These other approaches tend to work better when all the
information you are looking for will be found within the data. However, the abductive approach allows the researcher to constantly go back to the data and re-contextualize previously analyzed data when new information or material arises.

In the book, Charmaz details the procedure for how to move interview data towards a framework through three steps: Initial Coding, Focused Coding, and Theoretical Coding. The first step involves working through the data and finding the actions present in the data and coding them with words that describe that action. Charmaz recommends using gerunds, as in action words often ending with ‘-ing’, for these codes. These codes should be based in the data, and without applying pre-existing categories learned from the literature. Charmaz provides details and various options on how to discretize the data into individual datum that can be coded. The outcomes of the initial coding should be that the researcher gain a strong analytical direction of the data. Following this step is the focus coding stage, where the most prevalent initial codes are used to focus the other codes and synthesize the data. This is not a linear process and might require the researcher to previously analyzed areas based on later understanding. From this process we end up with focused codes, each as a camp of codes from the initial coding step. In the last step, theoretical coding specifies possible relationships between categories that have been developed among the focused codes. Charmaz describes a number of previously created ‘coding families’ for possible descriptors of the relationships between the focused codes. However, this step might not capture all of your data. As Charmaz indicates, “When your analysis indicates, use theoretical codes to help you clarify and sharpen your analysis but avoid imposing a forced framework on it with them.” [13, pp. 66] Additionally, Charmaz provides a list of problems that commonly occur during the coding process that a researcher would want to avoid. Among them are coding at too general a level, coding out of context, identifying topics instead of actions and using coding to summarize rather than analyze.
Further details about how the qualitative methodology was applied to the study can be found in Chapter 3.

In summary, it should be evident from the literature shown here that there are issues with the current assessment processes, and that information visualization is a possible support. In particular, faculty members need to engage with the process and more and collectively identify key goals that they want to achieve through the process. There are several visualizations tools for various educational purposes, yet they largely focus on data acquired from technological sources and are very specific to particular needs. Someone looking to utilize visualizations for any other purpose needs to start from scratch. This wealth of information provides the foundation that the framework and support tool can be built upon. Additionally, with McCracken’s and Charmaz’s guides on how to create, conduct, and analyze interviews, they can be built directly from participant responses.
Chapter 3

Methodology and Methods

The thesis started with two primary goals; (1) the development of a framework to describe the interplay between educational data usage and information visualization in a higher education setting, and (2) building an easily available support using the framework that will support the visualization of educational data for a range of stakeholders. The goal of the framework shifted along the way to a conceptual model, but being that the framework was the goal with which the study began, influenced many of the methodological decisions. Further details about this shift are described later in this chapter. To achieve these, a qualitative methodology was designed to develop the framework, primarily with faculty and support staff at universities involved with teaching and learning, specifically around assessment data gathering, analysis, and support. The methods and methodology were built largely using McCracken’s The Long Interview [37] and Charmaz’s approach to Grounded Theory [38], designed as three phases. Briefly, the phases were: an exploratory interview phase where I tried to identify the major concepts from which the model would be built; a framework phase in which I hoped to build a framework and used member checking in a focus group setting to solidify it; and finally, an evaluative phase in which feedback elicited from prospective end-users about the support tool through the form of an open-response survey. In this section, I will be discussing an explanation and justification for the methods I have chosen. Since the study used an emergent design approach, where the methods for subsequent phases were designed based on analysis up to that point, this section discusses the methodology, methods, and parts of the findings from each phase, in chronological order. As will be discussed, the resulting end products was not a framework but a conceptual model of the users, their practices and underlying beliefs, found in Chapter 4, which was used to develop the support tool described in Chapter 5.
3.1 Phase 1: Exploratory Phase

The purpose of this phase was to identify the major concepts that would be the foundation for the framework. From the literature search, I determined the three major areas the research sits in, and therefore needed to be explored were: the kinds of assessment and other educational data currently available or desired; the ways in which data is being currently used or would like to be used; and how visualization of data factors into that usage. Given that these were the areas that I wanted to explore, I came up with more specific research questions of what I wanted answered. The final version of these questions was:

1. What are the most common motivations to use educational and learning outcomes data?
2. What kinds of data are currently available to and/or collected by faculties?
3. What barriers have been the biggest hindrance to an efficacious use of the data?
4. Are there supports that have helped in illuminating information from large sets of data?
5. What are the attitudes and beliefs from faculty surrounding data collection and usage?
6. What key characteristics of visualizations maximize the provided insight pertinent to each of the common motivations for data usage?

The intention was to not only survey what kinds of data were being used and where, but also to allow participants to articulate their own concerns, plans for change and reflect on the value of the changes actually achieved. This was why I chose the long-form interview format as the main source of data collection in the exploratory phase.

3.1.1 Interview Construction, Sampling, and Execution

The construction of the interview protocol and analysis of responses was guided by two main resources: McCracken’s guide to long qualitative interviews from The Long Interview [37] and Charmaz’s guide to grounded theory in Constructing Grounded Theory [38]. Information from both were used to guide the practice and methods of qualitative data gathering and analysis.
The initial steps for the research were guided by *The Long Interview*. For the *Review of Analytical Categories*, I familiarized myself with the academic literature in the areas of assessment usage, visualization, and change management as detailed in Chapter 2. In the *Review of Cultural Categories* was a procedure of familiarization with current assessment regulations and initiatives in the primary location of study, Ontario, and at the primary institution of study, Queen’s University.

As part of McCracken’s *Discovery of Cultural Categories*, I designed the interview protocol. Using the guidelines and strategies provided by the book, the six exploration research questions were expanded into questions that elicited experiences from participants of data usage followed by follow-ups to expand on their attitudes and beliefs surrounding that usage. Additionally, the pool of participants was expected to include many different roles with differing depth of knowledge in any of the areas of the assessment process, program improvement, or visualization. Careful consideration was therefore put into the vocabulary and order of questions to avoid leading the participants and ensure participant and interviewer had a shared understanding of the terminology being discussed. The participants could use their own terminology which would be used for the remainder of the interview.

For example, the original wording of the first research questions was “What are the most common program improvement goals that have prompted data use?” was turned into two questions: “Are you involved in the management or interpretation of data?” and “In working with this data, do you use them to inform decisions to improve learning?” In between the questions, they were asked about what data they use, which had to purpose to answer the second research question. I chose not to use the phrase ‘program improvement goals’ because while I used it internally to mean a wide range of motivations, it might have narrowed the scope of the participant’s response. I reworded the research questions after a few interviews to better reflect participant perceptions. The full interview protocol can be found in Appendix B.
The questionnaire also used three elicitation tools, specifically to answer research questions 2 and 6, found in Appendix B. The first two take the form of surveys conducted during the interview that participants were asked to talk through, while the third was a mock-up that participants were asked to comment on. With regards to data usage, participants were provided with a list of data sources and were asked to discuss any ways those sources might relate to their practice. For questions related to visualizations, they were provided with unlabeled visualization mock-ups and asked to discuss their encounters with them. Finally, they were asked to provide feedback on an early mock-up of what our then current concept of what framework might look like. While these elicitation tools aimed to survey participants about how they conduct their practice, the tools’ purpose was equally to elicit participant attitudes. While completing the survey, participants were asked to describe their experiences corresponding to their survey responses. Through this, participants could share insights into concerns and beliefs that either they or their colleagues had around data usage, visualizations, and the practice of teaching and learning. This latter purpose of the tools would lead to much of the emergent and unexpected themes of the study.

The questionnaire was piloted with colleagues working in engineering education before being used with real participants. Changes from this largely involved rephrasing and reordering questions in such a way that participants could reflect on their experiences first so it might provide better responses about their practice. Once revised, I applied for and received ethics approval from the university ethics board. The application and approval were structured in such a way that initial consent from participant allows audio of them to be recorded for the first and second phases of the study. The final phase of the study was still in development at the time, and was added to the application as an amendment when ready. The letter for approval is included as Appendix A. Once approved, possible participants were contacted.
With regards to the participant pool, I narrowed the scope of the study to look at responses from two main roles: educational support staff who deal with educational data; and faculty, both in instructing and administrative positions. I wanted to ensure that I was sampling participants from a wide range of experiences and beliefs. The major criteria for sampling diversity included whether they were at Queen’s or not; whether they were faculty or staff; instructor or administrative role; whether they had a formal or informal role relating to assessment data or visualization; and whether they were from a professional program, a science program, or a liberal arts program. Support staff in this case refer to roles in university units that function to support teaching and learning in indirect ways, either by helping departments at an administrative level or help instructors with their teaching practice. This includes offices of research and planning and centers for teaching and learning. To find participants, I used Snowball Sampling where the initial set of participants were based on a pool suggested by the research team. From there, additional participants were selected from suggestions from the participants. The aim was to make sure at least one participant from each criterion was being sampled. This would help ensure that no crucial aspects of the framework that might be specific to a role or department type, would not appear in our data.

Since the team I worked in was largely from an engineering background, the initial set of participants and their subsequent suggested participants had close ties to engineering. Interviews were mostly conducted in person, though a few remote interviews were conducted over the phone. To ease with the logistical planning, participants were largely sampled from Ontario. Since education policy is driven at the provincial level, this may have been an important constraint on the scope of the support as institutions in other provinces might have different concerns and beliefs about assessment data. A distribution of the participant pool criteria can be found in Table 2.
Table 2 - Participant Distribution for Exploratory Phase

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faculty vs. Staff</td>
<td>5</td>
</tr>
<tr>
<td>Instructor vs. Administrator</td>
<td>5</td>
</tr>
<tr>
<td>Engineering vs. Other discipline</td>
<td>6</td>
</tr>
<tr>
<td>Queen’s vs. Other Org.</td>
<td>9</td>
</tr>
<tr>
<td>Ontario vs. Other Province</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Additionally, as part of the *Discovery of Cultural Categories* step, McCracken provides guidelines for researchers about how best to run interviews. Interviews roughly lasted one hour which, in most cases, was an adequate amount of time for most participants to complete the questionnaire in a way that let them thoroughly explain the ideas they brought up. The audio from all interviews were recorded with participant’s consent and then transcribed. Notes were taken during the interview, but the recording process guaranteed that no possible pieces of data would get lost.

### 3.1.2 Analysis of Exploratory Data

McCracken’s final step, *Discover of Analytical Categories*, deals with the analysis of the resulting interview responses. I believed that the analysis process would benefit from information and input from outside the data, especially since many of the participants were some form of researchers themselves. As such, rather than just studying them, the intent was to build this model with them. An abductive approach seemed like the best means to that end since it involved staying close to the data and re-contextualizing it as new information arises. As such, Charmaz’s approach to Grounded Theory was used for this step [38].

Given the length of hour-long interviews, NVivo, a qualitative analysis software package, was used to aide with the analysis. The software provides an organization workflow that keeps data organized, but is flexible enough to work with a variety of qualitative methodologies. The process used for Charmaz’s initial coding is as follows: working through an interview transcript, significant statements were marked as initial codes. The software has an annotation feature that
allows for all additional contextual information to be stored for quick reference. These
annotations ensured that when looking at the codes apart from the rest of the data, their
information would not be misconstrued. The bulk of interview transcripts were filled with
intermediary sentences from participants, or explanations to detail a single point. As such, by
separating the initial codes, they could be more easily analyzed without the clutter of the rest of
the interview.

Charmaz recommends that data be coded as summarized gerunds, or action verbs (e.g.
sorting, gathering, defining). Each statement from the participant that implied an action or a
process taking place was coded into their own gerund statement. For example, a participant
expressed: “So when I said that I encouraged departments to collect data, I don’t actually say
‘you need to collect more data’. The first thing that I say is ‘Analyze what you already have.’” In
this case, this sentiment was coded as ‘Using previous data first’. Once an interview went
through the process of initial coding, the action or process that each code was explaining was
described in a gerund. Each initial code did not necessarily map to a unique process, so often the
same process would be mentioned multiple times in an interview. From this process, I identified
the most prominent codes that were emerging from each interview with which I could better
focus the initial codes as required by the next stage.

With knowledge of these prominent codes, in Charmaz’s focused coding stage, those
initial codes of actions and processes were grouped together based on similarities seen between
them. These groups are what Charmaz refers to as focused codes. In subsequent interviews, the
initial codes were mapped to previously discovered focused codes, and if there was not a focused
code to sufficiently describe the new initial code, then a new focused code was created. From this
process, by the end of all the interviews, I had a set of focused codes that spanned a number of
topics. Some of these had implicit interactions, but were not yet explicitly connected in my
analysis.
As an aside, there were two broad coding mechanisms that were being used for different purposes. Charmaz warns that often the coding process is used to summarize rather than analyze. However, the elicitation tools in the interviews worked primarily as a survey tool. While tools worked well to elicit rich responses, the data that was a direct response from them was purely summarized. Since those responses were about factual occurrences, there was not much analyses that could come out of it. For example, while analysis can be performed on the responses describing why data is or is not being used by a participant, the response about what data is or is not being used cannot be analyzed much further. That information was still however very useful in building the support tool, as described in Chapter 5. The focused codes that most influenced the direction the study took are discussed further on.

Charmaz’s next step in building a framework is turning these focused codes into theoretical codes. By describing how these focused codes are related to each other, it can bring together the focused codes into a cohesive single structure that is “coherent and comprehensible” [13, pp. 63]. Together, these related codes would form the framework. Our team attempted this process of creating theoretical codes in a group setting to take advantage of our various areas of expertise. Cards were created for each focus code and laid out on a table where the team could organize and categorize their relationships. The outcome of this process was a workflow of the assessment process that combined most of the focused codes into a single structure. This structure however, would require significant amounts of additional work before it would be cohesive or comprehensible. More importantly, even in the framework’s unfinished stage, it was becoming apparent that what we were creating might not have aligned with our original intention. Specially, while this structure of related codes described conceptually what was happening in the area we wanted to understand, it had gotten too large and broad in scope to provide guidance into what a visualization support might look like.
It was from trying to use this structure to build the support that I realized that a framework might not have been the best option for the thesis’ goal of a support that educators can use to improve the use of visualizations in the data usage practice. Since the framework was meant to be a way to inform support would look like, I decided to shift the study’s first goal from creating a framework to some other structure that could more directly move the focused codes into a set of requirements for the support.

With the goal of the thesis shifted from a framework, I needed a conceptual framework with which to create this new structure in a way that was driven by the already discovered focused codes. However, a search through the literature around qualitative methodologies did not yield any conceptual frameworks or procedures for how to move data from participants into a set of requirements for what the support tool would be. This process of turning qualitative data into requirements is common in software design, but the processes I found lacked the research rigour I was looking for. In lieu of a pre-established conceptual framework, I used our eventual support tool product as a goal to from which to work back: From the inception of the study, the tool was intended to be a software tool, so I drew on the team’s experience in software requirements engineering to help guide the building of the new structure in a way that could still take advantage of the analysis that had been completed. Specifically, I used the collective interview data to determine the major groups of users and stakeholders that would interact with the support tool; grouped based on the roles as related to educational data usage. I used those groups as a starting point to construct a conceptual model of stakeholders and interactions to frame the focused codes. This included roles of stakeholders we talked to as well as ones we had not talked to, but whose roles were discussed in the interviews. These groups of stakeholders were seen as the primary roles that need to be considered when looking at visualization of educational data in a higher education setting.
3.1.3 Exploratory Findings

There were originally three groups that were determined from the interview data, with a fourth added after the focus group in the second phase of the study. I explain all four here, but more details on the last group’s discovery can be found in Section 3.2.

