Constraining the Landscape: Unpacking the Inquiry Learning Aspects of the Foundry Model for the Purpose of Curriculum Design

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Abstract

The purpose of this contribution is to outline the various iterations of implementation of the Renaissance Foundry Model (herein, the Foundry) for chemical engineering curriculum redesigns as guided by the levels of inquiry-guided learning (IGL).[1,2] When the Foundry is paired with the levels of IGL that delineate pedagogical decisions based on a scaffolded and student-centered approach to learning,[2,3] course redesigns hold the potential of increasing student engagement,[4] creative and critical thinking,[5] and collaborative learning skills.[6,7] Aligned with three of the levels of IGL (i.e., structured, guided, and open), the Foundry can provide students with an innovation-driven learning experience suited to their level of comprehension within their program of study.[1-3] Conception and implementation of all three levels will be illustrated via case studies representing various undergraduate chemical engineering courses at Tennessee Tech University.

Keywords

Renaissance Foundry, Innovation-Driven Learning, Inquiry-Guided Learning, Active Learning

Introduction

Several leading national organizations such as the National Academy of Engineering (NAE)[9] and individuals such as Grasso and Burkins[8] have indicated the need for a different kind of engineer. The attributes and skills of the "classical conductor" style engineer[10] can be expanded to lead to increased ability to identify and propose innovative solutions to ill-structured or complex problems that are abundant in our society.[11] Ultimately, a "composer style" engineer with a commanding knowledge of the fundamentals (as the composer needs to show a deep command of content knowledge) together with an effective integration of other skills including communication, managerial effectiveness, business economics, and social relevance (as the composer needs to know the audience which she or he is addressing) is a more enthusiastic and promising engineer-style of professional.[11] Scholars[8,12] have indicated that this new type of engineering professional is more along the lines of a "holistic-style" engineer. At Tennessee Tech University, the Department of Chemical Engineering (ChE) has been designing, implementing, and assessing courses based on an innovative, holistic-centered, platform for engineering education as encompassed by the Renaissance Foundry model (herein, the Foundry).[1]

The purpose of this contribution is to outline the various iterations of implementation of the Foundry on chemical engineering curriculum redesigns as guided by the levels of inquiry-guided

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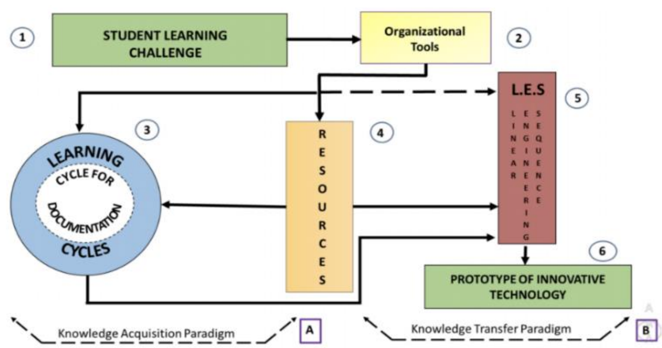
learning (IGL).[1,2] Aligned with three of the IGL levels (i.e., structured, guided, and open), the Foundry can provide students with such a process via an innovation-driven learning experience suited to their level of comprehension within their program of study.[1-3] We argue that leveraging these levels of the IGL within the Foundry allows instructors to "constrain" their students' content landscape when settling on an initial challenge, while still permitting students to continue within the iterative design process as part of their overall course requirements. In this contribution, we feature how content landscape was variously constrained to reflect the three levels of IGL indicated above within the scope of three chemical engineering classes: Transfer Science I (Heat Transfer), Transfer Science II (Fluid Mechanics), and Transport in Biochemical and Biological Processes (Biotransport). Following these case studies, implications for engineering education pedagogy with regards to holistic-centered learning environments will be discussed.

