Starting from Scratch: A Holistic Framework for Designing Digitally Delivered Graduate Programs for STEM Working Professionals

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Abstract

Provided the opportunity to create new, high-quality graduate programs from scratch, a framework was sought to help meet the intersecting needs of employers and employees, while cultivating a learning environment that honors the individuality of working professionals. Given Rensselaer Polytechnic Institute's (RPI) nearly 200 years of engineering and research excellence, it was natural to leverage the engineering design process to develop a modern solution. Though there are many variations of the engineering design process, this paper presents it as a sequence of six steps: identify, explore, design, create, test, and improve. The first three steps (identify, explore, and design) are the focus of this work. From these emerged a series of strategic decisions in program logistics (face-to-face, online, hybrid, etc.), curriculum design, and learning interface informed by thorough consideration of employer and employee needs as well as the latest in learning science. Due to the abundance of variety in how graduate programs are designed, this paper provides a detailed description of the design process such that other institutions looking to develop quality, digitally delivered programs, may consider this work. Consequently, clear connections are made between the needs of employers and employees, learning science, and research design. In all, eight graduate certificates, 10 sets of learning goals and competencies (LG&Cs), 25 project-based courses, and more than 60 projects have successfully been designed, developed, and delivered using the described process as a framework for program development. Future papers will explore how these courses and projects were created, tested, and improved through course development and review and revision processes that incorporate regularly cadenced instructor and student feedback.

Keywords: program design, program development, instructional design, graduate education, digital education, adult learners, engineering design process

1. Identify

Rensselaer Polytechnic Institute in the USA was founded in 1824 for the purpose of "instructing persons…in the application of science to the common purposes of life" (Rensselaer Polytechnic Institute, n.d.). As a Carnegie R1 research institution, Rensselaer has lived this credo by using an applied research and instructional approach to innovatively solve pressing global problems in Engineering, Science, Business, and the Arts. With its primary campus in Troy, NY, Rensselaer offers a full array of residential programs at the undergraduate, graduate, and doctoral level. Many programs approach real problems through cross-disciplinary, research- and application-based approaches and program constructs.

This "Innovating to Solve" approach also applies to Rensselaer's education delivery. In 1955, a group of employers reached out to Rensselaer and other universities with a different but common problem. At the time, the typical working professional who needed post-baccalaureate education had to take time away from work to attend a residential graduate program on campus, most likely leaving their employment for an indeterminate amount of time. When completed, some returned to their employer whilst others found new employment opportunities. Therein lay the problem: employers were losing too many of their high-performing employees to competing companies who were eager to recruit seasoned graduating students. As they say, all is fair in love and…employee recruitment. The employers sought an educational institution willing to partner to develop graduate programs that could be taken by employees without requiring them to leave their work; in other words, part-time programs offered in convenient locations. In response to this inquiry, Rensselaer enthusiastically saw an opportunity to live its legacy, refitting a building for classrooms and enrolling students for fall 1955 in Hartford, Connecticut. This location was near many

employer headquarters and the I-95 corridor in the northeastern US. Since then, Rensselaer has graduated more than 25,000 graduate students in Engineering, Science, and Business.

In 2017, the former President of Rensselaer, Dr. Shirley Ann Jackson, commissioned a new Hartford campus leadership to continue the legacy of innovation. This involved reviewing the program portfolio to ensure full alignment with the needs of employers and working professionals. An exciting challenge for the authors of this paper, the team took a "blank page" approach, determining up front that the best approach would be to design program and delivery models that optimally met the needs of employers and working professionals. All aspects of design and delivery were on the table for discussion and consideration, with regulatory and accreditation guidelines as a foundational construct. This process began with data collection from working professionals and their employers to precisely determine their needs.

This article summarizes the qualitative findings of the insights collected through interviews, then describes how Rensselaer used those results to inform the design and delivery of its programs to simultaneously optimize learning, engagement, and value to both working professionals and their employers. The article begins with a summary of the insights, then presents best practices from learning science that inform program design and delivery to align optimally with need, and finally, the preliminary qualitative findings resulting from the deployment of this model.

1.1 The Insights: Working Professionals

Rensselaer's team interviewed thousands of working professionals (WPs) over the last five years, asking specific questions of potential students to ascertain:

(1) What types of programs were being sought in terms of desired abilities;

(2) How the program needed to manifest to jointly fit in their lives and to optimally assist them in achieving their career aspirations; and

(3) What factors guided the students in finally selecting an educational institution, in the context of their individual decision process and criteria.

Each conversation was free flowing as they followed the direction of the topics WPs felt important, but notes were kept in the context of the three questions above. Those notes were anonymously aggregated using a meta-theme approach. The major themes can be summarized in five areas, where each is equally important:

(4) WPs are motivated by career aspirations. They have short- and long-term goals that they wish to accomplish in their professional lives. Each goal requires a combination of new abilities and experience in varying proportions, where experience is generally 60-70% of the need and new abilities are in the range of 30-40% of the need. Differently stated, not all promotions require education, or just education. Those goals that do require education require increments of discrete ability-enhancing education that may or may not align with traditionally designed graduate degrees. The student may need a smaller or larger increment of education to achieve each goal. Students today may potentially only have a vague idea of the long goal, but achievement of the long goal goes directly through the short goals in their mental maps (e.g., employees typically must be a Team Leader before they can become a Director in most organizations). All to say, the amount of education a student needs right now versus what they might need later is differently sized and of different priority. Perhaps the optimal educational experience would be one that gives them the ability set they need, now, and an increment of experience using those abilities in a manner seen as valuable by the employer.