Firstly, there are the **inquirers**, who are the educators or administrative faculty with either questions that they require educational data to answer or have known information they are trying to use data to communicate. Common examples of inquirers would be instructors trying to improve their practice by understanding classroom needs, or administrators trying to communicate program strengths or weaknesses to accreditors. Then, there are **data-transformers**, who use the gathered data to help the inquirers move the raw data into a form that allows inquirers to answer questions or make data-driven decisions. Good examples of people associated with this group might be educational support staff, whose role is often to help with teaching and learning, data analysis, or creation of reports. Then there are **visualization consumers**, who only see the data once visualized, often in reports or in dashboards. Possible stakeholders that fall into this group might be external accreditors reading quality control reports or faculty members being shown how their program is performing. And the fourth group are the **data-gatherers**, who collect, sort through and organize data from various sources. Users in this group are often seen as custodians of the data, with the knowledge of where data is located and how inquirers or data-transformers might gain access to them. The most common example of a stakeholder in this group is a faculty or staff member tasked with collecting and consolidating assessment data from individual instructors. Stakeholders in this group might also be external to the institution, data-gathering bodies with whom the other stakeholders have minimal interaction. In other cases, this group also describes positions that inquirers and data-transformers would like to see, but do not yet exist in how they currently conduct their practice; particularly when it comes to having a support who knows where data can be found and accessed.
Importantly, these groups are explicitly not mutually-exclusive to an individual. For the stakeholders for which this model describes the practices of, someone might identify their role as being in one, two, or all of these groups’ descriptions. In fact, it was more often that the participants identified themselves as many of these roles rather than as one. The purpose for separating them however, was to be able to see where the boundaries on these stakeholders are when their functions are performed by different people. With the groups separated, it lets someone using the model analyze the beliefs in that space as well as the relationship to the other roles.

After identifying these user groups, I developed a concise mission statement for the latter stages of the research that could easily explain what I was trying to achieve: To help data-transformers create visualizations for the data-needs of inquirers for purposes of communicating to and analyzing with visualization consumers with data collected and organized by a data-gatherer.

In the next step, the focused codes found from the analysis process relevant to supporting visualization usage were sorted into either the stakeholder group or the interaction between groups that the code most closely pertained to. As an example, the focused code “Only Changing When Broke”, which refers to the attitude that changes to courses or programs only happened in a department when there was something that needed to be fixed. This code was associated with the inquirer group. However, the code “Making Data Accessible”, which refers to transforming data into a manner that is usable by the inquirer; would might associated with the data-transformer. However, since this camp involves direct consideration and communication with the inquirer, the coding camp was sorted in the space between inquirer and data-transformer (I-DT). Figure 4 is an illustration of the user groups and the areas in which they interact. Each of these is an element of the model where focused codes were sorted. The finalized codes associated with each model
element can be found in Chapter 4, summarized in Table 4. The findings there are the result of the analysis process from this phase as well as the revisions caused by subsequent phases.

The analysis process was highly interpretive and relied heavily on my prior knowledge and experiences. My interpretation of the participant sentiments might be different than someone with a different background performing the same analysis. During the entire data gathering and analysis process, I journaled my decision-making process. The journals ensured that I had a record of my thought process as I came across codes or other areas of analysis that required a decision between one of two or more options. For example, as an action or process was found in the data I tried to code it only once or group it into a single camp. When there were such datum that could be coded multiple ways, it often denoted a gap in my understanding in the options and required further development. Each time I ran into an interview datum that challenged my current conception of the complete data, it impacted my overall thinking and opinions of the findings. Having the journals let me look back and track how that thinking on findings has changed during the course of study to where I am now. It also helped illuminate some the influence of my individual understanding on the final findings. These journals were the major source material for writing this section of the report.

Regarding the research questions this phase started with, the analysis from the interview largely answered them, save for questions 1 and 6. First, looking at the other questions individually:

2. **What kinds of data are currently available to and/or collected by faculties?** With the elicitation tool, I found what kinds of data was used and/or available to the participants. Although this did not benefit the analysis, it was valuable data when building the support tool, discussed in more detail in Chapter 5.
3. **What barriers have been the biggest hindrance to an efficacious use of the data?** The data elicited from this area of inquiry and subsequent analysis were the foundation for the support tool, discussed in more detail in Section 3.2 when developing the focus group.

4. **Are there supports that have helped in illuminating information from large sets of data?** This area of inquiry did not result in much information that was helpful, but the lack of clear responses provided confirmation that a support would be welcome.

5. **What are the attitudes and beliefs from faculty surrounding data collection and usage?** The findings from this area of inquiry, mostly from the analysis provided the focused codes that populated the model.

   As for the questions that I had more difficulty answering, I tried, from the interviews, to elicit direction responses to the first question “What are the most common motivations to use educational and learning outcomes data?” The responses from this approach were less fruitful than I had hoped for. From my basis in the assessment literature, I tried to focus this area of inquiry around ‘questions’. These would be questions that the participants would have that they are trying to use educational data to answer. I was surprised by the lack of questions the participants could provide when asked. When designing the interview questionnaire, I assumed, maybe naively, that with the prompts and elicitation tools, participants in administrative and faculty roles could provide me with questions they were already trying to answer. Their responses around the questions revealed interesting insights into their relationship with data and their belief system around ask questions. However, most participants would not have any they could think of offhand when asked directly about questions. Therefore, to find those questions that participants were looking for from the data, it often involved inferring it from the stories and anecdotes they shared.

   While this study is focused around visualization, the only question in this phase that was related to this topic was “What key characteristics of visualizations maximize the provided
insight pertinent to each of the common motivations for data usage?” From the responses of the visualization elicitation tool, there was little in the way of overarching findings. While visualizations were largely seen as a useful practice by all participants, there were no key characteristics that that stood out as being more important to focus on. Participants seemed to have varying opinions on each of the visualizations, and I was unable to find any common themes between the participant responses. The lack of common themes among the responses might be explained by the vast differential of experience with visualization between the participants. While I sought out participants with experience with educational data, their experience with visualizations was hard to determine prior to recruitment and was part of the reason for asking this question. Some participants used visualizations extensively, while others used a small set that they have gotten comfortable with. Even among those who only used one or a few kinds of visualization, there was not much commonality between participants about what visualizations were used even for similar purposes. I found that while a particular visualization type was in heavy usage in one participant’s practice, it would be almost non-existent in another’s. Given the lack of responses here, I instead relied on the visualization literature and our own team’s experience to determine what aspects of information visualization design would be most relevant to the study and used the data from this phase to inform the other areas of the study.

With an initial version of the model constructed, I wanted to return to the participants to check whether my initial findings made the right inferences and whether there were any gaps in the analysis that needed to be filled.

3.2 Phase 2: Model Building Phase

Since qualitative analysis is heavily influenced by the researcher’s worldview, a key part of conducting good qualitative research is member checking. This is the general process of returning to the participants after an analysis to confirm that your findings are an accurate reflection of their sentiments and responses. We decided to use a focus group approach to
expedite the member-checking. A focus group is similar to a long form interview, but with multiple participants at once and as such requires adjustments to how the session is run. The advantage of running a focus group over additional individual interviews or a survey was that multiple participants could be member checked within a single session, while also allowing opportunity for participants to interact and build off each other’s ideas. The interaction between participants allows the iteration time between a participant’s ideas to be shortened. The primary goal for the focus group was to take the skeleton for what I thought the model would be and move it toward a complete, validated version of the model. The bulk of the analysis from the previous phase revolved around the third and fifth research questions. As such, the focus group was largely focused on expanding understanding in those two areas.

To create the focus group, I worked backwards from what I wanted to achieve with the participants’ time. At the point after the interview data analysis, there were many focused codes in the model. To member check all the codes individually would take far too long for a single focus group session. Instead, I decided to focus on the key set of challenges that I found from trying to answer the third research question in the previous phase. These were found to be the main hindrances facing faculty and staff in their usage of educational data.

There were four main challenges that stood out from the initial set of codes. These are what I decided to validate with the focus group.

- **Challenge A** involved inquirers coming up with questions to ask when data is made available. Some of the participant responses indicated that they had trouble knowing what to do with the data once they had it. Also, the lack of questions provided by participants when asked indicated that there might be an issue around this.

- **Challenge B** revolved around finding a method of answering the question. This refers to whether someone has the adequate technical or research background to find an answer in a research-oriented, data-driven way, once they have a question in mind. This is also the
challenge where we thought visualization might provide the most support in using educational data.

- **Challenge C** was about communication between educators in different roles. Participants mentioned that even when there was a general area of inquiry in mind, it would take a notable amount of time for the people looking for answers and the people trying to help them to arrive at a question that is relevant to the inquirer’s interest, but also one that can be answered accurately with the data available.

- **Challenge D** was about the gathering of data. There were many concerns raised about the significant time and effort that needed to go into collecting data in an organized and structured form that was appropriate for analysis.

With the set of challenges finalized, I needed to confirm these were indeed the main hurdles that our participants were facing. I also created an early prototype for the support tool based on how I thought the tool might help overcome these challenges. The focus group therefore had three main goals: (1) check whether the general foundation for the model was an accurate representation of the user roles, as well as (2) to check whether the hurdles found from the analysis were indeed concerns that need addressing and (3) to check whether our planned approach for the support tool helps overcome those challenges.

The focus group protocol was then designed around these primary goals. With the nature of faculty scheduling, it was difficult to run a session any longer than one hour that fit into the schedule of 8 participants; a number chosen based on experience from colleagues running focus groups with faculty. For the hour, I designed three main activities, all of which shared the structure of reflection followed by discussion. A mock version of the focus group was run within the team and appropriate revisions were made, largely regarding clarity of questions, ordering of activities, and the logistics of the activity to save time. The full protocol can be found in Appendix C.
Participants for the focus group included 6 participants from the interview phase and 2 participants that could not be interviewed previously but were recommended by many participants. The 6 participants from the prior phase were chosen based on the richness of their response from the interview phase and to diversify the set of experiences in the focus group. Unfortunately, one participant could not make it due to an emergency. A replacement could not be found in time leaving us with data from 7 participants. Table 3 summarizes the participant distribution according to the categories from the exploratory phase.

Table 3 – Focus Group Participant Distribution

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Faculty vs. Staff</td>
<td>3</td>
</tr>
<tr>
<td>Instructor vs. Administrator</td>
<td>2</td>
</tr>
<tr>
<td>Engineering vs. Other discipline</td>
<td>2</td>
</tr>
<tr>
<td>Queen’s vs. Other Org.</td>
<td>7</td>
</tr>
<tr>
<td>Ontario vs. Other Province</td>
<td>7</td>
</tr>
</tbody>
</table>

The analysis for this phase differed from the exploratory phase; the purpose here was to confirm and adjust my current understanding rather than build from something new from the data. To achieve this, I summarized ideas from the focus group transcript based on how I arranged the focus group. The major ideas adjusted the information I had regarding the challenges and our approach to the support tool. However, there were a few instances where there were new initial codes added from the focus group data that did not fit the focused codes I previously had in the model. While also coding these new pieces of information, I looked at initial codes from focused codes that I had previously grouped to see if they had more relevance to these new focused codes and made appropriate adjustments.

The focus group was split into three activities, each focusing on one of the goals previously mentioned. There was an activity that focused on the stakeholder groups, another activity that focused on the four challenges identified, and one last activity that focused on the support tool prototype.
3.2.1 Stakeholder Groups Activity

The focus group began with a round-table introduction of all the participants. They were given prompts about what to describe about themselves and their roles. I hoped that reflection piece, and hearing about the other participants’ roles, would make it easier for them to identify themselves into one or more of the stakeholder groups and whether their practice matched up with the group descriptions. The purpose of the activity was to get feedback about the foundation of the model, which is to say, the stakeholder groups and the boundaries between them. Note, the names for the groups were different at the time of the focus group. The inquirer, data-transformer, and visualization consumer were originally named client, data-worker, and end-user respectively and changed due to the discussions from the focus group.

Responses to the stakeholder groups were mixed. The largest issue, proposed by a participant working as support staff in engineering, was that the delineation of the three stakeholder groups was “kind of like a 20-year-old paradigm where people only use data for one thing. Or they only have one lens on them.” The participant believed instead “everyone is a combination of all of these things,” referring to the group roles, “whether you're the person that's doing mainly the data analysis but you still have to question ‘Was that the right question?’… You have to put your hat, your client hat on to pretend if it’s going to meet their needs.” This was described as a “holistic perspective” by another participant in a support staff role. This idea was refuted to some degree however, when a participant in a staff role described their “primary job is to be a data worker. There's no confusion about that.” With the caveat though that “if [they are] to be any good at what [they] do, [they] have to have very, very strong relationships between [inquirers] and [visualization consumers].” They suggest that “by working closely with [inquirers] it's an alternative to wearing the hat.” This aligns with why I decided to separate the groups along the lines I did. Ultimately, whether it is accurate to make this delineation between the roles or not, it is important to emphasize the interactions between the stakeholder groups as much as the practices and beliefs happening of people within each stakeholder group.
Additionally, another participant in an instructive faculty role responded positively to the separation of the groups, specifying “I don't think it's a bad thing to delineate the three because I think what it does, it makes you consciously think about how you're using the data. Like okay, I need to think of what data I'm collecting. I need to think about how I might use it but also how might for accreditor.” This also validates our motivation for separating the stakeholder groups in our model.

Some participants had issues with the terminology. The inquirer group at the time was called ‘clients’, which they did not agree with. As one participant in a support staff role described, “Client to me is somebody that is expecting a service”, but in this case, “I would like to think more as stakeholders as well and use that terminology, so that they have some ownership over the process.” Since stakeholder was already being used in a larger context, I moved to Inquirer to acknowledge that participation in the process.

Additionally, during the discussion, the roles of inquirer and visualization consumer were often conflated and intermingled. In the analysis I clarified the distinction between the two groups in that the inquirer plays an active role and has ownership in the process, while the visualization consumer does not. The name of this group was changed from end-user to visualization consumer during the analysis to reflect the clarification between the two groups. The latter is the only stakeholder group of the final four that is not also an intended user group of the support tool. For example, when considering a department, the teaching and administrative faculty actively looking to improve their practice using data would be considered inquirers. While members of the department who are asked to engage with the data but who otherwise do not participant in prompting data usage would fall into the visualization consumer group. While people who solely fall into that group might be interacting with the data, asking questions and creating inferences, they would not have been the ones to initiate the process. A single person, however, might move between from a visualization consumer role to an inquirer, or vice versa, as time goes by.
At the time of the focus group, there were only three stakeholder groups; the data-gatherer had not yet been added. One aspect that many of the participants seemed to agree on was that there are very few people who specifically collect and organize data. While I originally attributed these activities to the data-transformer, it was not explicitly stated in the description of their role provided to participants. The first participant to bring it up said “there's something missing about where the data is… it's close to [data-transformer] but it's ‘where's the best way, the cheapest way, to find the most efficient way.’” Given that the participant who said this identified themselves as being in the data-transformer role, the response indicates that there are duties around data-collection outside of their realm. Later in the focus group, another participant in an instructive faculty role similarly mentioned that “part of the challenge is that we don’t always know where the data is and who's got what around campus.” So, there is clearly a want for a support that acts as a sort of data-librarian. From the interviews, while I had heard participants discuss colleagues exclusively in this role, I was not able to interview any of them specifically. This might have been why I missed some key information about it being its own stakeholder group. I added the data-gatherer based on these comments and focused codes discussing the collection of data that were attributed to the data-transformer group as part of the model were moved into this new group. Additionally, this is where the group name ‘data-worker’ was changed to better distinguish between these two groups.

3.2.2 Challenges Feedback

The next activity of the focus group looked at the four challenges. I wanted to know to what extent the challenges I found from the interview data were real challenges in the participants’ practice. Participants were provided a sheet with 5 stickers. Four of the stickers corresponded to each of the challenges, each with their own colour. The fifth sticker was left blank for the participants to be able to add any challenges that I did not address. They were also provided a set of scenarios for ways to use educational data (see Appendix C). Participants were
asked to place each sticker on a board with a spectrum that ranged from “Not an Issue” to “A Serious Issue”. Figure 1 shows the results of the exercise.

This activity and discussion took up an extensive portion of the focus group time and a lot of the analysis and revisions to the focused codes were done with the data from the responses to this activity. Overall, the activity worked well for its intended purpose. It clearly displayed which of the challenges were perceived as being larger or smaller issues to the participants.

