A case study in the implementation of convergent education: Diversifying frames of knowledge

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Keywords: Multi-disciplinarity, place-based education, convergent learning outcomes, problem-solving

Key contributions/ Pathways to collaboration

- This work advances the relatively new perspective of convergent education, which aims to develop professionals who are comfortable thinking across traditional boundaries in an effort to problem-solve within the context of society's current needs.

- This article presents a conceptual framework for defining and identifying convergent education as well as evaluating learning outcomes, that is transferable across university settings.
- Within our case study we find that despite the need for convergence practices, traditional academic structures predispose students and educators to remain disciplinarily siloed, particularly within the divide between STEMM and non-STEMM fields and fail to meet the goals of convergent education.
- This work provides, not only a pathway for identifying and evaluating convergent education, but also a foundation from which convergent practices can be compared across institutions. This helps define ways in which convergent education can be achieved at the undergraduate level.

Abstract

Convergent education calls for the dismantling of long held academic borders, and for the blurring of traditional academic divisions. It emphasizes the development of professionals who are comfortable thinking across traditional boundaries and who are equipped to best meet the needs of today's society through critical thinking and problem solving. In doing so, it focuses on issues central to and concurrent with a student's present experience. As we explore, we find that despite a variety of implementations of multidisciplinary approaches, an implementable framework for convergent education that is transferable across university settings seems lacking. We offer a framework for defining, identifying, and evaluating convergent education and apply this to a 2020 undergraduate course at the University of Portland. In addition to the development of a framework and analysis of convergent learning within the case study, we find that despite the ready need for and applicability of convergent-based education, more traditional academic structures predispose both students and educators towards educational outcomes that remain largely siloed, particularly in the divide between STEMM and non-STEMM majors. We demonstrate how the existing mismatch between intended convergent education outcomes and traditional academic structures may limit convergent education possibilities and we propose areas in which higher education can improve in developing professionals who are equipped to address the most pressing global issues.

Introduction

In 2020, students and faculty alike grappled with numerous global, scientific, and societal challenges. The world we collectively knew came to a grinding halt. Between the COVID-19 pandemic, local and international climate change impacts, growing awareness of systemically embedded racial justice issues, and political turmoil, individuals were inundated with opportunities to be both overwhelmed and inspired, often within the same breath. Within higher education, the year underscored the idea that single areas of expertise or academic disciplines, though capable of depth, are limited in their investigation, evaluation, and range of potential solutions. Intersecting arrays of lenses and perspectives are required to approach solutions to the world's most pressing, contemporary problems.

To address significant local and global issues, traditionally separate and often seemingly disparate disciplines must converge, forming new networks, partnerships, and bodies of knowledge. Also emergent was the essential recognition that many of the most pressing problems and their solutions are embedded within social and cultural contexts that bear the signatures of inequity, injustice, and limits to accessibility (e.g., Downs, 1970; McLeman & Smit, 2006; Mamelund, 2017; O'Brien & Leichenko, 2000; Saiz, 2009; Watts & Bohle, 1993). Addressing contemporary problems requires innovative education and research, and students must prepare for professional (and personal) lives in an increasingly convergent world. Society's current needs demand education that enables practitioners to collaborate across traditional boundaries rather than subscribing to traditional siloed and hyperspecialized models of knowledge.

A relatively new perspective in research and education, convergent education (or "convergence", used here interchangeably), largely dismantles traditionally held academic borders and silos, and blurs traditional academic divisions to emphasize the development of critical thinkers and problem-solvers (Brooks, 2017). While many multi-disciplinary approaches pull disciplines together or identify a problem and move between disciplines to find a solution, convergent education takes this reimagining of boundaries a step farther by producing connections between traditional institutional divisions (Brooks, 2017), while specifically including a contemporary problem-based, contextual focus.

Convergent education meets the needs of today's society by addressing issues that are central to and concurrent with a student's present experience through intersecting disciplinary lenses. It identifies the responsibility of researchers and scholars within higher education to develop pedagogical approaches that mirror our increasingly convergent world. In doing so, convergent education moves away from disciplinary isolation toward an emphasis on creative problem-solving that spans traditional academic and institutional boundaries and is simultaneously embedded in a contemporary context. It equips students to be solution-oriented when considering present issues and fosters the growth of future professionals who are adept at seeking solutions in areas where bodies and practices of knowledge overlap, and when necessary, visualizing and building those overlaps (Brooks, 2017).

The field of nanoscale science produced early adopters of convergent research and education, who, in the early 2000s, developed a broad framework for convergent research and an acknowledgement of the need for convergent-based education. A landmark 2003 book (Roco & Bainbridge, 2003) described convergence of technologies in research, addressing the need for extension of convergence into education, and international workshops began to examine convergence within both research and education (Roco et al., 2013). By 2014, convergence emerged as a focus within the National Academies of Science, Engineering, and Medicine (NASEM, 2014). In 2016, MIT released a study called, "Convergence: The Future of Health", and Springer published the Handbook of Science and Technology Convergence, containing numerous contributions specifically addressing convergence in education (Bainbridge & Roco, 2015). However, it is notable that these advances remain largely within STEMM fields.