(5) WPs are challenged financially and temporally. The WP who needs education as opposed to experience generally tends to be at an earlier stage of their professional career –-typically within the age range of 23-40. These are also the years of the greatest financial challenge for WPs as they are relatively early in their lifetime earning potential with corresponding early-career wage levels. They may have significant debt associated with their prior education. They are eager to establish progress toward life goals – families, children, mortgages, car payments – all drawing on their, again, relatively limited income level. Thus, they are reticent to make additional financial commitments, especially if they are unable to cognitively frame the expense of education as a long-term investment versus a short-run consumption activity. Coupled with the many draws on their time and energy - such as families, community commitments, professional duties and obligations – WPs are reticent to invest in additional education unless the "return on investment" is unambiguously clear. The education must fit into their life so that they can continue to make progress on all fronts of their lives.

(6) WPs demand a direct link between the potential education investment and their desired goal, given their goals described above and their limited time/money. If WPs cannot make the connection, they are not likely to start,

continue, or finish. The educational experience must be engaging in design such that they see themselves making progress toward their goal at all points, progress that makes their investment a good decision given the other pressures in their lives. As an aside, sometimes students use the term "busy work" to describe assignments – is that a sign of student cynicism or the expression of disconnect between what they hoped to achieve and what they think they are actually doing?

(7) WPs care about school rankings and reputations/brands, but only to the extent to which they can afford. Stated differently, they know that the promotion/goal they seek is a function of education and experience. If the cost of the education is too high compared to the out-of-pocket expense, they may be willing to rely more on their experience or find an education partner with a lower tuition level.

(8) WPs want education to be as quick or as slow as they need it to be.

(9) WPs may take anywhere from 1 week to 18 months to finally decide to invest in an education experience. According to the interviews conducted by Rensselaer's team, this decision process can take place across four stages, where each stage may take weeks or months depending how "pressing" the need for education is. The four stages are depicted below in Figure 1.

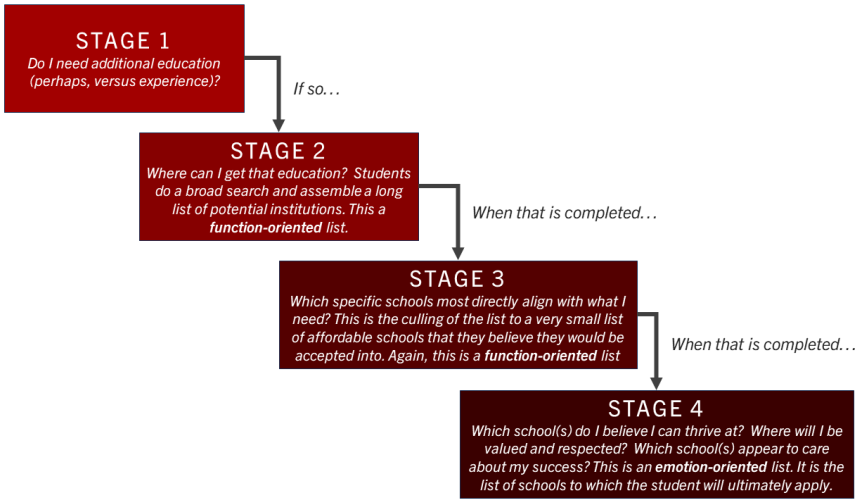

Figure 1. Stages of working professional learners' decision process to invest in an educational experience

Each individual WP has their own set of concerns and weighs the points above in proportion according to their individual situation. However, the general WP position suggests that education needs to help them make forward progress on their goal achievement or it will not be worth the investment of their limited time and money—no matter the reputation of the Institution.

1.2 The Insights: Employers

Rensselaer interviewed executives from approximately 450 different employers across many industries and sectors, with a few notable exceptions. Given Rensselaer's reputation as a STEM institution, particular focus was paid to organizations and industries that could be considered "intellectually intensive," defined as those industries and organizations that have a higher-than-average dependence on highly educated individuals in the production of their good or service. The team therefore focused on organizations that are highly dependent on "brain power" in the production of what they sell. These organizations are more reliant on, and willing to invest in, a highly talented workforce beyond employee retention purposes. With this definition, the scope of the interviews did not include sectors such as retail and recreation.

The Rensselaer team leveraged existing relationships, alumni/ae networks, and LinkedIn to connect with interviewees, with some interviews conducted face-to-face and others via Zoom or Webex. Employers ranged from organizations with 10 employees up to those with more than 50,000 employees. Each interview began with two overarching questions to stimulate the conversation – "What challenges (broadly writ) does your organization face?" and "How can Rensselaer help you address those challenges?" The team then followed up with additional questions based on their responses. Conversations covered a range of topics, which are aggregated and distilled into a set of general themes as follows:

(1) Employers want their employers to do more than just take courses. They want their employees to be able to directly contribute to the organization's success because of their education. They almost universally expressed an appreciation for education, but if they are contributing to the education in the form of employee benefits or through training and development budgets, they want results that have operational impact. It was notable that many employers expressed a degree of skepticism about the relevance of formal education to their precise challenges. Stated differently, employers want a return on their investment in their employees. They are not clear as to how that should be quantified, but they express that "they'll know it when they see it."

(2) Employers want to retain and promote their rising stars. These are individuals who are high performers, and employers want to prepare them for their next challenge: to promote them and keep them. These rising stars already have a distinct ability set – what they need is an increment of additional abilities that will help them in the new role. They want to be able to get their rising stars the exact increment of education they need now, to launch successfully in their new role. That increment of education can be defined, is discrete, and is oriented to ability augmentation. Examples are depicted in Figure 2.