From looking at the Figure 1, the challenge regarding coming up with a question (Challenge A) did not seem to be an issue for most of the group. The one participant that was further on the right was only there because their role in a primarily data-transformer position did not require them to ask questions so there is not much significance there. From the interview data, this was a challenge that was inferred based on the lack of direct responses, rather than a challenge explicitly mentioned by participants. This could be the reason why this challenge was not perceived as a serious issue. However, even though the group saw this challenge as a relative non-issue, later in the focus group one participant identifying as a data-transformer discussed how “a big part of what we do is we help people rephrase their questions so that we can narrow it down to what it is [the inquirer] really [wants].” So, while the challenge might not be coming up with a question, this indicates there is work required to turn it into a question that can be answered with sound research principles. Often questions in their initial conception can be vague, or whose answer would not provide valuable or actionable information. Additionally, the participants in the focus group were recommended and chosen because of their relatively extensive experience with assessment data; which might have influenced this response.
A - Coming up with questions of this nature. As in questions that, when you answer them, you help develop the course or student experience. If you find yourself saying “I don’t know what questions to ask”

B - Finding a process or method to answer the question in a data-driven, accurate way.

C - As someone with a goal requiring data: communicating what you want to find to someone who can help. Or as someone who can help: understanding what someone with a goal wants to find.

D - Gaining access to or gathering the appropriate data to answer such questions.

#1 – Getting positive reactions to data offers

#2 – Need resources/support ask Q’s

#3 – Engagement with data

#4 – Finding someone who can help (merge of C & D)

#5 – Personnel

Figure 1- The responses of how much of a challenge participants found the challenges I found from the interview data. Each circle along the spectrum represents where a participant placed that challenge along the spectrum. Vertical position is not important. Circles with numbers are challenges written by participants.

The challenge regarding finding a process to answer a given question (Challenge B) is fairly spread across the spectrum. Participants on the left end of the spectrum, one a faculty instructor and the other a support staff, said they have had little trouble answering data-driven questions, on the conditions that they already had the data and an answer existed. The three closer to the middle had similar responses, all three in support staff roles. Regarding when these participants have been helping inquirers; while the inquirers “have been successful with research projects or some innovative initiatives, [inquirers] usually need someone to work with them in terms of figuring out what the process would be to evaluate that particular initiative.” These inquirers “don’t really have a research background. They’re mostly kind of task-oriented people and so it’s difficult for us to work as a group to design a process for this.” The take away being
that the challenge can come in the form of not having sound methodology, rather than just not having the technical skill required as I had originally assumed.

One of the participants, an administrative faculty member, who placed it further on the right, did so because “somebody will ask me like ‘why aren't people signing up for this course?’ … It's like, well we don't know. Because those people are not here to be able to ask that data.” Another participant described this scenario as “an impossible question” with other participants agreeing that certain questions cannot be answered without significant additional resources. Therefore, it is important to caution users away from such questions. The other participant on the far right had mixed feelings about putting their sticker that far right on the spectrum. In their words, “on one hand, I think we've got fairly good processes and methods. But on the other hand, we have more complex questions for accreditation that we just simply can't answer.” It was this need for more complex solutions to answer more complex questions that originally sparked the idea for the study. These mixed feelings also suggest that while a user might think they have the adequate tools to answer their current questions, they might not be asking complex questions since a need has not presented itself.

The sticker for communicating goals (Challenge C) was also fairly spread out. Unfortunately, the discussion around this topic was sparse. The wording of the challenge did however initiate a conversation around inquirers not knowing what questions they could ask. A participant shared a hypothetical situation where “If you've asked people [from 20 years ago] what kind of things do you want from your music player? They would've all talked about features on their Sony Walkman and how many -- let's have more CDs. Let's have seven CD holders as opposed … none of them would have said oh, give me an iPhone.” The point being that inquirers do not know what data is available to them, or what kinds of research-oriented questions they could ask with it. The participant who added the #4 sticker added that this new challenge is what they meant with their sticker. The wording of the challenge that was presented (Challenge C)
implies that there is already a goal in mind that simply needs to be communicated. From this response however, it implies that it might be beneficial to have a reverse relationship where opportunities for questions are presented to the inquirer for them to formulate a question they did not previously know they could ask. In this case, the participants were suggesting presenting what data is available.

The challenge associated with acquiring appropriate or necessary data to answer a question (Challenge D) was by far the one that was perceived as being the biggest hindrance to the participants’ practice. When asked to clarify whether the hurdle is “in terms of not knowing where the data is? Or … gaining access to the data?” multiple participants responded that it was both. When asked “So just someone who knows where all the data is?”, as with the conversation around the stakeholder groups, a participant responded “Yeah. It would be really nice if there were some central somebody who is a support.”

Even when this challenge was added to the four being looked at in the focus group, I realized it would be out of the scope for the support tool. The forms in which data are stored and accessed across institutions, faculties, departments and especially between faculty members can have drastic variance. From the interviews, data storage and access was an important aspect that came up numerous times. So even though the discussion about the challenge could not affect the support tool’s design directly, I wanted to know how significant it was and how it compared to the challenges that could be addressed by the support tool. This information provides a known limitation of how far our tool can provide support in a user’s practice.

Looking at the written-in challenges, #2, #4, and #5 are all referring to a lack of support personnel. The participants find that they either do not have the time to perform all the activities around data-driven decision making themselves, or do not have the technical abilities or appropriate knowledge base. Much of their points were already raised above, where they would like to see someone in a central role, organizing data. The support also refers to peers and people
in similar roles in other units, and not just around the data but also around what people are doing with them. A participant described the institution as “silo’d … because it could be that certain units don't even think getting answers to [a question answered by another unit] is possible.” So, while having dedicated support staff would be beneficial, there could also be some benefit of fostering more communities of practice around these activities between units at an institution.

The other two, #1 and #3, are also related to each other but refer to another aspect of educational data usage. The #3 written-in challenge was about engagement with data, specifically that they are having trouble figuring out “how do you tie the data to something that is meaningful for the faculty that is part of their daily practice? That is part of their daily life?” Another participant added “the faculty get lots of data that they don't feel attached to, in terms of the ability to make some real decisions.” The faculty have “so many other time demands in a week” and do not have the time to bridge that gap from data to their practice themselves. Any tools to ease that process and save them time while doing it would likely increase that engagement. As part of that struggle with engagement, #1 describes the issue with the reaction received when data is presented: “Some people say great, thank you, and other people less so…the most difficult meetings I have every year, are meeting with the [mandatory quality assurance] teams to say here's the data that we're going to get. It's just a mind-blow because at different levels: They didn't realize we had it. They're not entirely thrilled that we're about to give it to them. They're not entirely sure, in some cases, what the heck they're supposed to do with this.” This, in some ways, relates back to Challenge B, of not knowing how to process the data to answer questions, but in a larger scope. When given data that they did not have before, these educators find themselves overwhelmed with what they can do. With all these concerns when receiving all this data, it is understandable that members of a department might be hesitant to readily engage with the process. It would be beneficial if they had some guidance about where to start.
Overall, the challenges I identified from the interview data worked as a good starting point to focus on the nuances of the challenges with which the participants could use support. Possible users of the support tool could use some help forming questions that are answerable in a way that uses sound research methodology. While they have methods of answering current questions they have, there might be more complex questions that require more complex processes to answer. These possible users do not always know what questions they can ask, or what data with which they can find information. They do not know where they can find data, or do not have access. They could use more support, or at least benefit from communicating with other units at the institution. The data feels disconnected with the daily practice of educators and when given data, they might feel overwhelmed with what to do with it.

3.2.3 Tool Prototype Feedback

The final activity for the focus group was to get feedback on our ideas for the support tool. As a team, we collectively arrived at the ideas as proposed solutions for the challenges. These were built into a basic prototype that had very limited functionality but provided participants with a mock-up of what I was hoping to achieve. Figure 2 is a screenshot of the prototype running. The main section provides a series of nested guiding prompts that either (1) successively narrows the user’s area of inquiry down to a well-defined, research-friendly question or (2) lets users browse through topics to a question they might find interesting. By well-defined, I mean one where the wording is precise and does not rely on assumptions in the kind or scope of the data. Once, they arrive at a question they would like answered with the dropdowns, the tool provides them with a visualization that I recommend for that purpose. At the top was a brief set of instructions about how to use the prototype and what its limitations were.

The main section of guiding prompts was designed to be a way of supporting challenges around coming up with a question and communicating the question. By having the nested guiding prompts, users could find a question that they would like answered and with that well-defined
question at hand, it would expedite the communication process between users needing support and those providing the support. The recommended visualizations were a way of supporting the challenge of finding a process to answer those questions, and also the initial goal of the study. As mentioned, even though we knew the gathering of data was a major issue, we did not know how to support overcoming it.

Figure 2 – Screenshot of support tool prototype used in focus group. It shows the guiding prompt system.

Unfortunately, due to some setbacks during the focus group, most of the participants had to leave before they could provide feedback on the prototype. Only 3 of the 7 participants provided complete responses, though more detailed feedback about questions were provided in a survey that is discussed below. The participants who remained tried to navigate the prototype while asking questions about the user interface and provided responses about how they thought it may or may not be useful.

The successive drop-down lists were largely taken positively. A participant mainly in the inquirer role appreciated how it helped narrow down a question: “It's really easy to kind of follow through the flow to like narrow things down. And that'll get at the aspect of sort of like -- what you were kind of getting at, I think was your [Challenge A] last time. It's like if you don't know what the questions are, you want to ask.” As participants in the data-transformer role, the other
two mentioned it would be “useful” and “exciting” to have a tool like this that helped the people they were working with get “to a point where they articulate” their questions. As mentioned, the data-transformer role often involves rephrasing questions and they believe a tool like this would “help in the research design, the interpretation of goals, possible questions or on methodology.” And in terms of helping bridge that conversation between inquirers and support staff, “it helps the vague question become a more detailed, structures question. So, it helps initiate a conversation that takes several leaps beyond what it might have been otherwise.” These strong responses were a promising start for this aspect of the tool, since the responses affirming the direction I was taking with the tool, without my prompting them.

There were some concerns as well. One participant was not sure about “how you get new questions added to the system”. This was admittedly a concern I also had, but did not yet have a solution for. The tool was never intended to have a recommended visualization for every question that an educator might have, but instead to provide a wide enough variety of examples. With them, an educator might find ideas for a visualization more suitable for their task. However, there might be aspects of educational data that the tool might not provide recommendations for and the participant’s suggestion was to have some manner of feedback where users could recommend questions that they want added to the system.

Another, and possibly larger concern was about getting users’ hopes up. An inquirer might use the tool to find a question they want an answer for, and while I can recommend a visualization to help answer that, the data might not be available or of a high enough quality to properly answer that question. This was not part of the original plan for the tool, and can be addressed by informing users about the limitations of the tool. I hope the tool might at least provide a goal of what data would need to be collected to attempt to answer that question.

In the case of all three participants, they noted that it would be “cool” and “very helpful” if the tool could draw on a centralized, pre-established repository of data. That way, the
visualizations would not just be a recommendation of how to visualize a user’s data but a ready-to-use visualization of the data they would want visualized. A tool of that scope would have been well outside the time constraints of this thesis however. While it would not be unfeasible to make a system that draws on a central repository, the project to create a central repository that has data fed from the course, department and institution level would be a significant project much larger than this study. This might however be an interesting avenue for future work at an institution, given how all three of the participants mentioned it.

The visualization recommendation was described as “too hard” for the majority of people in the inquirer role. Part of the concern of a participant in a data-transformer role was that when a user arrives at a question, the prototype suggested a type of visualization like “Histogram” or “Tree Map” and the participant felt like that was too much detail. They suggested instead to move away from technical terms and keep users focused on the question they want, not the terms.

One large foundational piece that came out of the tool feedback was with regards to arriving at questions. One participant, who works primarily in the data-transformer role, lets inquirers explore visualizations the participant provides as a way to let the inquirers come up with their own questions. With the design of what I had so far, I assumed that people would have found a question before looking at a visualization. The participant did agree though, that the architecture of the successively nested groups would be useful in helping inquirers articulate what they are looking for. By exploring the questions in our bank, they will be able to find ones of interest to them. However, looking at overview visualization is an excellent way to find areas of the data that are worth taking a deeper dive into and not an aspect of visualization or the question developing process that I previously considered.

Overall, the main takeaways from the focus group are:

- The interaction and strength of relationships between the stakeholder groups is equally important to focus on as the groups themselves
- There is often a process of refinement, where areas of inquiry are moved toward well-defined questions grounded in research design
- Collection and categorized storage of data is valued
- The questions being asked range from answerable, complex, and impossible
- Inquirers do not always know the kinds of questions they can ask
- When people are presented with data, there is a lack of engagement partly due to a lack of time and partly due to a lack of attachment with the data to their practice

3.3 Phase 3: Evaluative Phase

With the analysis from the focus group data complete, I built a model of how I saw educational data used, the major stakeholders involved, and the important concepts to consider for and between each group of stakeholders, as seen in Chapter 4. Now, we needed to create the support tool that could help overcome some of the challenges that I found in a way that accommodates the practices and attitudes of the relevant stakeholders; most notably, users from the inquirer and data-transformer roles. I also wanted to get a last round of feedback on what we had created before creating the first official public release.

For this final phase, I wanted to quickly elicit feedback from a large variety of sources. Therefore, I decided that a survey was the best way to achieve those demands. I would be able to send it out to large number of possible participants at once without having to schedule time with them. The survey format would also allow participants to test the tool on their own time, which would be a more realistic environment to test in. The benefit is that it would more accurately simulate how they might use such a tool in their own practice, outside of being asked to for a study. I decided to make the survey anonymous as well since many of the possible participants knew me from prior phases of the study. I felt the anonymity might allow them to be more honest with their responses. It also eased some issues logistically to keep everyone’s information appropriately confidential.
Similar to the prototype, the tool was built to guide a user to a well-defined question surrounding educational data usage through a series of guided prompts. For the question, the tool would provide a tailor-made visualization recommendation. The tool was built in collaboration with another member of the engineering education team, who had more experience in creating a web-based user interface for the tool. The recommended visualizations were designed by myself using the principles outlined in visualization literature, primarily from Munzner’s Visualization Analysis and Design [11]. The questions the tool recommends visualizations for were drawn from the interview response data. The initial version of the tool, built by the time of the survey, had visualization recommendations for a selection of the questions I planned to have in the final version. A detailed description of how I arrived created the questions and visualization recommendations, along with full list of the tool’s features can be found in Chapter 5. However, here I briefly describe the features we added to the prototype in response to the focus group feedback.

Figure 3 shows a screenshot of the tool that was presented to the survey participants. To make sure users know how to proceed when initially shown the tool, all our guiding prompts are phrased as questions and would require a response (seen on the left). Also, the tool’s interface uses drop-down menus that I hoped would be more familiar to users.
While it was always important to provide examples of code to users for those in data-transformer roles, I chose to hide what a user would immediately see when they reached a question. This choice was made due to concern that the details and information might deter users. Instead, when a user arrives at a question, the tool presents a visualization that suits the question and a description of how to interpret the visualization and the decisions that went into its design. A separate tab displays the code for the visualization.

Although I did not think the tool would be able to provide much support to users having trouble gathering necessary data, I tried to add features to support the data process to the extent we could. Specifically, for each of the questions I was recommending visualizations for, the tool would specify what kind of data a user would need to have to create the visualization. And we added a data-viewer section of the tool where, for each question, a user could browse the data in the format it started in. I am hoping this at least provides a goal to aim for when gathering data.

The survey was designed to be a way to gather open feedback about the tool. I chose an open response format since I did not expect to receive a large enough number of responses that I could perform a proper statistical analysis. Instead, I wanted to focus more on the written
feedback and use it to improve the tool. The survey was split into three types of questions. The first was our version of demographic data, where I asked the participant to self-identify as one of our four stakeholder groups (inquirer, data-transformer, data-gatherer, or visualization consumer). The second type of questions were focused on high-level feedback about the system, such as how well they perceive our ideas for the system: whether the guiding prompts were useful and made sense, whether our approach was reasonable, and generally whether they thought a tool like this would be useful to their practice. The last type of question was low-level feedback about our implementation: how our terminology and phrasing was, any issues they faced with the interface, and other aspects that dealt with the implementation of our ideas. Given that it was largely open-response questions, responses for specific questions were found among responses for others. Participants, when answering the high-level feedback questions would give points on low-level pieces. The full set of survey questions can be found in Appendix D.

In many cases it was challenging to identify the context that participants referred to. They would raise concerns without much follow-up or context which meant I could not take actions to remedy them. Since the survey was anonymous, this also meant I had no way of following up with the participants to clarify what they meant. As such, the responses that are discussed here are only for the ones where the responses had satisfactory clarity for me to know what they were discussing.

