Integrating User-Centred Design Approaches for a Course Design Framework for Interdisciplinary Studies in Teaching and Learning

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Abstract

This paper proposes the theoretical context for a course development framework to address the specific needs and challenges of teaching and learning in interdisciplinary studies (IDS). User-centred design (UCD) principles are used for this development process. Traditional course development frameworks provide a helpful guide in terms of setting out the steps necessary for successful course development. While these steps will inform the course development framework being proposed here, several alterations will be made. The unique demands of teaching and learning in IDS require skill development necessary for doing advanced interdisciplinary work and eschews linearity. The key feature of this framework is the inclusion of intentional iterative phases throughout course delivery that will allow for adaptation based on the incorporation of feedback in a variety of forms: self, instructor, peer, stakeholder (e.g., from service-learning supervisors), and cognitive skills assessment tools. The adaptive nature of this framework should meet the demands of the growing area of IDS.

Introduction

In this paper, a course development framework is being proposed to address the specific needs and challenges of teaching and learning in interdisciplinary studies (IDS). User-centred design (UCD) principles are used for this development process. Traditional course development frameworks

provide a helpful guide in terms of setting out the steps necessary for successful course development. While these steps will inform the course development framework being proposed here, several alterations will be made. Traditional course development frameworks often focus heavily on curation and transfer of information, knowledge, and certain domain-specific techniques, and they often espouse a linear approach to development and implementation. The unique demands of teaching and learning in IDS require skill development necessary for doing advanced interdisciplinary work and it eschews this type of linearity. The key feature of the course development framework proposed in this article is the inclusion of intentional iterative phases throughout course delivery that will allow for adaptation based on the incorporation of feedback in a variety of forms: self, instructor, peer, stakeholder (e.g., from service-learning supervisors), and cognitive skills assessment tools. The adaptive nature of this framework should meet the demands of the growing area of IDS.

Two key factors pose a major challenge to developing core IDS courses and program curriculum: the challenge IDS poses to the epistemological status quo in academia, and the diversity of practitioners within this domain. Both challenges are closely intertwined with the approach to knowledge inherent in IDS. Although the concept of interdisciplinarity remains somewhat ambiguous, one overarching theme is that interdisciplinarity is necessitated by complexity, and addressing complexity requires non-reductionist methodologies and integrative insights (Menken and Keestra, 2016; Newell, 2001; Repko et al, 2017). The rise of interdisciplinarity within academia and the consequent increase of demand for IDS programs is being driven by, among other things, the increasing complexity of society and the assorted entailments of this complexity (Menken and Keestra, 2016; Repko et al, 2017), and addressing such complexity is demanding an epistemic turn to the whole as opposed to the more traditional epistemological approach of focusing primarily on individual and discrete parts (Capra, 1996; Menken and Keestra, 2016). Turning to the whole entails a re-direction of attention from examining objects to a focus on processes and relationships (Capra, 1996, 2014). IDS is a content agnostic process, and IDS curriculum developers are thus compelled to foster the tools relevant to this epistemological shift.

The content-agnostic descriptor of IDS is reflected in the diversity of students often found in IDS programs, as such programs are typically designed to accommodate a wide array of students from a variety of disciplinary backgrounds. Their goals and objectives vary as do their expectations (Augsburg, Henry, Newell, & Szostak, 2009). In keeping with the ambiguity of the concept of interdisciplinarity itself, IDS programs have no standard structure; however, some scholars have suggested that a healthy IDS program should include courses from a concentrated selection of different study areas bookended by a cornerstone and capstone course that provides the academic framework for integrating multiple disciplinary perspectives (Augsburg et. al, 2009; Klein, 2010). What these core courses should consist of remains a topic of debate. What is clear, however, is that regardless of the specific goals and objectives of individual students, interdisciplinary work transgresses the traditional boundaries of academia, and compels an epistemological shift in knowledge production.

Indeed, IDS is said to both require and cultivate a robust cognitive toolkit (Repko, Szostak, & Buchberger, 2017) apt for addressing the demands of non-traditional non-reductionist academic work. While perspective taking, critical thinking, and integration are cited as the core competencies of IDS (Repko et. al, 2017, p. 92), these competencies require a host of cognitive skills including open-mindedness, humility, empathy, and intellectual courage, among others (Styron, 2013; Fortuin, Van Koppen, & Kroeze, 2013; Repko et al., 2017). It is the application of the process not the subject itself that is the most relevant in an IDS development course. Taking

the suggested bookending suggestion of program construction to heart, it seems reasonable then to designate an initial or cornerstone course for cultivating these skills and a final or capstone course for applying and refining these skills. For the cornerstone course, the challenge is to design a course that provides a general cultivation of these cognitive tools while meeting the specific needs of individual students, and UCD (Draper, Norman, & Lewis, 1986) approach can accommodate this challenge. As a starting place, this paper proposes a theoretical framework for designing IDS courses based on UCD principles and techniques.