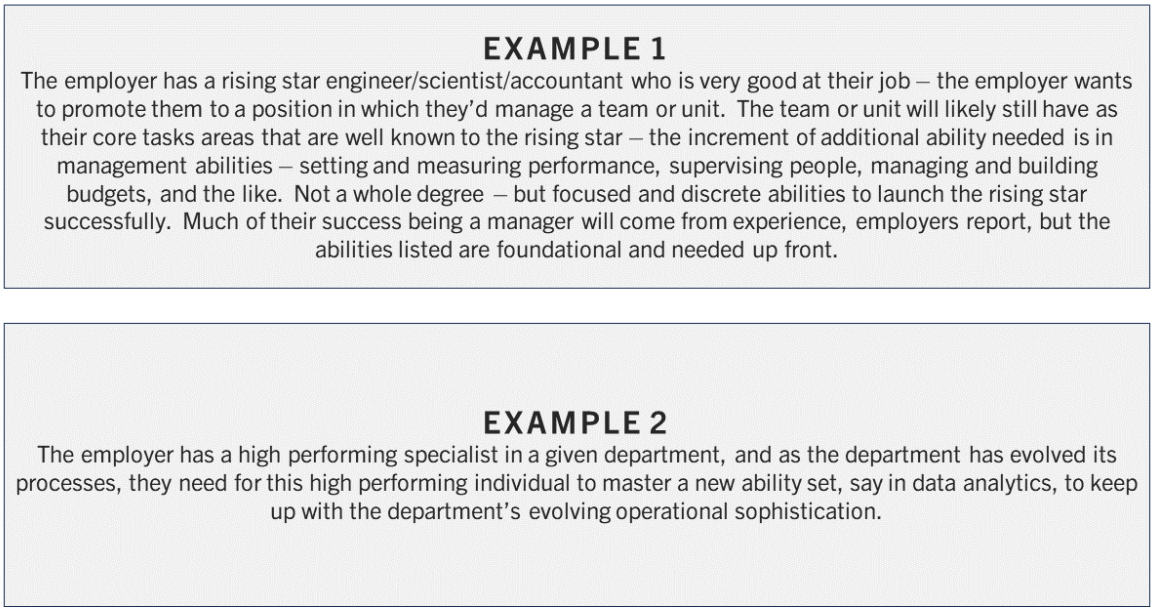

Figure 2. Examples of employer and "rising star" educational needs

(3) There are specific times when the employer needs someone with a conferred postgraduate degree such as a Masters or Doctorate in a particular area. For example, if they appoint a Director of Analytics, the individual assuming that position will need in-depth analytical and statistical training expertise. As such, most WPs need a foundational platform in an area – not full academic preparation. An example is located below in Figure 3.

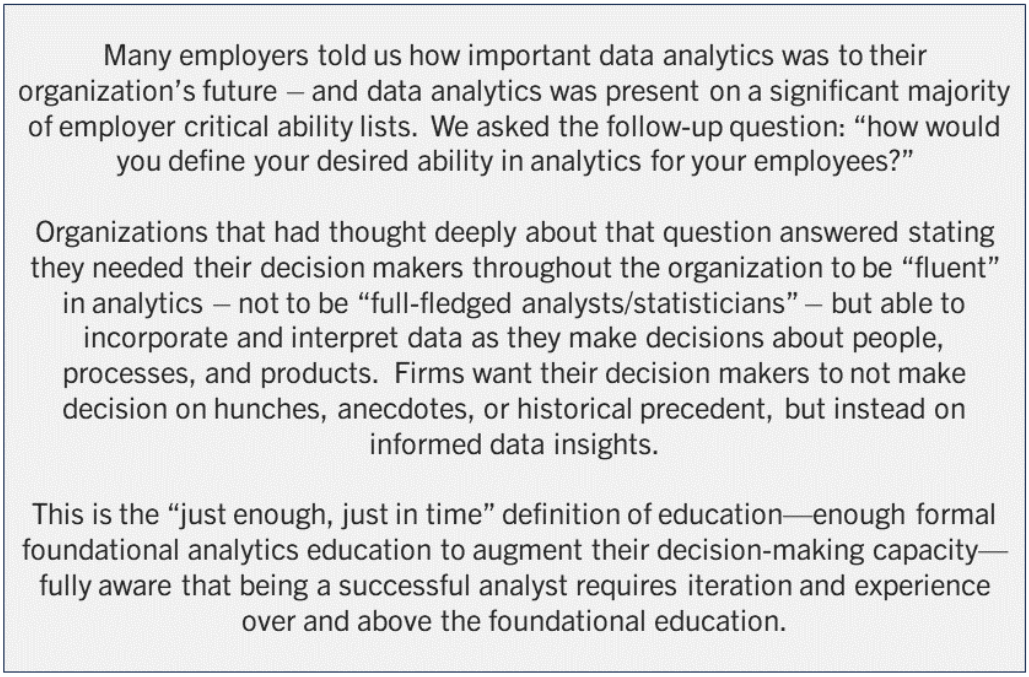

Figure 3. Example of employer needs for employee foundational knowledge in data analytics

(4) Employers do not want their employee's professional activities to be interrupted by the educational experience. Everyone is incredibly busy, and they need to stay focused on their area of responsibility.

(5) Employers want the education their employees get to be focused on their current or near-future productivity. In other words, long-term is great, but the definition of value to employers appears to be focused on augmentation of capacity and ability today. For the employer, employee retention is more difficult than perhaps ever before, and they want their investments in education to pay off while they still have the employee.

(6) Employers have specific short lists of capacity challenges their organization is currently focused on resolving. In general, and across industries, the following list had consistent educational needs:

1) Transitioning a highly able Specialist to an early Manager

2) Transitioning a highly able Manager to a Leadership position

3) Bring data analytic fluency to all decision makers throughout the firm

4) Building capacity in machine learning and artificial intelligence

5) Project- and Program management to ensure change occurs in a planned and intended manner

6) Systems/Process engineering to build operational effectiveness throughout the enterprise

Though this is a partial list, it reveals a consistent underlying message: each of the above suggests a movement from purely focused specialist roles to more general roles. Individuals are taking on new responsibilities that require them to have a broader focus, drawing higher order conclusions and making broader-based decisions. Each area is adding to, not replacing, the ability set of the individual. Each is therefore incremental in nature.