Overall, there were 10 responses from 30 people we sent it to. Again, I tried to select participants who I knew had some experience with data and would have an interest in such a tool already. I did not want to blindly send out the survey. I sent the survey out to people who were previously part of the study and people who were not but were recommended by colleagues or participants. Due to the anonymity, I cannot say how many of each participated.
3.3.1 Stakeholder Groups

For the question, I described all four stakeholder groups to the participants and asked them, in one question, to identify as any as their primary role, and in another, ask them to identify any as their secondary role. I also asked them if there was any aspect of our groups that they felt was missing.

Responses to these questions were consistent with previous data, without much additional feedback on the stakeholder groups. Of note among their selections, all the participants picked at least one secondary group and 2 of the 10 identifying within all four. Also, five participants picked data-gatherer and data-transformer together, making it the most common options selected together. Four of those picked transformer as the primary role. This is interesting given how our analysis conflated the two in the first phase of the study. From the open responses, there was little feedback. One participant did raise a concern with the name of ‘data-transformer’ but did not elaborate enough that I could make appropriate changes. Another mentioned that they often “teach” people how to be in these four roles.

3.3.2 High-Level Feedback

I linked the participant to the live server where the tool was uploaded. I asked participants to navigate to the tool, read the instructions, and try using the tool without being given a task to perform. First, participants were asked to provide feedback about the instructions. For the most part, participants indicated that they understood what the tool’s purpose was. However, from responses later in the survey, it seems there was a misalignment between some participants’ understanding and our intention. It clearly indicated that there was some work required to ensure the description clearly outlined what the intended functions of the tool are.

Following that, I wanted the participants to navigate the tool in a guided way so that they could simulate what it might be like to use the system in a real context. To do so, I created 5 variations of the survey, each with 3 unique scenarios. The scenarios presented a task to interpret
data in some way given a role, such as program coordinator, or educational support staff (these scenarios can be found in Appendix D). Participants were asked to act as though they were trying to complete that task and use the tool to find a solution using the guided prompt format. Each scenario was created with a question that had a recommend visualization in mind. I hoped the participants would be able to navigate to that question with the prompts for each task. Participants were asked for their thoughts on guiding prompts approach, its organization, and the participants’ overall attitudes on whether this tool would be useful to their practice. I will discuss the positive comments first, followed by areas for improvement, the neutral comments and finally the more critical feedback.

In terms of what participants liked about the tool, some liked the visualizations and the accompanying descriptions. Participants found the terminology used in the guiding prompts to be “clear and straight-forward” and “appropriate to the purpose.” And overall, one participant suggested “the questions themselves could be quite educational and prompt faculty to investigate those aspects of their curriculum.” Adding, “the visualization would present data in a user-friendly manner.” From a technical side, one participant responded, “as a means of expanding my skills and knowledge of R and a selection of commonly used packages, this is a great resource.”

There were a few high-level suggestions. While the guiding prompts were seen favorably by some, others found it cumbersome to navigate through the drop-down menus to browse the possible options. They suggested instead to provide an option to “see the entire decision tree in order to better understand the possibilities of the system.” Given that the prompts move from larger categorizations down to more granular topics after a few drop-down selections, there is no way of knowing what topics are at the end of a branch unless you navigate down several levels of drop-downs. An alternative approach might be to present the topics earlier on, and have the categorizations later. There were also suggestions about exporting the visualizations and providing citations for the data. However, the data I used for the visualizations were sample data.
from a previous study that was not intended to be used for decision making by the public. This is
one of the responses where I felt the participant might have misunderstood that I was providing
recommendations for visualizations for a general situation, and not trying to visualize their data
for their specific needs.

A few responses were observations which were neither positive or negative remarks of
the tool. A couple participants mentioned that the way the scenarios in the survey were phrased
made it quite easy to find the corresponding question in the system, while problems outside of a
test environment might be more complicated or presented in very different language and would
make finding the appropriate question “much less successful”. Although the selection of
terminology was largely received positively, a few were concerned that different educators might
interpret some of the questions differently than I intend. With the data I collected, it is hard to say
for certain how confusing the terminology would be for another user.

Much of the pointed criticism of the tool was with regards to the guiding question format.
Some participants found the generic wording “confusingly hypothetical”. Others felt like they
were “selecting random options to get down to the” questions with recommendations. It is
interesting that the guiding prompts in the prototype were largely received positively, but in this
format, was panned. While I thought the drop-down menu format would serve the same function
as the prototype, there was clearly some aspect of the design that was lost between iterations.

A possible reason might be a similarity in interface with tools that perform comparative
but distinct functions. The visualizations recommended in the tool are all coded in R’s Shiny
package. There is a similar program, Tableau, that is better suited to quickly create dashboards to
present data to many users in many formats. The standard Tableau dashboard has a similar layout
and aesthetic with options on the side and the visualization presented in the main area. Unlike our
tool, the options are all independent of each other and it is the intersection of the selections that
determines what data is visualized. However, what we are doing in our tool is very different.
Here, each selection drills further into an area of inquiry, and so each successive drop-down is based on the last. This is because our recommendations are tailor made to each question, and so the system cannot arrive at a question through independent selection. The similarity in interfaces might have misled the users about our tool’s intended purpose.

Two participants in particular seemed notably upset that the prompts were dependent of each other. One participant primarily in the data-transformer role articulated that they “would have liked the questions to be independent.” And although they both responded that they understood the tool’s purpose, they were judging it to a goal I did not intend for it to achieve. It might be important to make it abundantly clear that the successive selections are dependent on each other and our reasons for taking that approach. Or, alternatively present the questions in a way that allows users to see the entire decision tree without being overwhelmed as suggested.

Much like the interviews, there was little data regarding the visualizations. I purposely chose to exclude questions about the quality of the recommendations because proper visualization evaluation is an involved process that requires more time than I wanted to ask of the participants. Additionally, since each recommendation was tailor made to the question, evaluating a section of the recommendations would provide little feedback on our general visualization design process. A such, only a few participants’ responses had any mention of the visualizations I recommended. Of the few that did, they responded positively addressing the merits of the visualizations and the benefit of having the tool as a good resource. Although I was not expecting responses about the visualizations, so few participants mentioned them that it is hard to determine how much of a factor the effectiveness of the visualizations as recommendations played into their overall perception of the tool.

3.3.3 Low-Level Feedback

Participants were also asked about the user interface, language and general usability of the tool. Here, there were no strictly positive comments which is understandable since it is
usually frustrating or poorly functioning interfaces that standout as worth mentioning. One note of feedback regarding the visualizations was to provide as much data on the visualizations as possible, to make reading accurate measurements easier. When providing feedback on the tool’s instructions, one participant in the data-transformer role mentioned that there was too much technical information that might be better suited on a separate page. Like the feedback from the focus group, I agree that it is important to keep technical details and information a few clicks away from main page as not to intimidate new users, not in a technical role. Another suggested checking whether the tool would work with a screen reader to be AODA (Accessibility for Ontarians with Disabilities Act) compliant.

By far the most common complaint about the interface was how we implemented the drop-down menus. Due to a limitation in the way we implemented the system, the tool would break if the option for a previously selected drop-down was changed. Our solution was to make prior choices locked, and have an undo button that undid the previous selection. This seemed almost universally criticised. Thankfully, this was primarily a user-interface issue and can be fixed with smaller changes that do not require us to fundamentally change our design approach.

Overall, the survey provided very mixed results. Some participants were not impressed with the approach we have taken. From the assumptions in their responses, this might have been due to a perception problem about what the tool was intended to do. Hopefully, with clearer wording in the tool’s description it will alleviate some of those misgivings. However, for others, the tool was found to show some promise despite some minor suggestions for improvement. We hope that we can make a version of the tool that this latter group can find value in the recent future as we work toward presenting the tool in a way that more obviously illustrates its intended purpose and can provide value to the former group.

A summary of the limitations to the study’s approach can be found in Chapter 6.
Chapter 4

Model of Educational Data Visualization in Higher Education Setting

As mentioned, the goals of the thesis were two deliverables. The first was a model that
knit together some understanding of the processes and beliefs with which educational data are
visualized in the university setting. From the interview and focus group data, the analysis
revealed four main stakeholder groups that took part in the process of moving educational data
towards program and student learning improvement through visualization. The four groups were
found to be inquirers, data-transformers, data-gatherers, and visualization consumers which is
explained in more detail below. These groups represent distinct roles that are present or
considered within the process of moving data towards visualization. To build the model, each of
these groups was assigned a “concept space”. To each of these concept spaces, focused codes of
practices and their underlying beliefs were assigned that pertained to that group. Additionally,
concept spaces were also created between the groups, to which focused codes associated with the
interaction between any two groups was assigned. These groups and interactions spaces can be
seen illustrated in Figure 4.

For each group and interaction space, focused codes of processes and underlying beliefs
were drawn from the interview and focus group data. With these concept spaces, someone can
build a tool to support current practices knowing they are accounting for a diverse set of
stakeholder needs. All the codes in each space do not necessarily apply to practices of everyone
who identify in that group. However, because these codes apply to at least some stakeholders to
which these groups apply, the codes mentioned here should be considered when looking at
visualization of educational data in this space. The list of the codes associated with each concept
space can be found in Table 4. Following the table is a description of each concept space and an
explanation of all the associated focused codes.
Inquirers: Educators or administrative faculty who either have questions that they require educational data to answer or known information they are trying to communicate using data.

Data-Transformers: Analysts who transform previously gathered raw data into a form that allows inquirers to answer questions or make data-driven decisions.

Visualization Consumers: Stakeholders who only see the data once visualized, often in reports or in dashboards. Does not always appear.

Data-Gatherers: Staff or faculty who collect, sort through, and organize data from various sources; with knowledge of where to find or how to access data that would be most effective to answer a particular question. Does not always appear.

Figure 4- The model for how educational data is used at a university. It features four stakeholder groups and interactions between all of them.

Table 4 - List of focused codes associated with each concept-space in the model

<table>
<thead>
<tr>
<th>Model Space</th>
<th>Stakeholder Group</th>
<th>Focused Code</th>
</tr>
</thead>
</table>
| Group       | Inquirer                   | • Struggling only with complex questions  
• Adding to their lived knowledge  
• Distributing the questions asked and answered to other inquirers |
|             | Data-Transformer           | • Applying sound research methods  
• Using unintended data to answer a question in a valid way  
• Keeping data honest  
• Pointing to big issues |
|             | Data-Gatherer              | • Choosing size of collection  
• Collecting solely for external needs  
• Inventing new data sources outside normal responsibilities  
• Acquiring honest attitude data from students  
• Storing data with context |
|             | Visualization Consumer     | • Reading a richer story  
• Missing attachment to data  
• Lacking time |
<p>| Connection  | Inquirer ⇔ Data-Transformer| • Giving inquirers tools to answer questions themselves |</p>
<table>
<thead>
<tr>
<th>Role Combination</th>
<th>Responsibilities</th>
</tr>
</thead>
</table>
| Inquirer ↔ Data-Gatherer | • Refining research questions  
• Denying unreasonable/impossible requests  
• Not bringing people's hopes up |
| Inquirer ↔ Visualization Consumer | • Dictating what data is collected  
• Collecting data with context for question its answering  
• Knowing the kinds of questions you can ask with the available data  
• Accessing and withholding data |
| Data-Transformer ↔ Data-Gatherer | • Directing to best data available  
• Working within data already collected  
• Minding context in which data was collected |
| Data-Transformer ↔ Visualization Consumer | • Eliciting positive reactions when presenting data  
• Engaging stakeholders with data |

### 4.1 Stakeholder Groups

#### 4.1.1 Inquirer

These are stakeholders that play an active role in seeing educational data put towards improving programs and the student learning experience. Common examples of inquirers would be instructors trying to improve their practice by understanding classroom needs, or administrators trying to communicate program strengths or weaknesses to accreditors. These are some of the ideas that underlie their practice:

**Struggling only with complex questions**: participants explained they had good processes and methods to answer their questions with educational data, but could not answer more complex questions for accreditation. They saw the need to become savvier with data.

**Adding to their lived knowledge**: there is knowledge that comes from the lived experience of teaching students. Often this knowledge can seem at odds with information discovered through a data-driven process. However, data should not try to compete with, but add to that knowledge. Inquirers develop a confidence in data based on what they already know. They measure their trust in the data with how accurately it reflects their lived knowledge.
Distributing the questions asked and answered to other inquirers: there is a wealth of knowledge among inquirers in different units, but they do not have avenues by which to share the work they have done or are trying to do. For example, with accreditation, many departments across fields face similar requirements and could benefit from a sharing of ideas even if their content of study is different.

4.1.2 Data-Transformer

These are stakeholders, largely in support positions, whose primary role is bridging between data and application. Their role is to elevate raw data to a form that allows inquirers to make data-driven decisions. Often, this can include creating visualizations. Good examples of people associated with this group might be educational support staff, whose role is often to help with teaching and learning, data analysis, or creation of reports.

Applying sound research methods: a sound understanding research design is an important aspect of the role. When working with inquirers in a support capacity, the application of that understanding is often much of the support being provided.

Using unintended data to answer a question in a valid way: often, questions need to be answered without data that was gathered specifically for that question. In these cases, it is important to first evaluate whether answers found from that data provide insight that is unambiguous and not misleading.

Keeping data honest: data can be manipulated and presented in a way that distorts the accuracy of the insights. When transforming data into a form more readily usable for interpretation, there is an obligation to perform transformations in a way that does not distort the ‘truth’ of the data.

Pointing to big issues: the nature of their role does not often require that information is interpreted to “within a one percent accuracy.” Instead, it is more common to know and highlight
what the major issues and trends are, which requires a different approach “rather than a formal statistical slant on the data.”

4.1.3 Data-Gatherer

These stakeholders primarily collect and store data. Additionally, they might act as librarians and custodians of the data, with knowledge of where data is located or how to get access to it. Although, stakeholders in this groups are not as prevalent, the most common example are faculty members or staff who are tasked with collecting and consolidating assessment data from individual instructors. This could also be central units who have data collected for institution-wide administrative reasons. These might also be external, data-gathering bodies with whom the other stakeholders have minimal interaction. In other cases, these are positions that inquirers and data-transformers would like to see, but do not yet exist.

Choosing size of collection: data is most often gathered with a specific inquirer purpose in mind. During the data collection process, should the scope of collection include just what is necessary for the original purpose? Or, with extra effort, should a lot more data be collected that can be used to answer other questions that inquirers with access to the data might ask later?

Collecting solely for external needs: with limited time and resources, the only data that gatherers can dedicate resources to collecting are data required by external bodies, often related to accreditation.

Storing data with context: data is often used for purposes other than what it was initially gathered. How data is categorized and stored for one purpose would be influenced by a certain perspective that might not be shared with how it is being used later. So, providing adequate contextual and semantic information within or around the data to minimize misinterpretation is important.

Inventing new data sources outside normal responsibilities: when encountering questions that seem impossible given the needs of the how the data is collected, new ways to collect data
might be created but with considerable effort. In such situations, it would need to be judged whether answering those questions is worth the additional effort.

Acquiring honest attitude data from students: information from data on student attitudes can differ significantly from answers acquired informally, without data. Student might not want to be honest in writing the same way they are in person. As such, careful consideration needs to be given to how data is collected regarding student attitudes.

4.1.4 Visualization Consumer

These are the only passive stakeholders in the model. While they play a role in the larger process of moving educational data to change, this model distinguishes these stakeholders as not being part of the process of moving data to visualizations. When data is disseminated, these are the people that are disseminated to, often in the form of visualizations in reports or presentations. Possible stakeholders that fall into this group might be external accreditors reading quality control reports or faculty members being shown how their program is performing in a department meeting.

Reading a richer story: data is most often presented in tables, which can be tedious to read. The experience of reading reports for quality assurance and accreditation could be improved with more interesting ways of presenting data. People reading reports would like reports that tell richer stories.

Missing attachment to data: faculty can get shown a lot of data that they do not feel attached to. They do not think it can help them make real decisions in their daily practice.

Lacking time: with many time demands, faculty do not have the time to find ways to make the data useful to them. Supports that save them time with that process might increase their engagement with the data.