UCD approaches have well-established methods for addressing issues and needs of specific user groups in order to develop flexible interfaces and interactions (Rogers, Sharp, & Preece, 2011). These methods and tools of UCD approaches can be applied in the field of IDS education in order to design courses that can be adapted to accommodate the diversity of IDS students while cultivating the cognitive skills that are generally necessary: the key feature of UCD approaches is the iterative design process. Each iteration enables assessment and refinement of the learning environment which will allow the course to be adapted to any given student body at any given time to produce optimal learning outcomes.

The remainder of this article is organized as follows: the following section outlines the details of the cognitive toolkit. Then, a brief overview of generic course development frameworks is discussed. These discussions set the stage for the final section (Section 3) of this paper that outlines the components of the course development framework proposed here.

Related Work

The research presented in this article draws on the fields of the scholarship of teaching and learning (SoTL), interdisciplinary studies (IDS), and user-centred design (UCD). These areas provide foundational theoretical background for the framework being proposed here.

Cognitive Tools and Pedagogical Methods

In their widely used Introduction to Interdisciplinary Studies (Repko et al., 2017) textbook, the authors describe three core competencies of interdisciplinarity: perspective taking, critical thinking, and integration (Repko et al., 2017, p. 92). Chapter 4 of the text delves into the skills, values, and traits essential to these competencies. The text labels this conglomerate as "The Cognitive Toolkit," which includes the following items: empathy, ethical consciousness, humility, appreciation of diversity, tolerance of ambiguity, civic engagement, entrepreneurship, love of learning, self-reflection, intellectual courage, communication competency, abstract thinking, creative thinking, metacognition, open-mindedness, adventurous disposition, and patience. While these elements are not unique to IDS, it could be argued that the transgressive demands and holistic approach of IDS require a heightened competency in these elements.

In the IDS literature, it is suggested that doing interdisciplinary work fosters the aforementioned cognitive skills (Repko et al, 2017). Using pre- and post-survey method, Michele Everett (2016), for example, showed that students perceived an improvement in the elements of the cognitive toolkit upon completion of an interdisciplinary research project embedded into a core IDS course. Styron (2013) explains that

> interdisciplinary education allows students to see different perspectives and work in groups with the synthesis of disciplines being the ultimate goal. Encouraging students to reach beyond the typical constraints of a single content area and engage in interdisciplinary learning fosters critical thinking, creativity, collaboration, and

communication skills (Styron, 2013, p. 47)

Ivanitskaya, Clark, Montgomery, and Primeau (2002) comb copious amounts of literature from a variety of disciplinary sources to argue the capacity of IDS to foster the various elements of the cognitive development. Newell claims that acquiring traditional intellectual skills is enhanced by interdisciplinary education as determined by standardized testing (Newell, 1992).

If doing interdisciplinary work fosters the cognitive toolkit, and one wants to develop a framework for developing IDS courses, it would be necessary to know more concretely what interdisciplinarians do as a foundation for developing pedogeological strategies. In interviews with interdisciplinary scholars, Woodill, Plate, and Jagoda (2020) found several common themes: interdisciplinarians tend to embrace an exploratory disposition, pay little attention to the disciplinary structures, and prioritize mentorship and community. While many of the respondents in this project noted a gap between what they do as interdisciplinarians and what they teach their students to do, centering an IDS course on the various elements of the cognitive toolkit, particularly such elements as empathy, open-mindedness, tolerance of ambiguity and uncertainty, for example, should create a learning space amenable to an exploratory approach to knowledge that is minimally concerned with disciplinary structure and fosters community. The elements of the cognitive toolkit are skills-based, and not primarily a matter of information transfer. This is a challenge to a system that is still largely focused on successful information transfer through the curation and testing of knowledge and information. Developing these skills is thus a matter of repeated engagement and practice.

Teaching IDS is thus a matter of how creating a learning space the prioritizes the types of learning activities that cultivate IDS cognitive toolkit. An exploratory disposition, though not a technical term in the literature, arguably requires open-mindedness and empathy (among other things), the focus of learning will be on the activities and not specific content. The move toward a focus on process rather than content is not without precedent. Edelbroek, Mijnders, and Post (2018) have compiled a set of interdisciplinary learning activities aimed at cultivating the various interdisciplinary skills. Additionally, there is some research available for teaching components of the toolkit. Cuzzo, Larson, Mattsson, and McGlasson (2017), for example, proposes pedagogical tools of role play, journaling, and service learning (among others) as effective pedagogical tools for teaching empathy. Some scholars suggest a turn to the arts and improvisation techniques as a viable pedagogical approach to teaching open-mindedness. Improvisation techniques develop one's capacity to work within these somewhat challenging emotional parameters and build capacity for openness in a relatively low-stakes context. Characteristics of improvisation have a degree of consistency across artistic genres and involve listening, extending, and exploring (Verducci, 2016). While it will take more scholarly work to develop the requisite activities, the point to be made here is that the course framework for IDS shifts focus from what information should be taught to what activities should be facilitated.