This does not obviate the need for deeper ability augmentation for specific people in the organization, it only informs the broader needs of the organization. For example, in describing their analytics needs, a large aerospace and defense contractor with approximately 60,000 employees, stated they want every manager of budgets, people, and products throughout the organization to have analytics fluency, whereas they only need about 10-20 doctoral level analysts and statisticians at the corporate level "analytics office." This example accurately portrays the scale of opportunity.

Each employer had its individual concerns, and the themes above can be summarized as, "As employers, we want specific sets of abilities to augment the capabilities of our rising star employees. We want to promote where we can, retain where we can, and see direct positive impact on our organization as a result of our investment."

1.3 The Insights: The Intersections of Employers and Working Professionals

How can these insights inform the design of graduate education? Most convenient is to look at the points of intersection, as shown below in Figure 4.

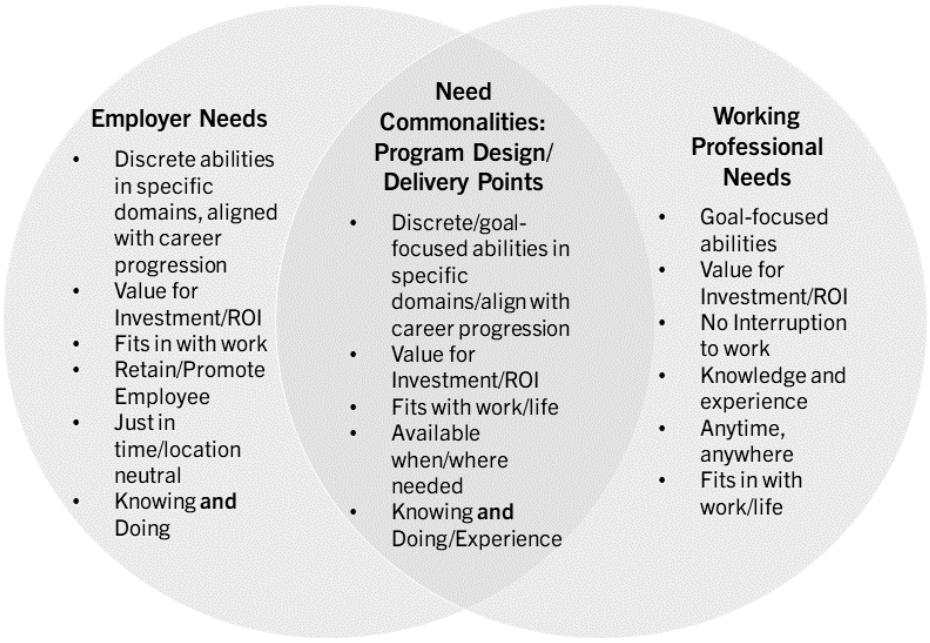

Figure 4. Intersection of employer and working professional needs that inform program design

Figure 4 above shows the points of commonality that can be taken as design criteria for insuring programs most optimally meet both employer and WP needs. However, one commonality bears drawing out further, and that is the need for ability augmentation when needed, where needed, and in a manner that fits into other personal and professional commitments. Many employers expressed this with more specificity: if they are going to partner with an institution to develop their employees, they need the education to be available to employees wherever they might be. The more distributed the employer, the more flexibility the educator must have to be the best partner possible with that employer. This suggests that online learning is optimal, but then the other factors come into play.

With no constraints, how can an online learning experience be designed that optimizes compliance with the above needs, and one that optimizes everything that is known about how students engage and learn? Many universities offer online learning, but does the current version of online education optimize learning and engagement in a manner that coincides with the needs of employers and working professionals? The next section synthesizes the literature related to designing online learning to support the needs of these populations.

2. Explore

The online format reduces barriers for WPs, as it offers the ability to engage in incremental learning experiences that align with their busy schedules. However, regardless of the flexibility afforded by this format, online learning must be designed thoughtfully to foster learner engagement and success. This section explores research related to identifying industry-aligned learning goals and competencies, designing projects to promote active learning, and leveraging digital design practices that support learner needs.

2.1 Identifying Learning Goals and Competencies

Designing a graduate program for WP learners is a strategic process—one that necessitates careful alignment between learner goals, professional competencies, and learning activities (Shah et al., 2018). This relationship must be intentionally designed and articulated, as WP learners need to visualize how competencies support their goals as well as justify their employers' investments.

Learning goals and competencies form the foundation of a well-designed program, as they provide a scaffold for the learner's development (Shah et al., 2018). For this reason, it is helpful to define learning goals and competencies

before drafting content, crafting assessments, or selecting educational technology tools. This practice, known as backward design, ensures congruence between competencies, instructional strategies, assessments, and all other course components (Chyung & Stepich, 2003). As noted above, this congruence is important for the WP learner, as they are weary of "busy work" that does not appear to serve a larger purpose.

Bloom's Revised Taxonomy (Bloom & Krathwohl, 1956) is a commonly used tool to facilitate the design of learning objectives and competencies (Anderson et al., 2001). This two-dimensional model includes the knowledge dimension and the cognitive process dimension. The knowledge dimension spans from concrete to abstract knowledge, representing the transition from fact-based knowledge to conceptual thinking (Anderson et al., 2001; Bloom & Krathwohl, 1956). The cognitive process dimension progresses from lower order thinking (LOT) to higher order thinking (HOT) skills, expanding from remembering, understanding, and applying to analyzing, evaluating, and creating (Anderson et al., 2001). Competencies can be crafted by determining the appropriate level along the knowledge dimension, then selecting a corresponding action that represents the desired cognitive process.

Designing learning competencies for WPs involves a creative interpretation of Bloom's Taxonomy. By the time the WP learner seeks to further their education, they likely have already surpassed the LOT skills and concrete knowledge related to their field. For this reason, learning must operate at the HOT skill level—reflecting actions like apply, build, experiment, recommend, decide, design, develop, and produce (Sánchez Carracedo et al., 2018). Each of these actions reflects the demonstrated ability to effectively leverage both knowledge and experiences in professional settings, an essential outcome for the WP learner (Anderson et al., 2001; Sánchez Carracedo et al., 2018).