4.2 Stakeholder Interaction Groups

The rest of the codes are associated with the interaction between each of the stakeholder groups.
4.2.1 Inquirer ⇔ Data-Transformer

Refining research questions: data-transformers often help inquirers narrow their areas of inquiry to precise and unambiguous questions that answer what the inquirers really want. Often, it turns out “the way they asked it first probably was not quite what they wanted.” This process can take a lot of communication between the parties to create a shared understanding of why this question is being asked and what data would provide the answer that best suits that.

Giving inquirers tools to answer questions themselves: rather than just helping with specific questions that inquirers already have, giving visualizations and other tools that inquirers can use to explore the data on their own and discover their own interesting areas for inquiry.

Denying unreasonable/impossible requests: while providing support can be crucial to building new insights, there are lines where the requests are unreasonable especially given the limited resources available. The data or format required to answer the question might be too onerous to collect, or even impossible. The data-transformer often dictates which requests would be a valuable use of time and can deny these requests.

4.2.2 Inquirer ⇔ Data-Gatherer

Dictating what data is collected: it is often the needs of the inquirer that dictate what data is collected. Data is not often collected without an associated need.

Knowing the kinds of questions you can ask with the available data: inquirers may not always know the kinds of questions available to ask. By providing them with what data is available for them to ask with, the possibility space for questions broadens for the inquirer.

Accessing and withholding data: largely due to privacy concerns, educators at the instruction level are hesitant to provide their course data to departments and other units. Additionally, also for privacy concerns, educators are not allowed access to much of the student data they did not collect. In both cases, there might be some value if the other party has access, but maybe not worth the risk.
4.2.3 Inquirer ⇔ Visualization Consumer

Discussion as a path to decision making: to affect change, it is often discussions inspired by what the data is highlighting that leads to decisions about how to move forward and not just data itself. The people that the data is being presented to are an important part of how it moves towards change.

4.2.4 Data-Transformer ⇔ Data-Gatherer

Directing to best data available: when trying to answer a question, it is not always obvious what the sources of data should be to arrive at the best answer. An intermediary that can efficiently guide a data-transformer based on their need can be helpful.

Minding context in which data was collected: when working with data that was collected for a different purpose, the context with which the original data was collected should be accounted for. This requires that the data-gatherer provide adequate contextual and semantic information to minimize misinterpretation and the data-transformer understand the process in which the data was collected. This can be especially true when the data was collected at a different time or by a different organization and people in the two roles might not have any way of communicating with the other.

4.2.5 Data-Transformer ⇔ Visualization Consumer

Eliciting positive reactions when presenting data: presenting data to people not already engaged with the process can sometime invoke a negative reaction. The people receiving the data might not know what to do with it and they do not see how it would add to their practice. So, data might be presented in a way that highlights positives first to get them interested, or other ways of overcoming that negative reaction.

Engaging stakeholders with data: when presenting data, there is a lack of engagement from stakeholders. The process for presenting the data should move to be more interactive and
engaging. Consumers should not just be provided with information, but ways to build new information with their experience.

Overall, this model was built to provide some insight into the beliefs that underlie the practices of each of the groups and their interactions with each other. It highlights areas that need to be considered when approaching solutions to create supports for the relevant stakeholders.
Chapter 5

Development of Easel: Visualization Recommendation System

The goal for the support tool deliverable of the project was to provide a tangible platform that promotes the use of visualizations in the assessment process in an effort to ultimately have educational data drive program improvement. With this goal and the conceptual model described in Chapter 4 in mind, the decision was made to design the tool to primarily support Inquirers, Data-Transformers, and the interaction between the two groups. Specifically, giving inquirers a way to browse the kinds of questions they can ask, providing data-transformers a resource to help design more complex visualizations, and expediting interactions by narrowing down areas-of-inquiry to specifically worded, answerable questions. These two groups were chosen as the primary stakeholders because their challenges could most readily be supported given the available experience and time.

The tool’s design aims to achieve these goals by providing a catalogue of diverse questions an inquirer might ask for which educational data can provide insight. For each of those questions, the tool provides a visualization recommended designed with information visualization design principles, along with resources to use and build such a visualization. For a user to find the particular questions that they might be interested in from the catalog, the tool utilizes a series of successively specific guiding prompts that a user navigates through.

The main elements of the tool are designed to support the inquirer and data-transformer, but considerations from the other stakeholder groups and interactions were supported where possible through minor features, described in detail further. Additionally, this tool is not looking to replace any of the roles defined in the model, only support areas identified by participants as being a challenge.
The final tool takes the form of an online web-application called *Easel: Visualization Recommendation System*. The name ‘Easel’ was chosen since the tool is built to support visualization needs of users, much like how an easel supports paintings and presentation slides. Easel can be accessed at: [http://shiny.engineering.queensu.ca/easel](http://shiny.engineering.queensu.ca/easel). This chapter is divided into three sub-sections. The first describes the features of Easel and how they relate to the stakeholders, and the second and third describe the processes for creating the catalogue of questions and associated visualizations, respectively.

### 5.1 Description of Tool Features

A clear area where a tool could provide support was in the communication and refinement of areas of inquiry. Responses from participants in the data-transformer roles indicated that a considerable aspect of their job was to guide the inquirers from their areas of inquiry towards well-defined, research friendly questions. To help expedite that process, our system has a catalogue of these questions that users can browse to find one suitable to their needs.

To help users navigate through the catalogue, the system was designed to be a series of successive drop-down menus as seen on the left side of Figure 5. For each level, the user is asked a guiding question to which they use the drop-down menu to select an answer pertaining to their area of inquiry. Their response in the drop-down menu prompts the next guiding question and accordingly populates the options for the subsequent drop-down menu. Using this method of subsequent questions and moving users down to a small group of questions to choose from served a two-fold purpose: Firstly, by narrowing down the intended purpose to a small group of questions, the hope is that while none of the question in the catalogue might satisfy the user’s need, they might find some satisfactory answer in between the final group of questions displayed to them. The process for how we grouped the questions are detailed in Section 5.2. Secondly, the phrasing of each question can be quite wordy due its specificity, and as a result, wading through a
large number can be cumbersome when you have an idea of what you are looking for. Therefore, limiting the options at each level of the guiding prompts to a small number eases that burden.

Figure 5 - Example of a visualization in Easel, with the guiding questions shown on the left.

The tool was also designed to support users with data they would like to explore, but without any pre-established areas of inquiry. So, the catalogue of questions was also categorized according to the data that was being used to create their visualization recommendations. A similar set of guiding prompts was created regarding the kinds of data a user might have available.

The visualization recommendations for each question were designed by myself, according to design principles outlined in the literature. The process outlined in Munzner’s Visualization Analysis and Design was the primary basis for the workflow used here to design each recommendation. This workflow was built and refined through many iterations of creating recommendations, and Section 5.3 describes it in detail. Additionally, a user guide was created from this workflow for users who cannot find the question they are looking for in Easel’s catalogue question. The guide walks a user through how to move from an area of inquiry to a visualization catered to their needs, and in the process creating a well-phrased, answerable
question. This guide is to be published by the study’s funding partner, Higher Education Council of Ontario, and is also part of the support material in the Easel tool itself. Additionally, these users who could not find their question in our bank can request that it be added to the system by way of the issue tracker on the GitHub repository where Easel is stored. Details for how to request questions can be found in Appendix F.

Along with each visualization recommendation, a description is provided of how the data is represented, how to interpret the visualization, and a summary of the design decisions that went into the design of the recommendation. Those design decisions are especially important, since the goal for the tool is not to answer every combination of criteria for questions. Instead, by proving a wide enough range of recommendations, the hope is the design justifications for each recommendation will let users feel supported when they need to combine questions to suit their needs. A code viewer is also part of the system to display the R (a statistical programming language) code written to create the visualization. Similarly, a data-viewer is provided to look at the format the data was prior to any data-transformations to create the visualizations. Each of the recommendations is coded using data. Much of this data was fabricated for the Easel, but the data-transformation code used input data in a format that would hopefully look familiar to users. The hope is that by seeing the initial format of the data, users newer to R can better understand what the transformations the code is making to the data. Also, seeing the data would provide a goal on how to format the data if they wanted to use code provided.

Finally, Easel is made to be open source. The web-application was programed in Shiny R and the code is available on GitHub. If anyone with experience in R would like to contribute to the project, they can add to the source code and make a pull request to have it officially added. Instructions for this process can be found in Appendix F. All future changes to Easel after the release of this report will be documented in its changelog, which you can also find in Appendix F.
While Easel was built primarily with the inquirer and data-transformer in mind, considerations for all the stakeholder groups went into its design. For inquirers, Easel provides a list of well-defined, answerable questions that will hopefully expand the opportunity space of possible questions and also expedite communication to data-transformers about their needs. For data-transformers, Easel can be a resource for how to better visualize specific kinds of educational data for specific needs as well as the code for how to create them. For data-gatherers, Easel provides a link from questions to the kinds of data it requires, which will hopefully provide some guidance on what to collect and some ideas for how data being collected might be used for in the future. And for visualization consumers, Easel will hopefully promote the use of more visualizations that better present data, increasing engagement and providing reports with richer stories.

5.2 Creating the Catalogue of Question

Coming up with the list of questions for which to create visualization recommendations was a multi-stage process of filtering and rephrasing. The first step was combing through the open codes from the interviews to find references to when participants mentioned information that they either currently seek out or would like to seek out. Largely, this came from the responses of the first survey elicitation tool used in the interview phase (Appendix B). Each of those codes from the data were then phrased into a question format where possible. This conversion meant the questions would have some consistency that allowed for easier comparison and grouping.

The next step was filtering down these bank of questions to ones where visualization could play some role in answering them and filtering out questions that could not. For example, one question that was filtered out was *Is this student peer review data trustworthy?* While it's an important question to ask, it is not the kind of question for which a visualization can provide insight. This filtering process was largely done based on the researcher’s experience with
visualizations. For some of the questions that were filtered out, a more specific version of the question that could be visualized was included instead. For example, How should our program change to adapt to professional needs? was replaced with When were skills taught in an academic program? While the original asks a larger question about what decisions should be made, the replacement narrowed down to a question whose answer could help inform those decisions. Additionally, questions that were very specific to the needs of a particular participant or role were rephrased to be more generalizable. To ensure the question did not lose its intended meaning, quotes from the participant that inspired the question were linked in NVivo for when clarification was required. An example was turning How does a student being in band X [of e.g. DELNA] affect their performance in their coursework? into What is the relationship between being in a group and a student’s coursework?

Finally, when it came to designing the visualizations to help answer each question, another round of rephrasing and filtering took place. The general design process used to select each visualization is described in Section 5.3. Part of this process requires abstracting the question into what the visualization is trying to provide insight on. At this stage, certain questions were not able to be abstracted, and so were filtered out. This stage of filtering was a key part in separating questions that could be answered with data and ones that could not. Some examples of questions that were filtered out here are Which teams might have interpersonal issues based on peer evaluations? and Do our assessments map well onto outcomes? In the case of the former, there was no derived value that would act as an adequate measure. While with the latter, it would require a lot of assumptions on the part of the department.

For other questions we found that the wording was vague and could have multiple interpretations. While for most of these cases, the wording was simply clarified to reduce ambiguity, there were some instances where the multiple interpretations were all equally interesting and worth visualizing. For example, How does attendance relate to assessment
performance? could either be a way to checking if total attendance over a semester has a relation to results or if attendance to a specific class relates to results, and instead of specifying to one, the question was split into How does a student’s total attendance record relate to assessment performance? and How does attendance to a specific class affect performance on an assessment?

To have the questions in the hierarchical format that would allow for the guided prompts, they needed to first be grouped in a way that was intuitive and obvious. The process for grouping was like that of the interview coding process. Similar questions were grouped together, and when groups got too large, they were further subdivided. These groups were then grouped based on similarities or opposites. Finally, further refinement happened to the phrasing and grouping of the questions through internal testing to ensure clarity with the meaning and terminology of questions.

By the end of this process, a total of 51 questions were discovered. Some other examples of questions include: Does being in several underrepresented groups have more of an impact than just being in one?, How are students performing between assessments?, What are the redundancies in a program?, What programs/disciplines have the largest population/proportion of particular student demographic group?

These multiple stages of filtering and rephrasing brought the questions to a level of quality and specificity that allows for them to provide the support the tool aims to. Specifically, in bringing a user’s area of inquiry towards a question that can be answered without ambiguity and in a data-driven way.

5.3 Designing the Visualization Recommendations

With a catalogue of questions that the tool would provide recommendations for, one or more visualization recommendations were designed for each question. The process for visualization design was an adapted version of Munzner’s process outlined in her book
Visualization Analysis & Design, which itself was a culmination from a range of literature in information visualization.

The book is meant to act as a text book for the entire field of information visualization. As such, is quite broad in scope and applicable to many fields, each with their own requirements for data interpretation and visualization. The kind of data and tasks found in the education field only encompass a portion of what the book has guidance on. The adapted process was therefore a trimmed down version of what Munzner describes. For example, the book outlines how to work with multiple kinds of data, including tabular data, network data, spatial data, and fields. The clear majority of work done in education is with tabular data. The process accordingly only focuses on the steps pertinent to this kind of data. The adaption process was iterative, and came from creating the visualizations for the recommendations and selecting what parts of the process were found to be most pertinent. Part of the recommendations were created with a colleague, and the workflow was originally designed to be a way for the them to contribute to the process in a structured way. From that collaboration, the workflow was further refined.

There are many finer points regarding information visualization that Munzner spends considerable time deconstructing. While this section summarizes the important points, we also highly recommend the book for anyone looking for a more thorough resource on the subject.

The adapted process is broken down into three broad steps; Understanding the Problem, Assigning Attributes, and Refining the Visualization.

5.3.1 Step 1: Understanding the Problem

Before taking steps to visualize the data, it was important to understand what kind of data was being used and the kind of problem the visualization is being designed to provide insight in. Understanding these two pieces of information about the problem made designing the visualization more straightforward and helped ensure that the intended goal for the visualization was best achieved. There are two parts to understanding the problem: knowing the type of data
being used and defining the task the visualization is intended to help with. Both were done
through a process of abstraction of categories defined by Munzner.

**Data Abstraction**

The first step in the design of a visualization in response to a question or need was
identifying the nature of the data required. The available datasets and attributes have implications
on how the data can be broken down and pieced together to answer the question that has been
posed. To do this, types of data available, the context of the data, and how it was collected needed
to be considered.

The process for this abstraction started with considering what data may be available from
the individual posing an educational question. Each question required careful consideration of the
role of the individual and what data someone using the tool might have available. What data
might be available was based on the interview responses from the first elicitation tool (Appendix
B). Initially, the data needed to answer the question was identified.

The data abstraction process required identification of the following characteristics from
each category in Table 5. This was done separately for each question for which a visualization
was being recommended. Each dataset was categorized into `data types`, which are the set of items
or attributes being visualized; the `dataset type` (of which only tabular data was considered for this
project); and `dataset availability`, which are dynamic if the data can change, or static if not. `Items`
in the dataset were determined by identifying the individual unit of analysis for each question,
corresponding to a row in a dataset. `Attributes` are associated with each item, corresponding to
columns in a dataset. For example, in the case of a table of `students` and their `assessment
performances` over a course, each `student` would be an `item`, while their `performance` on each
assessment would be an `attribute`. If, instead, one were looking at summary statistics (mean,
standard deviation, etc.) of different assessments, each assessment would be an item while each
statistic would be an attribute of that assessment.
Table 5 - Data Abstraction Categories. In parentheses are the different options from which you can assign each category.

<table>
<thead>
<tr>
<th>Datasets</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Types</td>
<td>Attribute Types</td>
</tr>
<tr>
<td>(Items or Attributes: Keys/Values)</td>
<td>(Categorical, Ordinal, Quantitative)</td>
</tr>
<tr>
<td>Dataset Types</td>
<td>Ordering Direction</td>
</tr>
<tr>
<td>(Tabular Data)</td>
<td>(Sequential, Diverging Cyclic)</td>
</tr>
<tr>
<td>Dataset Availability</td>
<td></td>
</tr>
<tr>
<td>(Static or Dynamic)</td>
<td></td>
</tr>
</tbody>
</table>

Each item in a dataset has attributes associated with them, which were identified by considering the semantics of the data required to answer each question. This process involved consideration of the context of each question and which attributes were needed as Key attributes and which were needed as Value attributes. Keys are attributes that can uniquely identify an item, while values are characteristics about the item. In the example of the students and their assessment performance, a student number would be a key, while their mark on an assessment would be a value. The distinction between keys and values are not intrinsic to the data and are often driven by the Task Abstraction, which helps clarify the purpose and goal of each question or need. Keys are always connected to the items of each visualization. For simple questions, often at least one key is required for each visualization, however for more complex questions, multiple keys can be required to identify grouping attributes. When looking at groupings of students, their student number might be one key while the grouping might be another.