Course Development Frameworks

A course development framework is a set of theories and practices that are used to guide the development of a course (courses) (Graves, 2001). Educators often turn to established research in education to ascertain a framework best suited for their particular subject area. Disciplines typically have well-established templates of sorts that incorporate teaching and learning theories and activities traditional to their subject area.

Several course development frameworks have received much traction within higher education. Most of these frameworks are generic and can be applied to different contexts and subject matters, while the others were developed for specific domains in mind, such as e-learning and adaptive

learning platforms. Graves's (2001) work, a *framework of components*, breaks down the course development processes into seven fundamental components: (1) needs assessment, (2) determining goals and objectives, (3) conceptualizing content, (4) selecting and developing materials and activities, (5) organization of content and activities, (6) evaluation, and (7) consideration of resources and constraints. This framework provides course developers with an organized way to conceive a rather complex course design process. The author also identifies two types of student's needs, *objective* and *subjective* needs. Objective needs are defined as the needs that can be derived from actual information about the learners, while subjective needs are derived from the information regarding the learner's cognitive and affective factors, pertinent to the cognitive toolkit in the context of IDS.

Backward design framework, originally proposed by Wiggins and McTighe (2005), is perhaps one of the most popular frameworks in the recent teaching and learning trends. In this framework, one would start with determining desired goals of learners and work backward to come up with the course content and delivery methods, rather than starting with the content/topics for the course in the traditional instructional design approaches. This model has been the bases for many other frameworks and pedagogical approaches, such as integrated course design, which extends the Backward Design model and breaks down the design processes into three major phases consisting of twelve steps (Fink, 2003). The framework proposed here is also loosely based on the backward design model, as it embraces the complexity of the IDS.

Frameworks for developing courses can provide a helpful infrastructure, but in so doing, they typically do not allow for iterative course development at the time of course delivery. While there is some degree of iteration over multiple semesters, within the semester adaptation to accommodate the real time needs of students is sometimes done intuitively. For example, an instructor who notices a lack of engagement with course material may try altering the mode of content delivery (e.g., from lecture to video demonstrations). Fundamental content adaptation, however, is not typically feasible.

To this end, there are some adaptive models that have been developed for e-learning or digital learning platforms. There are two problems with these: first, the cognitive tools such as open-mindedness and empathy are elements of human engagement thus need to be fostered in a collective rather than an individual environment. The adaptive models tend to focus on individual progress and adaptation to individual educational journeys. Second, these models overwhelmingly focus on information transfer rather than skill development. These problems make these models hard to implement in face to face settings that can accommodate collective environmental change. The concept of adaptive learning is imperative to the development of framework being proposed here. While the adaptive learning frameworks are usually developed for online and e-learning courses, the adaptability of the course content and its delivery methods is one of the focal points of the proposed framework. This adaptation will ideally accommodate the diverse goals and objectives of individual students within an IDS program and will provide the opportunity to make appropriate adjustments based on the student's learning progress throughout the course. The concept of adaptive learning is rooted in two kinds of pioneer work, AIES: intelligent tutoring systems (ITS) and adaptive hypermedia systems, and on the earlier development of courseware reuse systems (Brusilovsky, 1999). Courseware reuse systems allow instructors and course developers to (re-)structure existing courseware modules stored in a database to design and develop new courses in order to reduce wasted time and effort to redevelop the same course materials. These modules can often be shared and reused among different courses or programs (Olimpo et al., 1990). However, the courseware modules are structured prior to the beginning of the course and are rigid for the rest of the course, thus similar issues as previously discussed arise.

Adaptive learning educational systems can, therefore, mitigate these issues by allowing the course content and the pedagogical methods to be more fluid in order to accommodate the characteristics of particular groups of students and their learning progresses through the course (Kara & Sevim, 2013; Nguyen and Do, 2008). These systems typically incorporate adaptation processes in four major categories; (1) adaptive interaction, (2) adaptive course delivery, (3) content discovery and assembly, and (4) adaptive collaboration support (Paramythis & Loidl-Reisinger, 2004).