The Renaissance Foundry Model

Figure 1. Renaissance Foundry Engine[1]



The Renaissance Foundry is a pedagogical platform that promotes innovation-driven learning through an iterative process that engages student teams in knowledge acquisition and knowledge transfer with the purpose of collaboratively developing a prototype of innovative technology that addresses a student-identified challenge related to specific content.[1] Figure 1 provides an illustration of the Foundry Engine which highlights the elements encompassed within two central paradigms (or pistons): Knowledge Acquisition and Knowledge Transfer.[1] These paradigms are utilized as the momentum that facilitates learners' navigation of these six steps towards the construction of a prototype of innovative technology.[1] The challenge that learners initially identify in this process must be socially relevant and related to aspects of the content of focus if applied to a course in a given curriculum.[1,7] Moreover, motivated by active-learning and design thinking processes, students must work collaboratively and iteratively (between the two paradigms) to effectively construct new knowledge and transfer that knowledge towards the development of the prototype of innovative technology.[1,2,11]

Leveraging Inquiry-Guided Learning (IGL) Levels to Enhance Foundry Implementations

Inquiry-Guided Learning (IGL)

According to Lee,[2] IGL is encompassed within the larger scope of active learning strategies that help to bring student engagement to the center of these pedagogical approaches. For IGL, a scaffold approach is typically utilized wherein students will begin with more instruction coming from the facilitator of learning and then build to an environment where they feel comfortable navigating complex spaces using an open, discovery learning process.[2,3] This scaffold is comprised of four levels of inquiry (i.e., structured, guided, semi-guided, and open) where the student progresses from a more structured approach (i.e., learning that is heavily guided by the facilitator of learning) to a more open approach (i.e., wherein students are guiding the inquiry

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process) regarding learning exploration.[2,3] In essence, the levels of the IGL reflect a transition of authority from a facilitator of learning to the actual learner during progression through the levels of inquiry (i.e., structured to open).[2,3]

In the first level of IGL, a structured-inquiry approach is meant to help students navigate a pre-designed discovery process through parameters established by their instructor.[2] In the second and third level, a guided- and semi-guided inquiry approach is designed to facilitate students' navigation of more complex discovery processes by providing less guidance than the structured-inquiry approach within flexible parameters established by the instructor.[2] The degree of flexibility varies between these two levels with the guided being more structured and the semi-guided being more open, which helps to instigate student initiatives and engagement in the discovery process as they grow from novices of this type of learning approach to active learners.[2,3] In the last stage of the IGL, an open-inquiry approach is designed to provide students with full autonomy regarding the discovery process through only limited parameters established by their instructor.[2]

Constraining the Landscape with IGL Levels

In this contribution, we propose that the Foundry can be paired with the tenets of IGL to help facilitate a more holistic, active learning experience for students. Specifically, as illustrated above, the Foundry is meant to be an iterative experience wherein students will go through the six steps of the platform various times in the semester - as well as move back and forth through the knowledge acquisition and knowledge transfer paradigms at various times - towards the development of a prototype of innovative technology[1] Within each iteration of the six-step implementation, the aim is to help students garner more experience of the platform and become stronger, more independent learners.[1] IGL levels are a helpful guide to facilitate this transition. Every time the Foundry is intentionally implemented within a course or a program of study sequence, students should be moving from a structured (i.e., constrained) to an open (i.e., unconstrained) configuration of the platform (see Figure 2). Figure 2 provides an overview of how the dynamics of the IGL levels (left columns) work in parallel to different variations of the Foundry model implementation (right columns) process.