Values were determined by identifying what the recorded measurements or observations would be needed to answer each question. For example, determining if a class is improving over time requires measuring student performance on the skill of interest.

Once the different Data Types were confirmed, the identification of the Dataset Type was straightforward from Munzner’s descriptions. Since tabular data is the primary form of data found in the educational space, that was the focus here. This process would look slightly different
if network or geospatial data was being considered. Dataset Availability was determined from the nature of the question. Each question was characterized to whether all the data would be available at once (static) or whether the data would continuously be collected and added to the visualization (dynamic).

The attribute characteristics were clearly identified based on definitions and examples in Table 6. Note that keys can only be categorical or ordinal, not quantitative. The semantics of the data make both the attribute type and ordering direction easy to identify. For example, assessment results as percentages or GPAs can be clearly recognized as quantitative and sequential, semesters can be recognized as ordinal and sequential, and data such as program type is categorical with no ordering direction.

Table 6 - List of attribute types with examples

<table>
<thead>
<tr>
<th>Attribute Type</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Categorical (No ordering)</td>
<td>Types of fruit: Apples, Oranges</td>
</tr>
<tr>
<td>Ordinal (Ordered)</td>
<td>Shirt sizes: small &lt; medium &lt; large</td>
</tr>
<tr>
<td>Cannot perform arithmetic</td>
<td></td>
</tr>
<tr>
<td>Quantitative (Ordered)</td>
<td>Heights: 89.1 &lt; 90.4 &lt; (80.1+10.5)</td>
</tr>
<tr>
<td>Can perform arithmetic. Often measurements.</td>
<td></td>
</tr>
</tbody>
</table>

There were some attributes that were required by the visualization that was not directly available in the raw data. Instead, such attributes need to be derived. The nature of the derivation is linked to the task abstraction. Derivations are often needed for determining differences, averages, grouping, etc. and were considered additional value attributes when applicable. These attributes were categorized as well as part of the data abstraction.

**Task Abstraction**

The task abstraction process helped clarify the intentions and goals of each question or data need. By considering each question abstractly, as opposed to domain-specific, the fundamental purpose was more easily seen. This process also enabled recognition of similarities
between questions and the common use of visualization techniques. Furthermore, task abstraction helped identify the necessary transformations of data which guided the data abstraction process. The task abstraction categories can be seen in Table 7. Other than some minor context that it provided to the Data Abstraction, it was a separate process that could be done before or after.

Table 7 - Task Abstraction Categories

<table>
<thead>
<tr>
<th>Action Levels</th>
<th>Target Types</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analyze (Present or Discover: Exploration/Discussion)</td>
<td>Trend</td>
</tr>
<tr>
<td>Search (Target un/known ~ Location un/known)</td>
<td>Outlier or Extreme (Single item)</td>
</tr>
<tr>
<td>Query (Identify, Compare, or Summarize)</td>
<td>Distribution (Single attribute)</td>
</tr>
<tr>
<td></td>
<td>Dependency, Correlation or Similarity (Many attributes)</td>
</tr>
</tbody>
</table>

The task abstraction began with considering how the question or need is posed and the utility of creating a visualization to deliver a response. Utility includes improving visualizations for basic/common questions, as well as providing deeper insight into a class, program, institution, etc. Once a question is concise and focused, the task was relatively simple to classify. However, when the question was not focused, the task abstraction process helped narrow down the query to what it was really being asked.

The Task Abstraction is based on two primary concepts; Actions and Targets. In this workflow, the purpose for a visualization should be to perform an action on a target. An action can be categorized at three levels. At the highest, Analyze level, a visualization for an educational task will either be to discover new information or to present known information to others. Furthermore, Discover classification is further subdivided into Exploration when the analysis is being done by a single party, or Discussion when the visualization is used as a tool to facilitate group analysis. The two other action levels could be identified after the target is specified.

Targets are what a user is trying to determine from a visualization. It can be a Trend, an Outlier, or when more specific, a Feature. When dealing with attributes, the target can also be the
distribution of the data, or the extreme items in the data, or the target can be a dependency or correlation when there are multiple attributes. After the target type was identified, the action was categorized according to the next action level, its **Search** classifications. This required consideration of whether the identity of the target that is known prior to looking at the visualization, as well as if the location of the target among the data is known. The location often depends on the specificity of the question. For example, questions that focus on a particular data subset have known locations while generic questions tend to have unknown locations.

The lowest level, **Query** depends on the number of targets, your action could either be to identify one target, to compare multiple targets, or to summarize all the targets. For example, if goal of the visualization was to see if there is an increase or decrease in graduation rates over time, the query would be Identifying (action query) a Trend (target). While, if the goal was to see how one group of students were performing compared to the overall class, the query would be Comparing (action query) the Distributions (targets).

As was mentioned previously, this task abstraction method had the bonus of gauging the specificity of the current task. If a visualization was being created for a question that did not neatly fit into these task abstraction categories, it was likely the question needed to be specified more precisely. A question like *Are there cliques within a student team?* could not be neatly abstracted. And so instead could be asked like *Which student teams are demonstrating inconsistent perceptions?* to be more specific and more easily answered with the help of a visualization.

An area where the task and data abstraction overlap is when considering derived data, specifically in the case when the derived data reduces values; such as an average of the results of an assessment, or a bin count of students for a histogram. It was important to be clear about what target or targets were being identified or compared, so that those targets did not get reduced. For example, if the target of a visualization was a student, then any reduction of students would want
to be avoided. Example of that might include calculating the class average for an assessment or binning students for a histogram. In tabular data, like a table where each student is a row and each column is an assessment measure, a useful way to think about reduction was whether rows (students) or columns (assessments) were the ones being reduced.

Overall, the main steps for a data-type and task were:

**Data Abstraction**

1. Determined items and attributes of data.
2. Found the associated Keys and Values for the attributes.
3. Determined the attribute type and ordering direction (if applicable) for each attribute.
4. Figured out what data needs to be derived for the task.

**Task Abstraction**

1. Determined if the purpose for the visualization was to present, explore, or create discussion.
2. Determined what the target or targets were.
3. Determined whether the goal was to look for a specific target, and whether its location is known.
4. Determined whether the goal was to identify a target, compare a few targets, or summarize all the targets.

**5.3.2 Step 2: Assigning Attributes**

From the data abstraction process, a list of attributes; each that is either a key or value, and of a specific type (categorical, ordinal, or quantitative) was available. Additionally, based on the task abstraction, there might have been an order to the precedence of the attributes. For example, when looking at means and standard deviations of set of assessments, the task might either be to compare averages or spread of results. If looking at averages, then the mean would have a higher precedent, while if the spread of results was the primary focus then that attribute
would have a higher precedent. The other attribute might still be worth visualizing, but in a secondary manner.

In the example of *Do under-represented groups have the same graduating rate as highly represented groups?*, where the task is to compare trends of student graduation rates, the abstracted data table would be as seen in Table 8. Note that Year of Graduation was chosen to be an ordinal value since it was a key. Time has been discretized for this example, though for another task it could be treated as a quantitative value.

**Table 8 - Abstracted data table for question about graduation rates**

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Key/Value</th>
<th>Attribute Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic group</td>
<td>Key</td>
<td>Categorical</td>
</tr>
<tr>
<td>Year of Graduation</td>
<td>Key</td>
<td>Ordinal</td>
</tr>
<tr>
<td>Graduation Rate (Derived)</td>
<td>Value</td>
<td>Quantitative</td>
</tr>
</tbody>
</table>

With such a table, it was somewhat mechanical to come up with a first pass at a visualization with the use of visual marks and channels. A mark is a basic geometric element that depicts an item. Common marks you will see are points as with scatter plots or lines like we see in bar charts. Channels are different ways that you can control a mark's appearance. Common examples you will be familiar with are position, shape and colour. Position is the channel used in both a scatter plot and bar chart. A channel is used on a mark to represent magnitude (quantitative data) or identity (categorical or ordinal data). Of the channels available, some channels are better than others, largely according to how well humans are able to accurately read information from them. Based on empirical research, an ordered list of channels is available from most to least accurately perceivable. The list is in Table 9 for magnitude and identity channels:
Table 9 - Ordered list of Channels (from Figure 5.1 in Munzner [11])

<table>
<thead>
<tr>
<th>Magnitude</th>
<th>Identity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position on a common scale (Horizontal or Vertical)</td>
<td>Spatial region</td>
</tr>
<tr>
<td>Position on an unaligned scale</td>
<td>Color hue</td>
</tr>
<tr>
<td>Length</td>
<td>Shape</td>
</tr>
<tr>
<td>Tilt/angle</td>
<td></td>
</tr>
<tr>
<td>Area (2D size)</td>
<td></td>
</tr>
<tr>
<td>Colour luminance</td>
<td></td>
</tr>
<tr>
<td>Color saturation</td>
<td></td>
</tr>
<tr>
<td>Volume (3D size)</td>
<td></td>
</tr>
</tbody>
</table>

Notes about Channels:

Notice that position is on the top of both lists, but they are actually far superior than many of the other channels and were given special consideration and priority. Position can be a very accurate way of representing quantitative data, but by separating your marks into regions, it also is very effective in distinguishing categories. Also, some channels may interfere with each other and should be treated with care. For example, if a length channel is used on the marks in conjunction with a width channel, it might look like an area channel which would have unintended consequences on the perception of the data.

So now, with the table of keys and values, it was a matter of assigning channels to values based on whether they are quantitative or categorical and going down the list based on how many of each there are. Careful consideration was applied to ensure that the keys are still easily distinguishable, up to the extent that the task requires. Generally, with one key, your visualization would resemble a list of some kind. A bar chart can be thought of as a list of bars, each representing a quantitative value. With two keys, the visualization was likely to look something like a matrix. A heat map is the most common example, where there are rows and columns for identifying keys, while the value in each cell is represented by a quantitative channel, often
colour. With three keys, a 3-dimensional visualization could be used, but it is not recommended. Any more than three keys and more advanced techniques like recursive subdivision would need to be considered, where you have visualizations subdivided within the visualization. The majority of visualizations that were recommended only had one or two keys.

In the example of how to visualize *Do under-represented groups have the same graduating rate as highly represented groups?*, channels can be assigned as directed. There are two keys, demographic group and year of graduation. Spatial region, colour, or shape can be assigned to them. Since the task is comparison of trends over years, the different demographic would want to be in the same region for easy and natural comparison. So, colour was used for demographic group. The region channel was assigned to year of graduation. Since there is only one value, position on a common scale was used. The first pass at this visualization is a set of coloured marks that are positioned in 2D space according to a year and graduation rate.

Another aspect that was considered when assigning values is whether the visualization should be facetted or layered. Faceting is the concept of creating multiple, similar visualization beside each other separated by some key. With multiple keys, this is a good way to use a one-key visualization multiple times. This can be especially useful when the task is to compare a specific value along a key. Layering is another good approach, especially when the primary task is comparison of targets. Layering is when you display one visualization over another, often by reducing the transparency of the visualization on top. If faceting or layering, an order that makes sense for that grouping first needed to be found. There may have been an implicit ordering, or if not, an ordering was imposed. For example, when comparing groups with no implicit ordering the number of students in each group might be a possible ordering.

Overall, the main steps completed when assigning attributes:

5. Found what attributes are keys and values.
   - Determined whether values are quantitative, ordinal, or categorical.
6. Assigned channels in order based on values that are most important to the visualization.
   - Decided whether the visualization requires any faceting or layering.

7. Found or created the order of faceting or layering.

5.3.3 Step 3: Refining the Visualization

The final step was somewhat less methodical. Rather than it being about building a visualization, it was about evaluating and refining what had been designed so far. Once channels had been assigned to the respective data, the resulting visualization might have looked like a common visualization. At this point, it was important to check whether the visualization that was created is suited for the task it was intended to help provide insight for. While the common visualizations are prolific because of they have found use in many tasks, it is not always the case that those visualizations are the best suited for a given purpose.

Often, when a visualization designed for a specific task was built and displayed, the information that most readily presented itself did not suit the task that it was intended to bring insight into. If this was the case, there were two possible routes. The first was going back to Step 2 and finding other ways to represent the data in a way that more accurately and readily provides the information the question intended to find. This might have involved a few instances of trial and error. The other route was to find a task that the created visualization might be useful for, and moving back to step 1. There might have been an alternate question that was also worth asking that the current visualization provided some insight for. The advantage with this second route was that the visualization was already created. Building a visualization was a highly iterative process and it was common to redo previous steps once a final visualization was seen with the data.

If the visualization did provide the kind of information for which the task intended, all the necessary details to interpret the visualization quickly were provided. This included legends, labels, titles, tick marks on axis, text annotated on marks, and any other details that made interpretation of the visualization quicker. The formatting of the visualization, such as
background colour, axis grid lines and other aspects can have a significant impact on how easily information is readable. Often this meant trying different options and seeing what worked best, or even giving the eventual visualization consumers some options about how they consume the data.

For the example of *Do under-represented groups have the same graduating rate as highly represented groups?*, either a point mark or line mark can be chosen to represent the data (this would be the difference between a scatter plot and a bar graph). If points were chosen, the marks can be linked with lines to emphasize that marks within the same group are related. For the two position channels, there is no implicit reason in the data abstractions that dictate whether graduation rate or year of graduation should occupy the horizontal or vertical channels. However, because of convention, time occupies the horizontal channel. Doing so otherwise would make the visualization unnecessarily obtuse to viewers who are used to a certain visualization standard. Figure 6 is an example of what these choices might end up as.

Notice that since this question deals specifically with under-represented groups, it might have also been worth including an extra quantitative attribute for the percentage of population that group represents. As one would expect, the proportion would change year-to-year. Another channel could be assigned for this attribute so long as it does not interfere with the vertical channel occupied by graduation rate. Either, the current mark could be augmented or more could be added. One way of augmenting the current mark would be to use the angle channel so that each point is slice of a pie chart. Another way might be to use the horizontal position channel where the mark in each year is horizontally placed proportionally to each year region. Or a new set of marks could be created, where there is a bar chart in each year-region that represents the proportion of students. The options are plentiful, but the process provides a structured way of trying different, possibly viable approaches. The best way of finding the most effective visualization was to try different options to see what did and did not work for each task.
Figure 6 - Visualization for ‘Do under-represented groups have the same graduating rate as highly represented groups?’

Figure 7 through Figure 9 are some other examples of visualizations recommended Easel. The questions that they are used to answer can be found in the captions.
Figure 7 - Recommendation for ‘How are student ratings for other students changing over time?’
Figure 8 - Recommendation for 'How are students from a prior course performing now?'
Figure 9 - Recommendation for 'What are the typical selection of elective courses for students of a particular demographic group?'
Chapter 6
Discussion

Overall, the thesis accomplished its overall goal of to finding and supporting ways to promote the influence that educational data has in the process of program improvement. Higher education has a problem with how much educational data is used in their goals for program improvement. In addition to organization challenges regarding faculty engagement and knowledge of the assessment process, members of higher education institutions would want more tools for analysis to improve their assessment practice. Through the model building process, the research identified key barriers and beliefs around the educational data assessment cycle. From those, we were able to find areas in which all four of identified stakeholder groups could use support and built Easel, with some success, as a way to provide that support. Specifically, by providing questions to think about with recommended visualizations that would aid in answering them and in general, hopefully reducing the time investment required to find a more effective method of analyzing or communicating the data you have available. However, there were areas where the study had to make decisions about scoping that limit the generalizable value of the deliverables.