The recent trend of teaching and learning has placed more emphasis on the interactivity between teachers and students as well as among the peers. For example, the concept of active learning has been proposed decades ago (Bonwell & Eison, 1991), and has been integrated into classrooms. The interactions among all the teaching/learning stakeholders often allow the learning environment to emerge thus producing an optimal learning context for that specific group of teachers and students. This emergence is the result of the participants engaging in active learning, expressing themselves and responding to the others in the group in such a way to find a common ground. That is, they seek to understand each other by reacting to their learning environment consisting of their peers, teachers, classroom equipment, and technologies.

However, the above adaptive learning frameworks generally assume the e-learning or on-line platforms, and thus do not directly provide or consider types of interactive environments that are quintessential to active learning approaches. In other words, while the system may in fact be adaptive to individual students' progress and potentially their learning characteristics, adaptive e-learning approaches do not consider the environmental factors of their learning such as peer-to-peer or teacher-to-students interactions, not to mention stakeholder feedback such as from a supervisor in a service learning experience.

To summarize, as of yet, there does not appear to be an approach to address the specific demands of IDS learning. Existing frameworks are often focused on facilitating information transfer and retrieval, and they are often focused on individual students' learning without much consideration on their interactive and environmental factors. In IDS learning, the focus is more directed to cultivating a set of cognitive tools than the information transfer, and these cognitive tools can be fostered by taking more holistic approach that focuses on activities and settings rather than information and content.

Learning Analytics

Learning analytics (LA) is an emerging field of applied research and key to the course development framework for IDS being proposed here. According to the First International Conference Learning Analytics & Knowledge that was held in 2011, LA is defined as "the measurement, collection, analysis, and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs" (LAK, 2011). With the recent increase of the usage of learning management systems (LMS) at different educational levels, from elementary to post-secondary, a myriad of data has been accumulated. This data covers various aspects such as navigation patterns, pauses, reading habits, and writing habits (Siemens, 2013). Traditional LMSs, however, are not designed to support informal, just-in-time learning (Woodill & Akiyama, 2017), nor fully flexible and adaptive to accommodate different learning styles that are customized for a specific student in a specific environment.

Becker (2013) emphasizes that in LA, it is necessary to assess the influence of academic practices within the learning environment and that the process of learning must be assessed more rigorously than final learning outcomes. This shift of the focus in the assessment will require a redesign of assessment methods that have traditionally been focused on outcomes rather than the

processes. The author also discusses the social aspects of learning analytics, namely *social learning analytics*, which is "the study of the process of engaged social learning, which can occur in networks outside of traditional academia" (Becker, 2013, p. 65). This argument is in line with our discussion of the need of integrating more environmental factors such interactions with instructors and peers and the necessity to incorporate more frequent assessment of the course design and students' feedback into the current course design, in order to fully understand students' learning processes, in addition to the factors the traditional LMSs are tracking. We will further discuss how some of the LA models may be integrated into our proposed framework.

The Proposed Framework

The course development framework for IDS being proposed here is motivated by the principles of the UCD approaches that harness the power of learning analytics. The UCD approaches allow for iterative and incremental improvements of design ideas by frequently conducting evaluations and integrating interactive feedback from the target users and the results from these evaluations into the design processes (Ritter, Baxter, & Churchill, 2014; Shneiderman, 2010).

While there are several variations, most UCD approaches have a consensus on the four main modules. These modules include: (1) identifying needs and establishing requirements, (2) developing alternative designs, (3) building interactive versions of the designs, and (4) evaluating designs (Rogers et al., 2011). These modules are visited iteratively throughout the design process, and each module generally has sub-modules within itself that are also iterative. This section will highlight each of these four main modules of the general UCD to the modules of the framework proposed here.

The ultimate purpose of this framework is to describe the general steps for designing IDS courses. More specifically, the framework will help course designers to suggest a set of learning activities, or a *learning journey* for student groups that directs towards their goals and objectives (i.e., the learning outcomes, or a certain set of cognitive tools). The arrows in the diagrams (shown in Figure 1) indicate the iterative nature of these modules, suggesting that, at each iteration, the objective is to refine the students' learning journey. Because each student group has a set of strengths which are likely different from those of others, the goals of each will also likely differ. These differences are often more pronounced in the case of the students in IDS as they arrive from a diversity of backgrounds with different objectives and expectations. Existing adaptive learning approaches seem to lack more holistic learning opportunities. Our proposed framework will consider these differences in students' goals and characteristics to provide a learning structure that will cultivate the students' specific developmental needs. This will be enabled by integrating iterative and intermittent evaluations throughout the course.

We will now describe each of these four modules of the proposed framework in comparison to the four main modules of the UCD.