The WP's employer also often plays a part in the decision to further their learning, as employers have specific goals for their employees who seek education. Employer involvement may range from solely providing financial support to taking an active interest in the WP learner's experience. Thus, it is essential that competencies address critical ability gaps as observed by employers and the larger industry. This alignment can legitimize the program in the eyes of the industry, as well as justify employers' support for or investment in employee education (Costigan & Brink, 2015; Shah et al., 2018). This alignment becomes all the more important when designing programs for WPs in STEM fields, an area of focus for Rensselaer. This area has become transdisciplinary in recent years, as STEM professionals leverage tools, techniques, and methods from various disciplines (Ertas et al., 2003; Sharunova et al., 2020). As STEM organizations are often at the forefront of technological advancement, programs that focus on solving current problems with modern technologies equip graduates with inadequate skillsets (Rayney, 2002). For this reason, competencies should reflect what learners need to know, but offer flexibility in how that competency is accomplished. With this flexibility, WP learners can determine the "how" with the specific tools and methods that align with their organization's needs and available resources.

The learner's perception that the program honors their goals is crucial not only to their success and continuation in the program, but also to the sustainability of the program itself. As noted above, when the connection between goals and learning tasks is clearly articulated, learners are more likely to perceive the experience as useful and worthy of their investment (Alanazi et al., 2020; Lee, 2014). Learning designed in this transparent manner also allows the learner to draw a mental trajectory from course competencies to their professional goals, which can support their intrinsic motivation to complete their program (Yoo & Huang, 2013).

2.2 Designing Competency-Aligned Projects to Support Active Learning

With learning goals and competencies identified and aligned with employer and employee needs, the design phase proceeds to envisioning how learners will demonstrate mastery of those competencies. Though active learning takes place through the delivery of digital programs, the learning experience must be prioritized and carefully thought-out during the design phase. Adult learners experience higher levels of engagement and increased performance when they become active participants in their learning (Dringus, 2000; Freeman et al., 2014; Jo et al., 2020) Active learning creates pathways for learners to collaborate with their instructors to co-lead in constructing knowledge (Carr et al., 2015; Ford, 2010). This approach aids in the transition from pedagogy to andragogy, which refers to the practice of teaching adult learners. Andragogy elevates learning from passive, teacher-directed instruction to learner-directed experiences (Zemke & Zemke, 1995).

In digital environments, active learning may be practiced through engaging in problem-based learning, learner-led projects, reflective exercises, or critical thinking activities (Ornelles et al., 2019). In addition, exploring case studies can provide rich context for their coursework in relation to real-world problems that they may encounter in their own work (Yang, 2017). In higher education STEM programs, learners who engage in these active learning projects

achieve outcomes and develop HOT skills at higher rates than those who solely take exams or other traditional assessments (Deslauriers et al., 2019; Freeman et al., 2014).

Designing projects with active learning in mind promotes the ability to "learn by doing" in an authentic manner. Authentic learning is learner-centered, allowing for contextualization of the content, tasks, and deliverables within the learner's personal experiences and goals (Han & Resta, 2020). The ability to make these real-world connections creates a learning experience that is inherently more meaningful (Fish & Wickersham, 2009; Lee, 2014). Authentic active learning prioritizes the different contexts to which learners can apply the content over the physical learning environment, a practice that can be successfully accomplished in the location-neutral digital classroom (Han & Resta, 2020; Heath & Mclaughlin, 1994).

In order to design projects that support active and authentic learning, it is helpful to present learners with a scenario that is grounded in a real-life, field-aligned problem—mapped to the course competencies. This may be considered as a situation-problem, in which learners are called to react to the scenario by acquiring new knowledge through an aspect of play or direct learning (Bot et al., 2005). Following these "situation-problems" with a challenge invites the learner to critically examine a problem, question, or need related to the field which prepares them with real-world applications, methodologies, artifacts, and reflections that they can apply directly to their work in the field (Pérez-Rodríguez et al., 2022). The "situation-problem," or "scenario," provides learners with the "what" and "why" behind the learning experience. The heart of the project experience lies in the task of determining the "how" as learners work through solutions to the proposed challenge.

After drafting projects with these considerations in mind, competencies can translate seamlessly into learner-facing rubric items that facilitate the evaluation of learner success. The use of competency-aligned rubrics in course design not only facilitates learner understanding of the parameters of the project but also allows instructors to measure their work against rubric items (Tanis, 2020). This practice sets the stage for instructors to provide targeted formative feedback that invites learners to actively engage with recommendations for improvement (Ragupathi & Lee, 2020). This practice facilitates the transition of the learning experience from task-centric to learner-centric, supporting the WP learner's goals of engaging in meaningful learning (Ragupathi & Lee, 2020).

2.3 Implementing Digital Design Practices to Support Learner Needs

As the physical classroom might be considered the homebase for traditional learning, the learning management system (LMS) is the learner's hub in a digital classroom. The LMS delivers educational content to learners, providing tools to facilitate teaching and learning in one centralized location (Demir et al., 2021; Pinã, 2013). As the LMS is the main access point to connect learners to learning content, its design must demonstrate purposeful, unified technological integration to create a simple user experience (Santelli et al., 2020). Though most LMS options offer basic features like discussion boards, grading, and announcements, these tools must be presented in a user-friendly, easily accessible manner to ensure that the learner feels supported, comfortable, and engaged (Alanazi et al., 2020). This clear user experience should extend to LMS access from mobile devices, as graduate learners appreciate the portability of this format to engage with course materials at their convenience (Baldwin & Ching, 2019).