There are limitations in the participant sampling. Firstly, most of the participant pool were people who work quite extensively with data or are already committed to the assessment process. There are however, other educators that have their doubts about the usefulness of data and the possible benefits of the overall assessment process. These stakeholders who are less engaged in the assessment process were a major topic of discussion during the interviews and it would have been beneficial to get their feedback about what their main concerns were and their concerns on what would increase their engagement. In the interest of finishing the thesis in the original timeline, I decided to limit the scope to beliefs of stakeholders who were already trying
to use educational data. Additionally, feedback for the tool in Phase 3 could have been sent out to a larger pool to get a more diverse set of responses. The survey was only sent to the list of possible participants from the interview and focus group phase. In hindsight, that was a limitation on the pool that did not add much to the study. The GitHub issue tracker should provide some way of users outside of the study to provide some feedback about the tool.

We also purposely decided not to talk to students. There has been literature demonstrating the value in using visualizations to reflect student performance data back to students [39], [40]. However, we felt that it would significantly increase the amount of data required to develop an adequate understanding of the beliefs and attitudes of students with educational data. We assumed that those beliefs would look very different from those of educators, and so excluding them from the study would not have a major impact on the benefit that included stakeholders would get from the tool. Additionally, our interview process relied heavily on the participants’ lived experience and we thought it unlikely that many students would have a wealth of experience reflecting on data in their education. This would be an important avenue to pursue further given the overall goal of improving the student learning experience.

With regards to the analysis, the goal of the study from the beginning was to ultimately capture rich qualitative data around educational data usage to find an avenue for support surrounding visualization, at first in the form of a framework and then a model. An ideal conceptual framework for the analysis would have been one that guided the analysis of data from individual participants to a model that would inform the requirements of the support tool. Unfortunately, our literature search did not yield any frameworks suitable for that purpose. Computer science does have some guidance in the form of requirements engineering and elicitation, but the data analysis process was not found to have the level of rigor found in qualitative research methodologies. So, while grounded theory is primarily geared towards building full-fledged frameworks, we used a part of Charmaz’s grounded theory methodology to
create and fill our model. Overall, I believe that using the qualitative methodology made for a better support than if we had approached this from a more traditional software design approach. There were aspects of the participant responses that would not have emerged if I had not employed the grounded theory approach that would go on to affect the support tool. However, I had to draw the line between using the structure of requirement engineering and up to the focused coding methodology from grounded theory and stop before the theoretical coding stage. This was based purely on my own understanding of both fields, rather than recommendations from any literature. Given a similar project moving forward, I would opt for an approach that could be better justified by the literature in both fields.

There were a few topics that came up frequently in the interviews and focus group that were not fall into the scope of the study’s deliverables, but could still be areas for support. The largest of which was around data collection, dissemination, and access. The way data is stored can vary significantly between departments, institutions, and especially individuals. So we did not see many opportunities in finding a support that would useful to many stakeholders in a generalizable way. It is certainly a struggling point that seemed universal among the participants of the focus group: Knowing how to get the best data to answer a question and knowing what data was available to be used. This would be a worthwhile avenue for institutions to pursue given the amount of data that could be accessible. It would require significant effort and planning, but would open many opportunities to make that data more readily useful to the educators trying to improve their practice. Hopefully our model would provide some initial guidance about the stakeholders and their beliefs.

Another related topic that emerged was having a central hub not just of data, but other data driven initiatives that were happening around an institution. There are many people struggling with similar questions around areas like accreditation, engagement and quality assurance. However, with no group already set up to discuss these initiatives they all end up
working alone. Institutional support units like centers for teaching and learning provide some support and direct inquirers to other doing similar work, but it is still done in a very ad hoc method. Investing resources into creating such a community of practice would likely see effective usage of educational data go up.

The research was primarily conducted in the scope of Queen’s University. Further research would be required to determine the applicability of the model outside of this scope. The study attempted to get viewpoints from outside the university, but there was a significantly less interest. For the few interviews that were held with participants outside of the institution and province, there were no explicit discussions that discussed how their experience might contrast with outside their institution or province. As a result, it is difficult to say how much of the findings are limited to the scope of this institution. Many of the discussions revolved around interactions among and between faculty, administration, and support staff. While the topics seemed common across departments ranging from engineering and liberal arts, the major practices and underlying beliefs might differ in other institutions or provinces.

There were many scoping decisions that went into designing Easel. Specifically, there were sets of questions that I chose to leave out of the catalogue of question for reasons other than those reported in the filtering process. Firstly, there was some discussion of faculty perception or evaluation questions, such as How are our faculty doing? or questions that compare publication count with teaching results. These were excluded since there was some concern that that these are not questions that should be looked at and it was not directly beneficial to the goal of improving the student experience. Other questions that were avoided were ones where the scope would have been too large, as in on a multi-institution level. Other questions where the data required would be unrealistic to have collected. Also, certain questions did fit our criteria, but the visualization was out of the scope of our technical ability, such as questions looking at student team results and perceptions. In some of these cases, there are entire dedicated projects trying to find effective
ways of visualizing those questions. The goal for this thesis however, was to provide educators and staff supporting them an initial foray into the broader field of visualization they might not yet be exposed to. Each of these excluded questions could be answered by someone with adequate experience if the need arises.
Chapter 7

Conclusions

The thesis produced, firstly, a model of how visualization of educational data can be used towards institutional and program improvement in a university setting. Based on the practices and interactions of participants, the study defined and verified the existence four major stakeholder groups that interact with each other in the process to move educational data towards program changes. Secondly, Easel was created as a web-application to support instructors and administrative staff in their endeavours to increase and promote educational data usage and assessment processes.

The model was used here as a basis for building Easel, but could be used by other researchers looking to build supports to promote educational data usage. The main takeaways are that there is a current lack of support for educators looking to have educational data play a larger role in their instructional practice and that the data needs to be more engaging to the daily practice of faculty for the assessment process to be more widely adopted. The model also suggests a number areas for future research, including creating a central hub for data, organizing communities of practice around data usage, or comparing ideologies at other institutions. For each of these, the model could be used a preliminary point of entry for further research.

Easel will have its first official release alongside the release of this thesis. After, it will be updated with improvements. Some of these are already planned, while others might be suggested from usage. In the short term, there were issues raised about the interface for which better solutions could be implemented. In the long term, some improved functionality such as interactive visualization recommendations would like to be added. Details about changes after the release of this report can be found in the Easel change log. Instructions for how to access it can be found in Appendix F.
The findings from the interview and focus group identify clear areas where the process of moving educational data towards program improvement can be supported. However, in its current form, Easel is not convincing to some users in its ability to support their practice, possibly because they not understand the tool’s intended usage. While, there are some other users who seem to see Easel as a promising support to their usage of educational data. So, the hope is that the latter group can find value with in the near future as continued improvements work toward expanding Easel’s value to a larger audience.
References


Appendix A
General Research Ethics Board approval for study
May 19, 2016

Mr. Ajay Sivanand
Master’s Student
Department of Electrical and Computer Engineering
Queen's University
Kingston, ON, K7L 3N6

GREB Ref #: GELEC-114-16; Romeo # 6018201
Title: "GELEC-114-16 Framework for Visual Analytics of Learning Outcomes Data to Support Institutional and Program Improvement"

Dear Mr. Sivanand:

The General Research Ethics Board (GREB), by means of a delegated board review, has cleared your proposal entitled "GELEC-114-16 Framework for Visual Analytics of Learning Outcomes Data to Support Institutional and Program Improvement" for ethical compliance with the Tri-Council Guidelines (TCPS 2 (2014)) and Queen's ethics policies. In accordance with the Tri-Council Guidelines (Article 6.14) and Standard Operating Procedures (405.001), your project has been cleared for one year. You are reminded of your obligation to submit an annual renewal form prior to the annual renewal due date (access this form at http://www.queensu.ca/traq/signon.html; click on "Events"; under "Create New Event" click on "General Research Ethics Board Annual Renewal Form for Approved Studies"). Please note that when your research project is completed, you need to submit an Annual Renewal Form in Romeo/traq indicating that the project is 'completed' so that the file can be closed. This should be submitted at the time of completion; there is no need to wait until the annual renewal due date.

You are reminded of your obligation to advise the GREB of any adverse event(s) that occur during this one year period (access this form at http://www.queensu.ca/traq/signon.html; click on "Events"; under "Create New Event" click on "General Research Ethics Board Adverse Event Form"). An adverse event includes, but is not limited to, a complaint, a change or unexpected event that alters the level of risk for the researcher or participants or situation that requires a substantial change in approach to a participant(s). You are also advised that all adverse events must be reported to the GREB within 48 hours.

You are also reminded that all changes that might affect human participants must be cleared by the GREB. For example, you must report changes to the level of risk, applicant characteristics, and implementation of new procedures. To submit an amendment form, access the application by at http://www.queensu.ca/traq/signon.html; click on "Events"; under "Create New Event" click on "General Research Ethics Board Request for Amendment of Approved Studies". Once submitted, these changes will automatically be sent to the Ethics Coordinator, Ms. Gail Irving, at the Office of Research Services for further review and clearance by the GREB or GREB Chair.

On behalf of the General Research Ethics Board, I wish you continued success in your research.

Sincerely,

John Freeman, Ph.D.
Chair
General Research Ethics Board

c: Dr. Brian Frank, Faculty Supervisor
   Dr. James Kraupp, Collaborator
   Ms. Natalie Simper, Research Associate
March 22, 2017

Mr. Ajay Sivanand  
Master’s Student  
Department of Electrical and Computer Engineering  
Queen’s University  
Kingston, ON, K7L 3N6

Dear Mr. Sivanand:

RE: Amendment for your study entitled: *GELEC-114-16 Framework for Visual Analytics of Learning Outcomes Data to Support Institutional and Program Improvement; TRAQ # 6018201*

Thank you for submitting your amendment requesting the following changes:

1) Focus Group Protocol (v. 2017/03/14);

2) Revised Letter of Information and Consent Form for Second Phase (v. 2017/03/21);

3) Revised Recruitment Email (v. 2017/03/14).

By this letter, you have ethics approval for these changes.

Good luck with your research.

Sincerely,

John Freeman, Ph.D.  
Chair  
General Research Ethics Board

c.: Dr. Brian Frank, Supervisor  
Dr. James Kraupp, Collaborator  
Ms. Natalie Simper, Research Associate
June 29, 2017

Mr. Ajay Sivanand
Master’s Student
Department of Electrical and Computer Engineering
Queen's University
Kingston, ON, K7L 3N6

Dear Mr. Sivanand:

RE: Amendment for your study entitled: **GELEC-114-16 Framework for Visual Analytics of Learning Outcomes Data to Support Institutional and Program Improvement; TRAQ # 6018201**

Thank you for submitting your amendment requesting the following changes:

1) To run a survey with people who have participated in the study so far as well as new participants who have not yet been part of the study; 15-20 more participants;

2) Survey Questions (v. 2017/06/26);

3) Consent Form – Survey (v. 2017/06/27);

4) Letter of Information – Survey (v. 2017/06/27);

5) Recruitment Letter for people who have already consented to be part of the study (v. 2017/06/26);

6) Recruitment Letter for people who are not yet part of the study (v. 2017/06/26).

By this letter, you have ethics approval for these changes.

Good luck with your research.

Sincerely,

Anne Godlewska, Ph.D.
Acting Chair
General Research Ethics Board

c.: Dr. Brian Frank, Supervisor  
    Dr. James Kraupp, Collaborator  
    Ms. Natalie Simper, Research Associate
Appendix B

Questionnaire for Exploratory Phase interviews

Participants: Faculty members with experience with either learning outcomes and program evaluation or management of outcomes assessment processes

Duration: 60 minutes

Intro:
“Hello, my name is Ajay. Thank you for participating in this interview. We have asked you participate so that we can better understand how collected data is being used to facilitate program improvement. With this data, we will eventually build a tool that can support members of faculties in the interpretation of their data. This interview will run approximately one hour.

“As mentioned in the letter of information, this interview will be recorded so that I can go through the responses at a later time. At any point you feel uncomfortable, you are welcome to end to the interview. If at any point between now and [three months from now], you are uncomfortable with the responses provided, please let me know by e-mail and your participation and responses will be removed from the study.”

Questions:
[Underlined words are those that might be adapted to words used by the respondent.]
[Highlighted questions will only be asked to participants that the questions are relevant to.]
1. What is your role at your institution, faculty, or department?
2. When you review student results, do you find that you are able to use the results to support improvements in student learning?
3. Are you involved in the management or interpretation of data?
4. What kinds of data do you have access to and of those, which do you use? [A list of common kinds of data will be provided for them to check off.]
   a. While moving through the checklist, could you please provide some insight into how you use or plan to use that data?
5. In working with this data, do you use them to inform decisions to improve learning?
6. Does visualization of the data currently play a role in your interpretation process?
   a. From this list of visualization, how would you rate their usefulness? [Provide them with a number of visualization which they can rank].
   b. What relationships are you looking to identify with these visualizations?
7. Do these decisions link into higher course/program improvement goals?
8. How would you characterise these goals as specific to you? What were the drivers for initiating these goals?
9. Do you feel you are meeting these goals?
10. Were there challenges you faced in interpreting the data to achieve those goals?
11. What tools or techniques do you currently use to help you in interpreting these data?
12. As we mentioned, the ultimate aim of this project is to build a tool that can support faculty members with their data. We are working on a framework that will inform the design of this tool. [A current version of the framework (Tool 3) will be shown and explained accordingly.] Do you feel like there is anything missing from this framework or anything that you would add to this framework?
13. Finally, is there anyone you have worked with or heard about that you believe might be a beneficial participant to this study? If so, could you describe their role to your best understanding.

14. Is there anything else you’d like to share about understanding data and student achievement?

**Concluding remarks**

“We appreciate the time you’ve taken to provide us with your thoughts and views. Are there any questions before we wrap up?”
### Interview Elicitation Tool 1:

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Interview Elicitation Tool 2:
Program Improvement Goals

Drivers
- Institution/Board
- Faculty
- Accreditation Body

Stakeholder
- Administration
- Support Unit
- Instructor

Scope
- Institution | Faculty
- Department | Course
- Student

Available Data

Type
- Ratio
- Ordinal
- Categorical
- Qualitative

Measuring
- Learning
- Engagement
- Participation

Direct/Indirect

Formative/summative

Purpose
- Correlation
- Comparison
- Prediction

Analysis Type
- Temporal
- Topical
- Network

Key
- Courses
- Outcomes
- Students

Examples

LMS Log Data
- Login occurrence
- File access
- Forum posts

Assessments
- Grades
- Word frequency

Curriculum
- Program tree
- Learning outcomes

Visualizations

Constructive Realignment

Histogram

Tree Map

Network Diagram

Heat Map
Appendix C

Focus Group Protocol and Materials for Model Building Phase

Number of Expected Participants: 8

Runtime: 1 hour

Equipment: Identifiers for participants, audio recorder, focus group supplementary materials (paper and writing utensils for participants, self-adhesive data hurdles). Participants have been asked to bring laptops, or laptop is provided.

Protocol:

Time

0:00 Hello and Welcome,

My name is Ajay. Thank you all for agreeing to participate in this focus group. As you might remember from the letter of information, the purpose of our project is to build a support that can help members of faculty and university support staff achieve their various data needs with the help of visualizations. We have identified all of you as having some experience working either directly with data, or supporting the usage of data towards the goal of improving the student experience.

In the first phase of our study, we interviewed a variety of faculty and staff whose roles related to data, working in and outside the university. My goal for this focus group specifically is to validate and discuss some of our findings from the interviews, specifically around our how we interpreted data being used, by whom, and the attitudes surrounding them. The format for the focus group will be an introduction exercise, followed by three activities, each with an accompanying discussion. In total, this session will run just under 1 hour. Each activity has an accompanied set of instructions or supplementary material. I have provided areas for you
to take notes. These are meant purely for your own note taking purposes. I do not plan on using any of these notes in my study, so there is no need to make any notes understandable.

As you know (from the letter of information) I will be recording this session so that I can go through the responses at a later time. If anyone feels that they do not want to be recorded please let me know now, or alternatively if after the session, you are not comfortable with the responses given, please let me know, and your responses will be excluded.

Are there any general questions about the project or the format of the focus group before we begin? Additionally, at any point, if you feel like you need clarification about any terms being used, feel free to ask.