Identification of Cognitive Toolkit

Within the first UCD module, "Identifying needs and establishing requirements," the designers would typically start with reviewing literature and studying relevant documents. They would then interact with target user groups several times, potentially starting with the preliminary user observations, which would generate questions to be asked in the follow-up interviews and focus-group sessions with those users. More specifically, within the context of the IDS education, the overall course outcomes need to be established by first identifying relevant stakeholder groups such as the program administrators, the institution, accrediting bodies, instructors, the students,

and potential employers. From these groups, several types of information can be expected such as established teaching and learning norms, best practices, current trends, student characteristics, institutional expectations, and certain constraints and restrictions such as time (e.g., a number of lectures within a semester) and available resources (e.g., classroom equipment, expertise. Identifying needs and establishing requirements typically involves the tasks of gathering and reviewing relevant documents (such as syllabi and/or employment trends) and conducting user interviews and/or surveys[1].
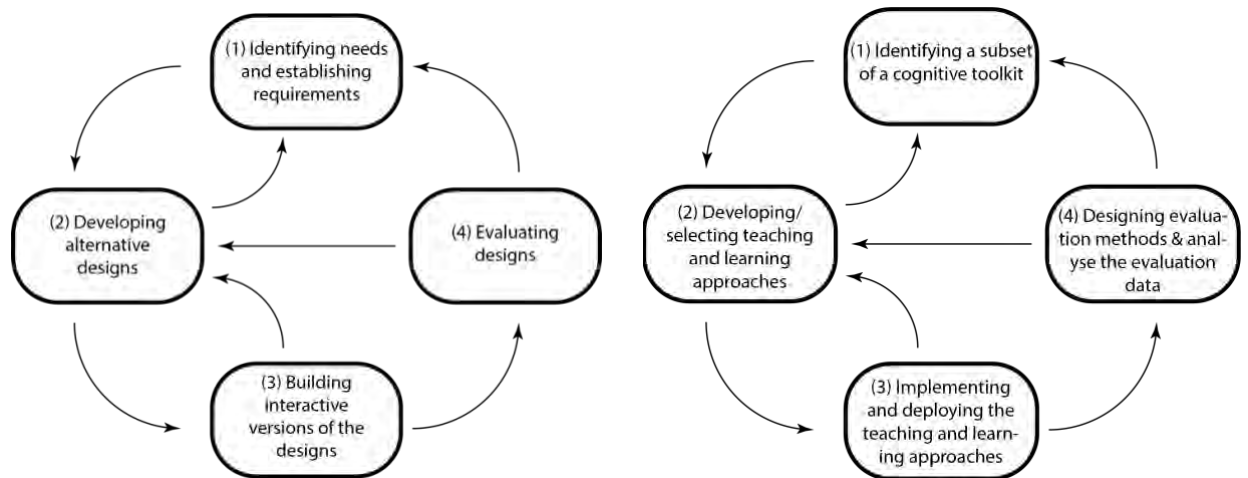
(a) General User-Centred Design framework with four main components. The arrows indicate the iterative nature of this framework.

(b) Overview of our proposed framework for IDS course design, also consisting of four components, compared with the UCD framework

Figure 1: Comparative diagrams of (a) User-Centred Design Framework, and (b) our proposed IDS course design framework.

With this foundation in place, the preliminary task of the course developer is to determine which cognitive tools need to be fostered. This task can be accomplished by administering an initial assessment tool that employs VALUE[2] rubrics used to assess such elements as empathy, open-mindedness, intellectual courage, tolerance of ambiguity and uncertainty, and critical and creative thinking. Based on the results from this preliminary assessment, it can then be determined which cognitive tool(s) to initially focus on, as a group, and for individual students. Note that the focus as a group is as an important aspect of learning as individual focuses, in that the group dynamics have great impacts on the students' learning environment. This aspect is often lacking in the traditional adaptive learning frameworks that tend to focus on the progress of individual

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[1] The authors of this paper intend to complete a broad scale research project in which these initial steps will be initiated with a variety of groups within the IDS community. The objective is to provide a foundation of course outcomes and expectations for eventual IDS course developers. This foundation should allow individual course developers to focus more specifically on the needs of their students and community partners (if need be).

[2] VALUE rubrics are nationally normed assessment tools established by Association of American Colleges and Universities. An initial assessment activity template will be created in the course of the broader research project and can be adapted by individual course developers/instructors. The objective in this paper is to establish the theoretical framework in advance of the specific details.

students as discussed. Although the assessment is individual, these tools are products of collective interactive environments thus the class can be broken into groups according to the assessment outcomes.