Within the LMS, having a consistent structure and navigational design across courses is essential to prevent confusion or learner disorientation (Casey et al., 2021). Learners build confidence when they encounter these consistent, anticipated elements across digitally delivered STEM programs, which can reduce their hesitation around engaging with new topics that they may perceive as challenging (Yang, 2017). This practice applies to both the design of the user interface and the way in which projects are presented, as well as the terminology used across courses to refer to similar concepts, features, or navigational items. Designing a standardized template to leverage in course building can ensure that all learners within a program experience these consistent elements (Lewis, 2021).

3. Design

Given the identified needs and the takeaways from learning science, the Rensselaer team selected a set of solutions that required strategic choices in four key areas: program logistics, curriculum design, role of instructors, and the learning interface. "Program logistics" includes, but is not limited to, the details of how the programs were to be structured and operated, as well as what types of offerings were to be provided. "Curriculum design" incorporated not just the subjects covered, but also the nature in which offerings were to be built and delivered, including modality of course delivery. "Instructor roles" refers to the responsibilities of instructors and how they would facilitate experiential learning and student growth. The "learning interface," simply put, is the software that students would use as their digital classroom.

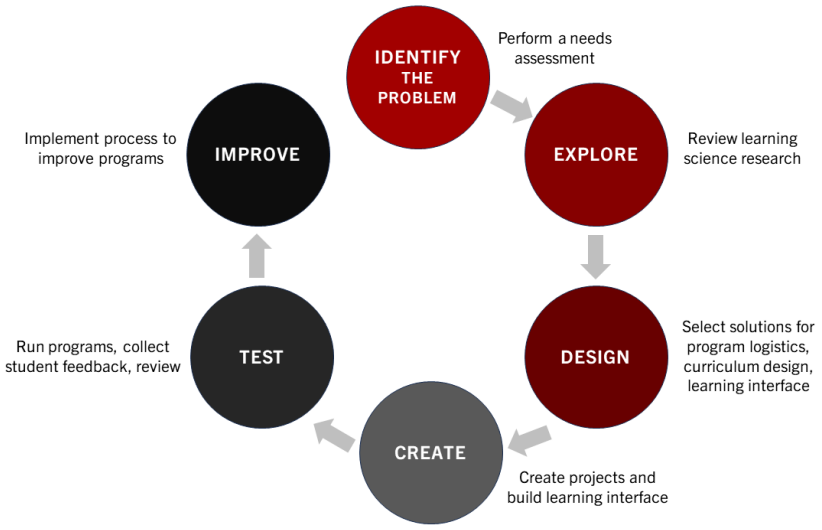

Figure 5. A six-step articulation of the engineering design process and how it was used as a framework for developing digitally delivered graduate programs for STEM working professionals (note: this paper only covers the "Identify", "Explore", and "Design" steps)

In addition to the needs of employees and employers, takeaways from learning science provide guidance on how to optimally facilitate learning. A key theme that emerged was an emphasis on considering learners as complex humans and aligning design choices with their motivations and life circumstances to cultivate an environment for them to thrive within. A simple term that was used to encompass this idea was the "student experience."

Prioritizing the "student experience" did not only help develop design constraints, but perhaps more importantly, a culture that prioritized honoring learners as humans with unique emotions, goals, preferences, perspectives, and prior experiences. If doing so was important for the success of businesses interfacing with customers, then it was thought as being even more important for students in an educational program where they are, on one hand, customers making one the largest financial investments of their lives, while at the same time experiencing a journey of personal and professional growth. Thus, emphasis was given to designing a student experience that could meet the expectations of the customer while cultivating the environment that provides the necessary preconditions for learning and growth to occur. Table 1 outlines the areas in which solution choices were required, the solutions/designs chosen, and how those were perceived to meet the shared needs of the employers and employees, as well as the needs associated with a providing a superior student experience that cultivated the right environment honoring students as individuals. A discussion of how each area was designed to meet the needs shown is provided next.

3.1 Program Logistics

The logistics of a program must fit with WP's lives and honor their work and personal life commitments. Table 1 shows that a complex system exists, such that choices in program logistics, curriculum design, and learning interface are interrelated through the needs of employers and employees. Consequently, each decision made can validate, or invalidate, multiple underlying needs. As Table 1 below shows, digitally delivering the programs was selected as a cornerstone of the solution since digitally delivered programs are readily accessible to potential WPs across the globe and support key needs. It was a priority that all potential students should be able to participate so long as they had a computer and high-speed internet connection. Alternative choices for program logistics could easily violate the stated needs though, such as requirement of a residential portion of the experience or necessitating attendance for multiple, weekly classes, even if online.

Table 1. Traceability matrix showing how the employer, employee, and learner needs are addressed by solution choices in the areas of program logistics, curriculum design, and the learning interface

	Employer and employee needs					Learner needs	
	Fits with work/life	Available when/where needed	Discrete/goal-focused abilities in specific domains/align with career progression	Valuable for Investment or ROI	Knowing, Doing, and Experiencing	"Easy to Use" Learning Interface	Iterative Learning
Program Logistics							
Digitally delivered	X	X				X	X
Various "size" offerings (course, graduate certificate, degree)	X	X	X	X			X
Curriculum Design							
Articulate skills with LG&C			X	X	X		X
Project-based			X	X	X		X
Learning Interface							
Canvas with custom navigation		X				X	

In considering program logistics, the "size" of programs was also reviewed. Through conversations with employers and employees, it was evident that the right "size" of program must be offered. It was clear that ability sets may necessitate programs of different length as some skills may be learned quickly while others may take longer to master. Likewise, some sets of abilities are more discrete, and employers/employees may desire new abilities in less than the time it takes to complete an entire master's degree. To enable design flexibility around this, without sacrificing satisfying other needs, courses were chosen as a building block of all programs, where courses are credit bearing, term-based experiences that can be started in the Spring, Summer, and Fall. To address various levels of need, options are made available for participants to enroll in individual courses as well as 3-course graduate certificates. As all courses and certificates are credit bearing, they were designed to be "stacked" into master's degrees, provided they meet the requirements of the intended degree. In this way, employees and their employers would be able to choose what level of abilities align with their needs, even if these changes over time, and stack smaller courses and programs together to achieve a master's degree.