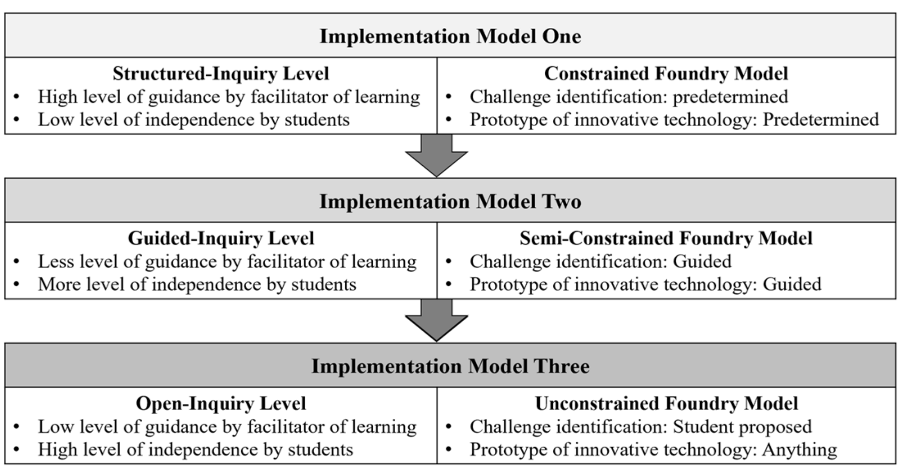

Figure 2. The IGL levels as Compared to the Various Foundry Implementations

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Therefore, the purpose of constraining a course landscape becomes twofold: a) to help facilitate learners' introduction to the Foundry process while b) simultaneously building the skills of the individual necessary to help them better understand a strong challenge selection in subsequent Foundry applications[20] (Figure 2). In the following we provide specific examples from course redesigns based on the Foundry that have been coupled with the IGL levels for this purpose.

Case Study Illustrations with Observational Data from ChE Courses

Constrained Foundry Landscape Examples

When the Foundry is coupled with a structured inquiry approach, it becomes a constrained landscape wherein the initial student-identified challenge options are selected from a predetermined pool of options that integrate aspects of the assignments or project.[20] This pairing is typically utilized with learners who are not familiar with the central content of the lesson (e.g., this can be central to the course topic or to an aspect related to the course topic) and are unfamiliar with the intricacies of the Foundry model. Examples reflective of the constrained Foundry landscape from three chemical engineering undergraduate courses are provided below.

Heat Transfer: In Heat Transfer, a modified cup challenge activity is utilized to introduce students to the pedagogy behind the Foundry via mindful abstraction.[5] In this activity, students are tasked with achieving given prototypes (*e.g.*, specific configurations of stacked cups) with limited organizational tools and resources (*i.e.*, one string per team member, one hand, and limited verbal communication).[5] Within these constraints, students must acquire knowledge of their teammates' strategies for completing the task through nonverbal communications and then transfer that knowledge via utilization of teamwork to create the predetermined challenge. If this action fails, students must return to the knowledge acquisition paradigm in order to determine a new strategy – or to identify how to better facilitate the current one – and progress again through the knowledge transfer paradigm in order to achieve their final design.[5]

Fluid Mechanics: In the second course of the sequence, Fluid Mechanics, the constrained Foundry landscape is illustrated in a contract assignment in which the facilitator of learning asks students to prepare a team contract to delineate roles within their team project. Students are prescribed certain elements for creating team contracts effectively representing a constrained prototype. These explicit elements include but are not limited to: the responsibilities of team members, a timeline for task completion, and methods of accountability should a team member not complete an assigned responsibility. It should be noted that without prior training, many teams thought it relevant to include the facilitator of learning as a method via which conflict resolution should occur. This is an indication of characteristics or traits related to novice active learners.[2]

Biotransport: Three versions of a Jeopardy-inspired game have been leveraged in the Biotransport course with each providing various levels of a constrained Foundry landscape.[20] Each version has involved an activity in which the class is divided into two teams (or sides) and the sides participate in a friendly competition in which they answer questions related to the course content. Instead of dollar-value categories, the boxes on the game board (prepared in PowerPoint) have typically been labeled with types of medical devices, to aid with challenge identification for student teams as part

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of course projects (Figure 2).[20] These pre-determined categories can be further explored in a manner consistent with a constrained Foundry landscape in which students must work on a problem related to a category given by the instructor and thus do not have to extensively engage in challenge identification.

Semi-Constrained Landscape Examples

When the Foundry is coupled with a guided-inquiry approach, it becomes a semi-constrained landscape wherein the initial student-identified challenge options are less limited by predetermined options chosen by the facilitator of learning.[20] Students must take initiative to engage in the challenge selection process while still utilizing the parameters provided by the facilitator of learning to ensure the challenge is relevant for the overall learning process.[1,2] This particular pairing is typically utilized with intermediate learners who are more skilled at navigating the central content of the lesson (e.g., this can be central to the course topic or to an aspect related to the course topic) and have some familiarity with the Foundry model.