Development and Selection of Teaching and Learning Approaches

After determining a subset of cognitive tools to be focused on, the next step is to select types of learning activities and course delivery methods (e.g., class discussions on certain topics, essay writing, drills, etc.) that are known or suggested to foster the elements of the cognitive toolkit. Using the UCD analogy, the initial aim of the designers in this phase is to come up with as many different design solutions as possible that will potentially satisfy the requirements established in the first module. In the IDS course design context, the idea is to develop an "activity bank," from which the instructor can choose activities that are customized for a specific group of students as well as for individual students. This approach will allow for the flexibility in the course design processes over the duration of the course in order to adapt for the new information and added/modified requirements based on the results of intermittent assessments that will take place during the course. This activity bank will grow and be refined over time, and it can also be shared among the educators in the similar domains. The community-based approach to developing these banks is also an important aspect as the IDS education matures.

There are various UCD tools that can be used to choose the most appropriate design solutions such as those based on a set of usability studies (e.g., A-B testing, Heuristic Evaluations, Focus groups). However, the initial subset of design solutions is often determined by using prioritization grids. There are several variations of these grids. For example, the IBM Design Thinking Toolkit ("Design Thinking Activities and Tools - Enterprise Design Thinking") provides the grid that is shown in Figure 2 as one example of prioritization grids. In this grid, the horizontal axis represents the feasibility for the team/organization, which often includes the resourcefulness and availability of skillsets/expertise in the team, and the vertical axis the value (importance) to the target user groups. The idea here is to map the different design solutions on this plane, based on the votes by the team members along with these parameters. The solutions that reside in the upper-right quadrant (i.e., called "No-Brainers," important and highly feasible) will most likely be chosen to be implemented, while those in the lower-left quadrant (i.e., called "Unwise," unimportant and infeasible) will generally be discarded. The solutions in the remaining areas, the middle-top area (called "Big Bets," important with moderate feasibility) and the lower-right area (called "Utilities," not as important but highly feasible) may still be chosen to be added to the list of the solutions to be implemented, depending on circumstances.

The IDS course designers can adapt these grids in order to narrow down the particular subset of the activities from the activity bank. For instance, the course designers may use the above grid (with a minor modification of the term "user" to "students") to map the different activities by evaluating them on how important particular cognitive tools are to the given student group, potentially based on certain assessment rubrics like VALUE as well as on how feasible each activity is (e.g., "Can the students complete it within an allowable time period?", "Do we need special equipment or facilitators in order for the students to work on this activity?"). The initially chosen subset of activities can then be deployed in class. The process of selecting the subsequent sets of the activities can then be conducted throughout the term in a similar manner, capitalizing on the intermittent assessments of the course design. By employing this type of iterative processes while integrating the new information obtained from the within-semester feedback, the course can be altered in such a way so as to minimize the potential issues often caused by different needs of different student groups as is characteristic of IDS programs.
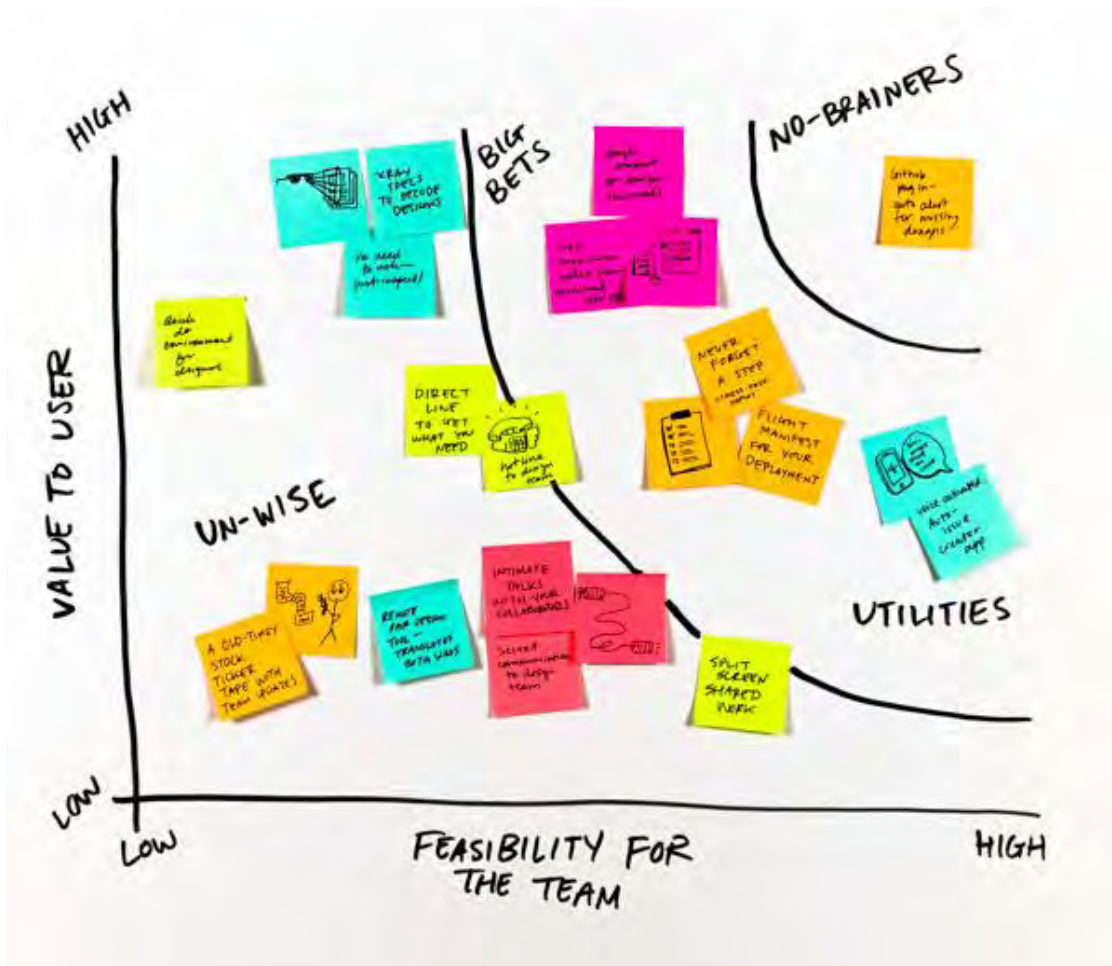
Figure 2: Prioritization Grid.
IBM. (n.d.). *Prioritization Toolkit: Enterprise Design Thinking*. Retrieved from
http://www.ibm.com/design/thinking/page/toolkit/activity/prioritization