To ensure that valuable abilities were gained no matter the size of the program, learning goals and competencies (LG&C) were used to articulate the skills students would demonstrate mastery in. In alignment with the needs of the WP population, the LG&C needed to provide professional abilities such as leadership and change management alongside technical abilities such as systems thinking or modeling and simulation. For multi-course sequences, such as graduate certificates, overarching LG&C were articulated to ensure courses work as a system and to ensure core abilities were demonstrated in various contexts. To ensure attainment of the abilities was measured, project assessment rubrics were built using the LG&C with a binary evaluation schema. In this way, evaluation and feedback are provided on the abilities that each offering promises to deliver, fully closing the loop on what is designed, advertised, and attained. The process for doing so is described next in the "Curriculum Design" section.

3.2 Curriculum Design

Proper curriculum design must be employed to bring the learner to full mastery, transcending lower orders of thinking such as memorization. High order thinking and advanced abilities are optimally achieved with increased learner engagement where authentic doing occurs alongside the guidance of seasoned professionals who embody a mentorship approach. Thus, in designing curriculum, a project-based solution was chosen. Rensselaer at Work's definition of project-based courses necessitated that they were one, or more, projects. Stated differently, projects are not only part of a course, they are the course. This is in contrast to a course in which homework, tests, and quizzes are the focus and the course ends with completion of a project. Instead, the course begins with immersion into a project and students remain immersed in the project until the course is complete.

Identification and articulation of LG&C can occur in numerous ways. Here, a "backward design" approach (Chyung & Stepich, 2003) was used for the design of all program curricula. This process began with an initial articulation of the LG&C where the learning goals tie together a set of related competencies. Learning goals and competencies were defined based on the program type, a search of existing training and development opportunities, other education programs, consultations with multiple stakeholders at employers as well as subject matters experts and instructors. To deliver professional and technical skills desired by organizations and employees alike, LG&C combined both aspects. A critical design feature of LG&C is that they were actively articulated and described what someone was able to do, but not necessarily how. In this way, LG&C can remain relevant even when tools and methods change, as the underlying skills often remain relevant for longer periods of time.

Once an initial set of LG&C were established, scenarios for authentic doing were identified using common efforts undertaken by professionals with responsibilities in the given program area. This was accomplished through facilitated brainstorming meetings with SMEs and instructors. Takeaways from conversations with employers were also often invoked to provide context relevant to employer partners. For instance, in data analytics, a data analyst might be asked to forecast future sales for a new product based on market study data and sales from a pilot offering. In the area of systems engineering, a manufacturing engineer working in operations may be asked to use simulation to analyze the performance of a manufacturing line and assess queuing times, resource allocation, and production volumes. Overarching scenarios such as these were collected to ensure projects were rooted in authentic doing.

Next, the LG&C were "mapped" to each project. In this way, prior to identifying specific topics, building learning resources, or writing projects, the authentic context for project work was first established. The competencies necessary to successfully achieve the goal of the project were identified next. When designing larger, overarching curriculum that was to be interwoven, the largest "unit" was chosen, under which authentic scenarios were defined. For instance, although a graduate certificate consists of three courses, LG&C are articulated at the certificate level and then selected based on the project scenarios. Given a sequence of scenarios, estimates for the time required to complete each were made which then led to the identification of the projects that could fit within each course. This methodology also helped determine if courses were to be taken sequentially, or not.

In general, the design of projects took on two different forms: i) fictional scripting that places the student in a specific role within an organization where they are provided a set of challenges to resolve and ii) non-fictional scripting requiring students to identify and work towards a solution using a workplace situated challenge. Careful consideration was given to the logistics of using the second form. Considerations included diversity in employee roles, level of seniority, availability of any necessary data, and level of coworker/organization involvement in successful project completion.

At the end of the design phase, each course had an initial description, and number, of projects to be completed, along with an initial map of the LG&C for each project. This enabled an assessment of LG&C coverage across multi-course programs such as graduate certificates, or a required sequence of courses for a degree. An initial requirement established that all LG&C be assessed at least once in each program. Commonly, certain LG&C were found to be central and were mapped to multiple projects across multiple courses.

3.3 Learning Interface

In addition to traditional academic program design decisions, program design for digital learning requires careful exploration, selection, and use of technology solutions. To support a superior student experience, the learning interface should be easy-to-use. In exploring aspects of website design, user experience (UX), and user interface design (UI), several critical principles emerge. These include: i) minimal clicking ii) consistent look and feel to ensure intuitive navigation iii) one single place for students to get everything they need ("one stop shopping"). This meant eliminating requirements for signing into multiple software to successfully complete coursework. Instead, a

single sign on (SS) solution was used that is also mobile friendly. In addition, the learning interface should support the instructor-mentor relationship and so having integrated instructor messaging allowing for effortless communication between instructors and students was critical. Likewise, proper configuration and use of tools for providing evaluation and feedback were prioritized.

Multiple software solutions were explored, but the customizable nature of Canvas (an Instructure product) led to its selection. One valuable feature of this product is that it is HTML based and enables customization of UX and UI. Courses are templatized prior to insertion of project scripting, learning resources, rubrics, or any other content in a course.

Figure 6a. A snapshot of the custom home page in Canvas used throughout all courses. Five consistent navigation "buttons" are used

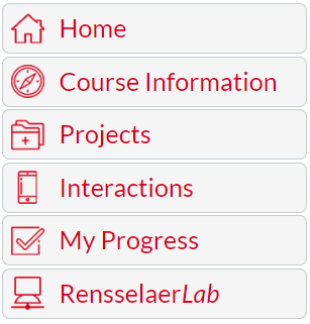

Figure 6b. Navigation menu implemented on subsequent pages within a course navigation utilizing the same navigation cues as the course home page

Figure 6a shows the home page used for all courses, providing five icons for navigation. On all other pages, a navigation menu (Figure 6b) is implemented. Due to its ease of use is, in part, attained through a consistent look and feel, from page to page, there are repeated elements, colors, fonts, and navigational cues. Thus, no matter where a student may be in a course, they are able to freely navigate to any other section without using the familiar forward, or backward, buttons common to many learning management solutions.