Heat Transfer: Within the Heat Transfer course, after students have an initial understanding of the pedagogy behind the Foundry and how to transition between the knowledge acquisition and knowledge transfer paradigms iteratively, a semi-constrained Foundry landscape is employed with a flipped-classroom approach. A short video tutorial of COMSOL® software was created to instruct students to recognize elements of a physical system within the software structure. After students were assigned the task of viewing of this video to be completed outside of the classroom, the facilitator of learning developed a problem statement wherein students were presented with a semi open-ended problem where they were asked to apply COMSOL to simulate a physical system that would best address the goals of the problem statement. As a semi-constrained landscape, the parameters were flexible for completing the assignment, however guidelines were still provided.

Fluid Mechanics: This example builds on the team contracts activity of the constrained Foundry landscape in the Fluid Mechanics course. As a semi-constrained Foundry landscape, students are trained via discussions with guest speakers and specialists in order to develop a strong social contract as well as a rubric by which that contract might be assessed. The training provides examples of contracts for purposes similar to that which students are asked to construct. After receiving guidance regarding the importance of certain key elements necessary for a strong contract (i.e., parameters within the assignment), they are tasked with creating their own contract and rubric. It should be noted that students implemented such elements of the team contract as previously provided as a constraint, however, they now did so in a way that did not recruit the facilitator of learning for conflict resolution, representing traits of more advanced, independent learners.[2]

Biotransport: In the most recent offerings of the Biotransport course, students have participated in a problem-solving approach in which teams solve a problem using each of four techniques: thought exercises, analytical solution methodologies, experimentation, and simulation. In this semi-constrained Foundry landscape, example problems and solutions developed using each of the four problem solving approaches listed are completed together with the facilitator of learning over a one- to two-week span. The teams are challenged to come up with their own problem and to solve it using each of the four techniques. As a semi-constrained Foundry landscape, the parameters are

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again guided but flexible and student teams can complete the activity using a learning tool selected from the pool offered by the facilitator of learning.

Unconstrained Landscape Examples

When the Foundry is coupled with an open inquiry approach, it becomes an unconstrained landscape wherein the extent of Foundry is considered to be in full use as initial student-identified challenge options are only limited to the relevancy of the course and students hold full autonomy of their discovery process.[1,7,20] This pairing is typically utilized with advanced learners who are deeply familiar with both the central content of the lesson (e.g., this can be central to the course topic or to an aspect related to the course topic) and the Foundry as an innovation-driven learning platform.[1]

Within each of the three courses representing the Foundry curricular redesign, students are unconstrained in their challenge identification for the overall course project. Each facilitator of learning simply asks that the students utilize course topics in their design and/or analysis of the prototype of innovative technology that result from their implementation of the Foundry as the teams progress towards the development of their prototype of innovative technology.[1] Without constraints, teams are free to identify challenges to address via the iterative progression through both paradigms of the Foundry in the pursuit of developing a prototype of innovative technology.[1] As a result, facilitators of learning cannot readily predict what real-world challenges that students might choose to address, and ultimately, student creativity reigns in a way unstifled by course instructors that might lead to more innovative and societally-relevant solutions to problems potentially overlooked or not yet considered.

Implications and Conclusions

Ultimately, the purpose of this contribution was to outline the various iterations of implementation of the Foundry for chemical engineering curriculum redesigns by IGL processes (i.e., structured, guided, and open).[1-3] In terms of implementing the Foundry to produce holistic-style engineers, such a coupling between the IGL processes and the implementation of the Foundry within a constrained, semi-constrained, and unconstrained landscape provides a useful progression of student learning that could be applied to the sequential design of a course or to a curriculum sequence.[7,21] From a pedagogical perspective, what this coupling of the inquiry-guided processes with the Foundry demonstrates is that there is useful learning progression that can be leveraged to help novice learners become advanced Foundry learners through an internal and external course design sequence. Based on our initial applications of these elements to the courses described above, there are preliminary observations from our teaching experience that successful connections between student learning and the navigation of the Foundry model were made via this type of IGL progression.[7,20] In future research, we aim to delve deeper into understanding how these processes help students develop the skills necessary to become holistic-style engineers by studying aspects of these topics both qualitatively and quantitatively.

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