Implementation and Deployment of Teaching and Learning Approaches

Once a set of developmental tools are selected it is then necessary to implement and deploy these activities. There are several different ways to do this; for example, the instructor can essentially pick one activity that they believe to be the most effective/appropriate and tell the students exactly what they need to do (e.g., "answer these one hundred math questions," "write an essay on the 18th Century industrial revolution"). This approach is familiar and traditional, but it often assumes that each student has more or less the similar skillset/tools and goals, thus it often ignores their diverse backgrounds, skills, and goals, that are typical of the IDS student groups.

Typically, the content of a course is rather concrete to the extent that it is meant to convey some aspect of disciplinary knowledge, and often the delivery method is flexible, but the framework proposed here inverts this scenario. This framework proposed a set of activities or delivery methods as the more concrete element that can be executed with information from any knowledge domain. For example, role-playing is well-known to cultivate empathy and open-mindedness, and so an instructor might consider building a set of role-play scenarios. Students could contribute to building the scenarios thus providing an opportunity for instructors to gain a

better understanding of their students and their individual academic backgrounds. Building a scenario would require students to bring their prior knowledge to the fore in co-constructing scenarios and producing an analysis of the scenario from the point of view of their area(s) of study. The role of the instructor would be to introduce variables into the scenario that challenge students' knowledge and pulls them into a new experience consistent with cultivating the cognitive toolkit while providing a platform for student to apply their disciplinary knowledge in new domains and novel ways. This type of activity would provide a space for the development of an individual and personalized academic experience in the cultivation of the IDS cognitive toolkit. This approach is analogous to the common UCD methodologies that involve the target users at varying levels of design processes.

Design of Evaluation Methods and Implications for Data Analytics

After the completion of the suggested activities, a set of assessments are conducted to measure students' progress towards the goals and the specified learning outcomes (i.e., a subset of the cognitive toolkit). That is, an evaluation of the design of the course will be completed in order to obtain new information that can be used to influence the course design in positive ways.

These assessments should be done along multiple axes, reflecting multiple perspectives; "Did it accomplish what we have in mind (instructors' perspective)?", "Did it get students where we want them to be (instructors' perspective)?", "Did it meet students' needs and expectations (students' perspective)?", and "How much did it get to the requirements of other stakeholders (e.g., departmental and institutional perspectives)?" Assessing the students' progress from multiple perspectives conforms to the common UCD evaluation methodologies such as expert evaluations (reflecting perspectives of instructors/administrators) and user-studies (reflecting perspectives of students/peers), and integrating the feedback from the students themselves (i.e., the target "user" group) is one of the most important aspects of the UCD principles in order to assess and maximize the user experience (UX).

The results of the assessments will then be analyzed and the newly obtained information will be used immediately to modify the course design or to generate new design solutions so that the current group of students will benefit from them. This the real-time adjustment to the course design based on the assessment results is crucial so that the instructors can maximize the learning effort of the current group of students. These processes will then be repeated (i.e., selection and deployment of teaching and learning approaches, and then the assessments from multiple perspectives) until the end of the term so that, ideally, the course design converges to something that is optimal for the current group of students.