As projects are the building block of all courses, project structure is needed to maintain a consistent look and feel as well. Figure 7 shows what users see when clicking the "Projects" button. Courses begin with a "Start Your Journey" which provides the overall narrative for the entire course. Then, each project includes a "Scenario and Challenge" along with "Approach." Again, each element of this page design is consistent among courses. The "Approach" for each milestone was built using the "Assignments" page in Canvas so that all instructions, resources, rubric, and ability to submit work were found on a single page. This eliminated extra clicking for students to submit work, view rubrics, or view project instructions. As Figure 8 shows, within the Approach, any resources that students required were incorporated directly using hyperlinks that opened in new tabs so that students were never directed away from their project work.

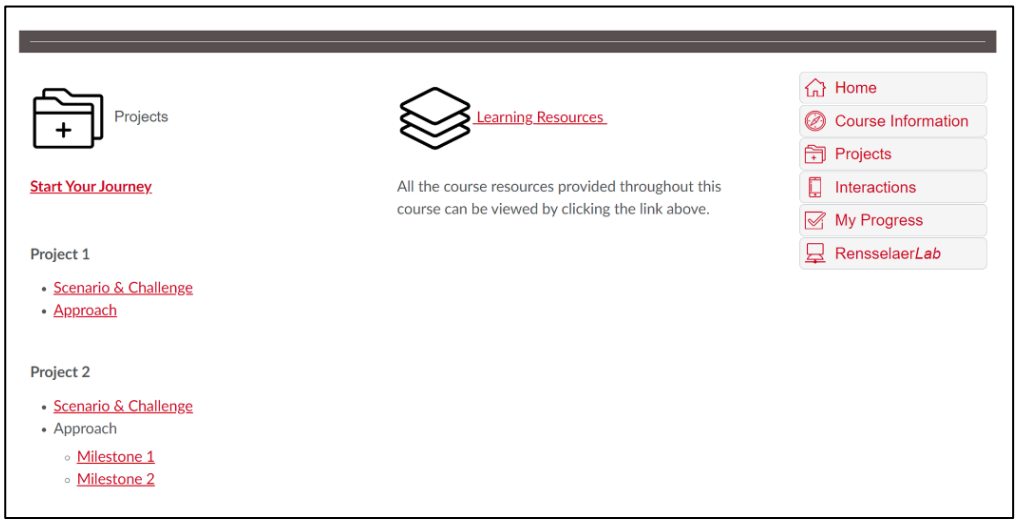

Figure 7. Snapshot of the "Projects" page of the RensselaerStudio used throughout all courses

The page included a link to the section(s) of a project, a collection of the learning resources used within the project(s) as well as the right-hand navigation menu with the same navigation cues as the home page.

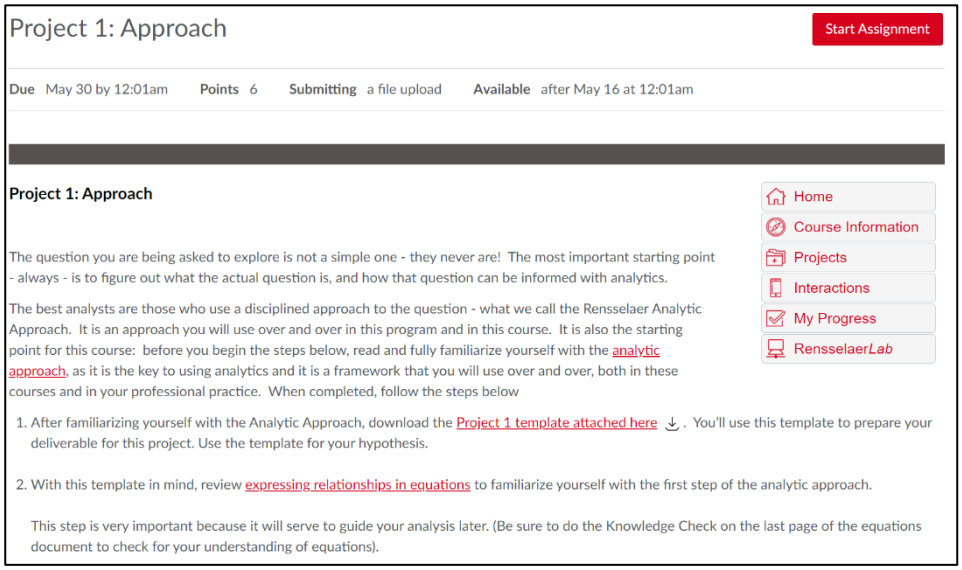

Figure 8. Snapshot of "Approach" showing a) narrative style scripting of how to complete the given milestone along with hyperlinks to learning resources, b) description of preparing your deliverables, and c) rubric built using the mapped learning goals and competencies

4. Conclusion

This paper presents a framework for how Rensselaer Polytechnic Institute leveraged the first three steps of the engineering design process to identify learner needs, explore research-informed instructional design solutions, and design online graduate programs based on those inputs. A special focus is given to how each decision was made in alignment with the needs of employers and employees, as well as learning science so that others may use this work to help inform and support their own program design, especially when their choices may differ from conventionally designed and delivered programs in higher education. To further support this work, a forthcoming paper will focus on how the fourth, fifth, and sixth steps of the engineering design process were leveraged in program creation: iteratively creating the designed solution, testing it to evaluate its effectiveness, and improving it. The forthcoming paper will also discuss the role of the instructor-mentor in supporting learner success, considerations for delivering engaging digital learning experiences, as well as successes and methods to address areas of improvement.

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