0:05  **Introductions**

*Purpose of activity: Through abstracting their own roles, it will hopefully prompt some memories of their experiences with data to get them into a mindset about data-usage.*

I would like to begin with an introduction exercise for everyone to get to know each other and roles at the university. Please take 3 minutes to think about your role at the university and the kinds of data you work with. There are some questions on the provided handout to help guide you. After, I will ask you to provide a brief introduction along those lines.

0:06  [3 minutes to work alone]

0:09  Now, I would like everyone to go around the table and introduce themselves.

[~30 seconds per participant (4 minutes)]

**Actor Groups**

*Purpose of activity: participants define their roles somehow and just give feedback directly about what we have in terms of Clients, Data Workers, and End Users. So use this as a way to define those definitions better and more concretely based on the participant experience.*
I am hoping that working on your introductions will have prompted some memories of how you might interacted with each other, or people of similar roles. With that, I’d like to move to the first activity. [Showing them the purpose statement we have, with actor groups]. We are calling all the people that will directly interact with the toolkit or byproduct as ‘actors’. From the interviews, these are the three groups that we were able to sort from the data and their corresponding roles. I would like you to please determine where you see yourself in these groups, how the activities you perform match up with the group and whether you think in your experience there are any participants to this process that are missing?

[~5 minute discussion, while I am taking a common, displayed set of notes about what is being said.]

**Toolkit Requirements**

*Purpose of activity: get a sense of the common hindrances when trying to use data.*

For this next activity, I would like you all to imagine you were given the task or are supporting the task of using data for one of the purposes outlined on the Activity #2 paper. In the package, you will find a list of “hindrances” or hurdles [examples can be found at end of protocol] we identified from our interviews. Additionally, you will find a diagram of an axis from “Serious issue” to “Not an issue”. When working with a problem like this, what would you say has been the biggest hurdle? Please arrange the hindrances along the diagram, writing the hindrance identifier along the axis. You can set aside ones that you feel do not apply. I will give you five minutes to arrange the hurdles on your axis by writing down where you think they fit.

[5 minutes to rank]
0:27 Now that you’ve got an idea of how you feel these hindrances affect your work, could you please arrange them accordingly on this larger diagram by sticking them on. [A large poster will be setup with the same axis for participants to stick the hurdles on.]

0:28 [2 minutes to paste on wall]

0:30 [Have participants discuss how their rankings might be different and what they see as solutions or ways to alleviate them. Hopefully through the difference of opinions, there will be some interesting discussion about what the most important hurdles are and to whom.]

0:40 **Toolkit Usability and Usefulness**

*Purpose of activity: check if the proposed process for the toolkit is something that they find useful. Additionally, check if the breadth of our scope captures the majority of their needs.*

Finally, for our final activity, we have created a functional mock-up of what we would like the final support toolkit to do. From my interviews with several of you as well as other participants, we have consolidated a list of questions (or what we are calling “data-needs”) that you might encounter in your practice that we think visualizations can help resolve, given the appropriate data. Examples of these are the questions from the previous activity.

0:41 From my previous correspondence with you, I have asked you to think about a problem or question you have faced with the data. I am going to give you 2 minutes to articulate the that as a data-need the best you can. Some examples are shown on screen.

[2 minutes]

0:43 We have created an interactive mock-up of the functionality that we would like our eventual toolkit to provide. Before getting to that though, I would like to mention that this is still a very early stage of toolkit, using software intended for other purposes. As such, it is not entirely indicative of what we are imagining, however, any feedback is appreciated.
In your package, you will find a URL at the top of sheet for activity #3. Once you have navigated to the toolkit, I would like you to pick one of the questions from the list and work through the toolkit to see if can arrive at it. In the package, you will find a package with a brief questionnaire that I would ask you to fill out and think about as you are using the toolkit. I will give you five minutes to interact with the toolkit. Please feel free to ask any questions while you’re doing so. The visualization examples you see in your package correspond to ones we recommend from the toolkit.

[5 minutes for them to interact with the toolkit, while filling out checklist.]

Now that you’ve had a chance to interact with the toolkit, what are some thoughts that arose? Were there any major gaps you found in the process? Does the process seem clear and understandable to follow? And finally, would a support of this nature be ultimately useful to your own work?

[<10 minute discussion]

Wrap Up

I’d like to take these last few minutes to thank you so graciously for your time. The responses from this will have a direct impact on the toolkit and give us the confidence that we are putting our time towards something that will be useful for members of faculty and staff such as yourself. Are there any questions that any one has before we wrap up?

Thank you again.
Activity 1:
Purpose of our project:

To help **data-workers** create visualizations for the **data-needs** of **clients** for purposes of communicating to and analyzing with **end users**

Actor Groups*:

- **Client**: Users with goals and/or questions requiring data to achieve or answer  
  - Includes: Instructors, Administrators, Educational Developers
- **Data-Workers**: Users with a background working with and/or gathering data  
  - Includes: Teaching and learning support
- **End User**: Users viewing or analyzing with visualization  
  - Includes: Clients, students, accreditors, public

* One person can be any combination of one to all three.

Activity 2:
Example of Hurdles that will be provided:

A. Coming up with questions of this nature. As in questions that, when you answer them, you help develop the course or student experience. If you find yourself saying “I don’t know what questions to ask”

B. Finding a process or method to answer the question in a data-driven, accurate way.

C. As someone with a goal requiring data: communicating what you want to find to someone who can help. Or as someone who can help: understanding what someone with a goal wants to find.

D. Gaining access to or gathering the appropriate data to answer such questions.

- [Blank one for them to write in]

Axis to be placed on:

<table>
<thead>
<tr>
<th>Not an Issue</th>
<th>Serious Issue</th>
</tr>
</thead>
</table>

123
Appendix D
Survey questions for Feedback Phase

Feedback for Easel: VRS

Description and Scenario

Using Easel: Visualization Recommendation System
Please find our visualization recommendation system, Easel, at this address: http://shiny.engineering.queensu.ca/easel/. Take some time to read the instructions and try the system. In the following page of the survey, we will ask you to work through the system in a guided way.

Please Note: The system is still in development, so there are portions that are still not entirely complete. Sorry for any inconveniences this might cause.

Rate how you feel about this statement:
I understand the purpose of Easel: Visualization Recommendation System from the instruction page.

- Disagree (1)
- Neutral (2)
- Agree (3)
- Strongly Agree (4)

Additional thoughts:
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________________________________________________________________
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Role Identification

The recommendation system was designed on the premise that there are often multiple people involved in the process of working with educational data, each with different skillsets and designated roles. Easel was designed to provide support for tasks in each individual’s respective role, as well as to expedite the communication process between these roles by creating a common set of examples that anyone in the process can point to. Here we are looking to see where you might fit into our model. From our research, we have determined four main groups of stakeholders.

• Firstly, there are the **inquirers**, who are the educators or administration with either questions that they require educational data to answer or information that they are trying to use data to communicate.

• Then there are **data-gatherers**, who collect, sort through and organize data from various sources.

• Then, there are **data-transformers**, who use the gathered data to help the clients move the raw data into a form that is useful for the client's needs.

• And finally there are **visualization consumers**, who only sees the data once visualized or being reported on, often in reports or in dashboards.

Primary Role

While a single person can be many of these roles, please identify which group you would identify as your primary role. Choose One:

- Inquirer (1)
- Data-Gatherer (2)
- Data-Transformer (3)
- Visualization Consumer (4)
Secondary Role

Do you identify with any of these roles in a secondary capacity? Choose as many that apply:

☐ Inquirer (1)

☐ Data-Gatherer (2)

☐ Data-Transformer (3)

☐ Visualization Consumer (4)

In working with educational data, are there any aspects of your role that you feel might not have been identified among our stakeholder groups? Additionally, are there any other comments you might have about the grouping of roles?

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________________________________________________________________
In the email invitation, you were provided with a survey code. Please select the survey code you were given:

- I wasn't given one. (80)
- 0529 (81)
- 6538 (82)
- 2743 (83)
- 8906 (84)
- 4565 (85)
Guided Easel Trial (Program Coordinator)

Once you have had a chance to try Easel, we would like you to try and use the system to support the following scenario: Imagine you are a department program coordinator and you have been tasked with providing answers for the following questions.

Please select all the scenarios you were able to find an adequate recommendation for from Easel.

☐ Task 1: You want to know what kind of applicable, non-core courses are being taken by the international students in your program. (1)

☐ Task 2: Your program has a number of options, each of which includes courses focusing on communication taught outside your department. Additionally, the students can optionally be in a co-op program or not, whichever option they are in. You have just tested all the students on their communication skills in a department run course and would like to see how each discipline is doing as well as whether the students in co-op are doing better or worse. (2)

☐ Task 3: The students in your program have taken a standardized assessment each year and you would like to see if there are students who are performing a lot better or worse throughout the assessments. (3)
Guided Easel Trial (Program Coordinator)

Once you have had a chance to try Easel, we would like you to try and use the system to support the following scenario: Imagine you are a department program coordinator and you have been tasked with providing answers for the following questions.

Please select all the scenarios you were able to find an adequate recommendation for from Easel.

- Task 1: You want to know what kind of applicable, non-core courses are being taken by the international students in your program. (1)

- Task 2: Your program lets students complete their first two years at a number of affiliated colleges. You would like to compare how students are doing in their third year based on where they completed their first two years. (2)

- Task 3: An instructor of a Statics II wants to know if they should watch for specific students based on their assessment results from Statics I. You happen to have the grades from the previous course and the instructor has just run a quiz early on in the semester. (3)
Guided Easel Trial (Course Instructor)

Once you have had a chance to try Easel, we would like you to try and use the system to support the following scenario: Imagine you are a course instructor for multiple courses and you are looking to find answers for the following questions.

Please select all the scenarios you were able to find an adequate recommendation for from Easel.

☐ Task 1: You are teaching an interdisciplinary course with students from many academic backgrounds. You want to see how all the groups are performing and specifically whether they are all improving, or whether there are any groups that might require more attention. (1)

☐ Task 2: You teach a project course where students are in teams of 5. They complete peer-evaluations at the midterm and end of the semester. You have noticed that certain students have had trouble with their teams and would like to see how the ratings from team members has changed between evaluations. (2)

☐ Task 3: The Signals courses you teach is split into two courses taught in the fall and winter. You would like to see how the class’ knowledge (based on assessments) compares from the end of the first course to the end of the second. (3)
Guided Easel Trial (Course Instructor)

Once you have had a chance to try Easel, we would like you to try and use the system to support the following scenario: Imagine you are a course instructor for multiple courses and you are looking to find answers for the following questions.

Please select all the scenarios you were able to find an adequate recommendation for from Easel.

☐ Task 1: You teach a project course where students are in teams of 5. They complete peer-evaluations at the midterm and end of the semester. For certain teams, you are interested to see how the team members' opinions have changed between evaluations. (1)

☐ Task 2: You are teaching Biology 201 and have the grades from the students coming from last year's Biology 101. You would like to be able to see what subset of students from last year's course you will be teaching. (2)

☐ Task 3: You are teaching an online course and to improve retention and course interaction, you have implemented a reward system that provides 'badges' to students who are achieving and maintaining a certain set of criteria. You would also like to be able to quickly see how many students are achieving each criteria. (3)
Guided Easel Trial (Data Worker)

Once you have had a chance to try Easel, we would like you to try and use the system to support the following scenario: Imagine you are in a staff position at the university that supports instructors and administrators in their practice and you have been tasked with providing answers for the following questions.

Please check the scenarios you were able to find adequate recommendation for from Easel.

☐ Task 1: A national organization collects data from multiple institutions for a national survey. As part of it, they provide the data for your university back to you. Along with this year’s data, you have been asked to display how your institution is performing over the years for a discussion at the office of the dean. (1)

☐ Task 2: Your department is preparing for their accountability review. For the report, you are looking for a richer way to present the information of how many students are above and below the GPA to receive honours in your program. (2)

☐ Task 3: You work at the university unit that handles the gathering of administrative data across the university. The equity office has asked you to look into and find a way of presenting how graduation rates differ for underrepresented groups in the past ten years. (3)
For each of the questions the scenario tasked me with, I found the order of guiding prompts (drop down menus) to be intuitive and obvious to arrive at the question.

<table>
<thead>
<tr>
<th></th>
<th>Disagree (1)</th>
<th>Neutral (2)</th>
<th>Agree (3)</th>
<th>Strongly Agree (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1 (1)</td>
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<tr>
<td>Task 2 (2)</td>
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<td>Task 3 (3)</td>
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Additional Thoughts:

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End of Block
Open Feedback

General System Feedback

In this section, please describe how you feel about the kind of support that the recommendation system provides. We will have separate questions after about your thoughts on the interface. For each question, please rate how you feel about these statements and provide some thoughts about your experience using the recommendation system.

With regards to the guided prompts (the drop down menus) to arrive at a data-question, the overall organization and workflow of how the system is set up is appropriate for the system's purpose.

- Disagree (1)
- Neutral (2)
- Agree (3)
- Strongly Agree (4)

Additional Thoughts:

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The terminology used to describe educational concepts is familiar and understandable.

☐ Disagree (1)
☐ Neutral (2)
☐ Agree (3)
☐ Strongly Agree (4)

Additional Thoughts:
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Overall, this seems like a useful support tool for my practice.

☐ Disagree (1)
☐ Neutral (2)
☐ Agree (3)
☐ Strongly Agree (4)

If rated highly, can you describe how you might find this useful. If rated poorly, why do you feel it might not get used?
________________________________________________________________
Were there any aspects of the recommendations system that were particularly confusing or hard to understand or navigate?

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Are there any aspects of the recommendation system’s interface that you would like to see changed?

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Are there any visualization questions or branches of visualization questions that you would like to see as part of the recommendation system?

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End of Block
Ending Block

Thank you for participating in the study.

We greatly appreciate you taking the time to try what we are creating and hope that you found it interesting enough to be worth your time. Your feedback will be used to create the final version of the recommendation system and help ensure that we can maximize its usefulness.

Further Contact

This survey is anonymous and we do not require this, but if you would like to be contacted when we release the final version of the recommendation system, please provide your email here:

________________________________________________________________
Appendix E
List of Visualization Resources

These are some resources of visualization examples. They can be useful as a resource to find
interesting and novel ways of visualizing data.

1. Raw Graph (http://app.rawgraphs.io) Works with your CSV files and provides
   visualizations that will get populated with the data you upload. The has a neat interactive
   way of choosing the different channels for the data in each visualization. Try their app
   with the "Try our samples" button at the link.

2. The Data Visualisation Catalogue (http://www.datavizcatalogue.com/) Uses a hierarchical
   format to show you an array of visualizations that are suitable for different kinds of tasks.
   With each visualization, there is a thorough description of the visualization and a
   breakdown of its 'anatomy'.

3. Data Visualization: Visualization Types (http://guides.library.duke.edu/datavis/vis_types)
   A list of visualizations around the web and academia sorted according to Scheiderman's
   taxonomy.

4. A Tour through the Visualization Zoo (https://queue.acm.org/detail.cfm?id=1805128) A
   significant survey of "sophisticated and unusual" techniques for visualization with a
   thorough description with benefits and alternatives. Each example has an interactive
   version as well.

5. Visualisation :: Choosing a chart (https://github.com/widged/data-for-good/wiki/Visualisation-:::-Choosing-a-chart) A list of other resources that categorize and catalogue visualizations.
Appendix F

Easel Repository Information

Easel is stored on GitHub, where we will continue to update it after the release of this report. The maintainer is Dr. Jake Kaupp. Easel’s official repository is stored at https://github.com/jkaupp/easel. From there, you can view the Shiny code we used to build the app.

All future changes to Easel will be recorded in the official change log (https://github.com/jkaupp/easel/CHANGELOG.md).

If you would like to request a new question be added to Easel, you can use Issue Tracker (https://github.com/jkaupp/easel/issues). Click the New Issue button. Use the title “New Question Request” and use the comment field to explain the question like included in the app. We cannot guarantee that the question will be included. If we are able to create a visualization for it however, we will do our best to add it to the app. NOTE: You will need an account with GitHub to do this.

If you would like to add features to Easel, you can do so by Forking the repository, making your changes and creating a Pull Request. You can find more information about Forking and Pull Requests at GitHub’s help pages:

Forking a Repository (https://help.github.com/articles/fork-a-repo/)

Pull Requests (https://help.github.com/articles/creating-a-pull-request/)