Further, at the end of each term, enough data will be accumulated on what activities each student has completed and the results of all the assessments that were conducted. It is expected that some students did progress in the intended areas of cognitive tools while some may have improved in other areas that were not included as intended outcomes. Some may not even have made any progress in certain metrics. There are also certain cases that students may not have completed the assigned activities (e.g., missed a lecture or did not hand in a homework), thus the data of how much they have completed which activity (e.g., 80% of the assigned activity is completed by Student A) will also be available in this dataset. That is, there will now be available data on the students' learning "paths" associated with specific teaching and learning approaches.

The accumulated data can then be utilized in order to optimize the framework so that it can suggest a more suitable set of teaching and learning approaches to a specific student(s). There are a set of data analytics tools that can be explored: Genetic algorithm (GA) (Haupt, 1995) is one of such algorithms that are widely used for purposes similar to ours. In our example, each activity

can be represented as a gene and each student's journey is represented as a group of genes, or a *chromosome* in GA. Each chromosome is associated with *fitness*, which will be calculated from the assessment results. The students' data will be first clustered into several groups based on their characteristics, and for each group, an initial set of *populations* (i.e., groups of chromosomes) will be created based on the randomly selected genes. The goal is to create the most optimal chromosome within each group that minimizes the cost (or that maximize the learning outcome) by going through multiple generations while employing the standard GA operations (selection, crossover, and mutations). Other algorithms that can potentially be incorporated into the framework are decision trees and random forest (RF) algorithms (Breiman, 2001). In the case of a single decision tree, the data space is split recursively at each node so as to increase the impurity of the resulting subsets of the data (Quinlan, 1986; Strobl, Malley, & Tutz, 2009). In our case, the objective is to find an attribute (e.g., teaching and learning activities) at each node that effectively and efficiently partitions the data space so that subsets of the data space will correspond to outcomes of the assessment results (i.e., to determine which teaching and learning activity improved or worsened cognitive toolkit assessment results). In the RF algorithm, we can address common overfitting issues of a single decision tree by using a group of many decision trees that are likely to converge and thus, potentially improving the overall performance of the algorithm (Fernandez-Blanco, Aguiar-Pulido, Munteanu, & Dorado, 2013). By incorporating these approaches, the framework will generate the most ideal learning paths for a given class and for individual students. It will be helpful to continue to collect this learning analytics of data over years, presumably improving and refining the data analytics models.

Conclusion

In this article, a theoretical framework for developing Interdisciplinary Studies (IDS) courses was proposed. This framework consists of four main modules of course design processes, based on the common approach of user-centred design (UCD) methodologies, and provides theoretical scaffolding to guide course developers. These four modules are: (1) identification of cognitive toolkit, (2) development and selection of teaching and learning approaches, (3) implementation and deployment of teaching and learning approaches, and (4) design of evaluation methods and implications for data analytics.

The first module starts with identification of stakeholders (students, instructors, potential employers, administrators, etc.) and collecting necessary information from them to establish relevant requirements such as established teaching and learning norms, best practices, current trends, student characteristics, institutional expectations, and certain constraints and restrictions such as time and available resources. Based on this information, the course designer will determine which cognitive tools need to be fostered.

The second module is to generate a set of teaching and learning approaches (called an activity bank) that are known to foster the selected requisite cognitive tools. The idea at this point is to generate as many potentially useful activities as possible. A subset of activities from this activity bank will then be selected based on certain criteria as established from the first module. Tools such as prioritization grids that are developed and used in common UCD methodologies can be used for this section process.

The third module is the implementation and deployment of the selected set of activities. While there are different ways to accomplish this step, given the diversity of students' goals and experience, an ideal approach is to give options of activities that are more rigid in terms of rules

of execution but open to or accommodating the implementation or overlay of content from the students' disciplines ore areas of study. Options can be given in different levels of flexibility.

The fourth module is to conduct course design assessments, which will evaluate the course design from the perspectives of all the stakeholders. Assessment of students' progress from multiple perspectives conforms to the common UCD evaluation methodologies, and integrating the feedback on the course design from the students themselves is in line with one of the most important aspects of the UCD principles, which is to maximize the user experience (UX). The results of these assessments will then be analyzed and incorporated into the current course design. This immediate feedback loop (as opposed to waiting until the end of a term to make modifications to the course design) allows the current group of students to benefit from it by capitalizing on the potential convergence of the course design in the most optimal way.

Finally, the discussion of how to incorporate the data analytics approaches in this framework is provided. Based on the accumulated data on the students' learning paths with the associated teaching and learning approaches and their progress, some data analytics algorithms such as Genetic Algorithms and Random Forest can be used to model students' learning performances and make suggestions for teaching and learning activities that will likely result in the most ideal outcome of their learning journey.

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