The National Science Foundation, charged with promoting scientific research and development of researchers, identified convergence research as one of 2017's 10 Big Ideas for Future NSF Investments (NSF, 2017) seeking to develop research that is "driven by a specific and compelling problem" and employing "deep integration across disciplines", while also emphasizing communication across disciplines. Uniquely, the NSF concept of convergence centers on not only addressing current problems in an innovative fashion, but thinking futuristically to identify new frameworks, methodologies, and lexicons that could produce new avenues for inquiry. The goal is not simply to produce NSF-style

convergent researchers, but professionals whose identities transcend traditional disciplinary boundaries as they address current problems and anticipate the future.

Within higher education and research, however, convergence has frequently involved only disciplines within STEMM fields (e.g., nanoscience, technology, life sciences, and medical professions). Since the aim of convergent education is to go beyond academic boundaries to center on current, pressing issues, we also must integrate knowledge and ways of thinking from both STEMM and non-STEMM fields (Herr et al., 2019). The intent is to spur not only solutions and innovation, but new partnerships, networks, and frameworks for research, knowledge, and education. Simultaneously, both convergent education and research are not limited to academic disciplines, but expand to include government, industry, and civic stakeholders (NASEM, 2014), further embedding problem-solving within contemporary contexts and societal structures.

From an implementation perspective, convergent education presents certain challenges. Convergence does not always fit neatly within traditional curricula or academic structures. Convergence potentially requires large scale, long-term institutional shifts as well as changes in the support structures for higher education in general. As Herr et al. (2019) outline, new lexicons carry with them time costs in the form of cross-discipline learning curves, and frequent adjustments of course materials and textbooks to keep pace with the current context. Specific future workforce needs are difficult to project, and established bureaucracy and status quo can inhibit large-scale change (Convergence Center for Policy Resolution, 2019; Herr, 2019).

As we explore, we find that despite a variety of implementations of multidisciplinary approaches, an implementable framework for convergent education that is transferable across university settings is lacking. We offer a framework for defining, identifying, and evaluating convergent education and apply the framework to a 2020 undergraduate course at the University of Portland. We demonstrate the presence of convergent education and learning, even as it exists alongside traditional disciplinary structures, and highlight areas in which traditional discipline-based education have enabled or limited convergent education outcomes.

Background

From a conventional academy structure centered on developing leaders within traditional disciplines (Gilbert, 2007), interdisciplinarity gained popularity in the mid-1990s and early 2000s as a positive reconceptualization of a stagnant academic culture. Interdisciplinarity emphasizes the analysis and synthesis between disciplines to create a holistic view (Choi & Pak, 2007). It is considered a "re-mapping" of traditional disciplinary structure, but through a reimagining of boundaries, rather than a dismantling of this structure (Becher & Trowler, 2001), and encourages skills in identifying patterns, synthesizing knowledge, and pushing beyond discipline-specific expertise (Brooks, 2017; Choi & Pak, 2007; Klein, 1996).

Transdisciplinarity has emerged as an additional reconceptualization, flipping the focus of interdisciplinarity to center around a particular theme or problem, and integrating between disciplines (Choi & Pak, 2007; Mead et al., 2021). Rather than pulling disciplines together to create a coherent whole, transdisciplinarity identifies a particular problem and moves between disciplines to find a solution. Convergent education takes this reimagining of boundaries a step farther by producing connections between traditional institutional divisions (Brooks, 2017), and maneuvers within a collection of academic divisions simultaneously incorporating both academic and non-academic stakeholders, while specifically including a temporal component and contemporary contextual focus, a critical component of convergence.

Recent pedagogical approaches such as problem-based learning (PBL), while similar to convergence in being student-, team-, and problem- centered (Ersoy, 2014; Wood, 2003), center on applying appropriate problems to increase knowledge, rather than on problem-solving itself (Wood, 2003). Similarly, work-integrated learning (WIL) emphasizes practice-based application of skills beyond academic environments (Zegwaard, 2014), however it does so with an emphasis on developing students who are familiar with organizational practices (Cooper et al., 2010) and who can function within a structured work environment (Jackson, 2015). Convergence emphasizes problem-solving skills and specifically emphasizes current context in the identification of problems, alongside building problem-solving skills that are required in an array of sectors and contexts.

Few researchers have explored what constitutes convergent education in a university setting, attempted to evaluate its outcomes, and done so across a university rather than within a single course or program. Where researchers do evaluate convergent education strategies, they are specific to effectiveness within a particular discipline (Cropley, 2015), form of presenting information (Finogeev et al., 2020), or group such as technology educators (Norris et al., 1999). In most cases, research centers within technological disciplines, an irony given the foundational pillar of convergent education of transcending boundaries. Our conceptual framework creates a means of both determining whether convergent education has been achieved and evaluating the data across disciplines to understand outcomes. Implementing this framework, the first of its kind, within our case study, demonstrates transferability across university settings.

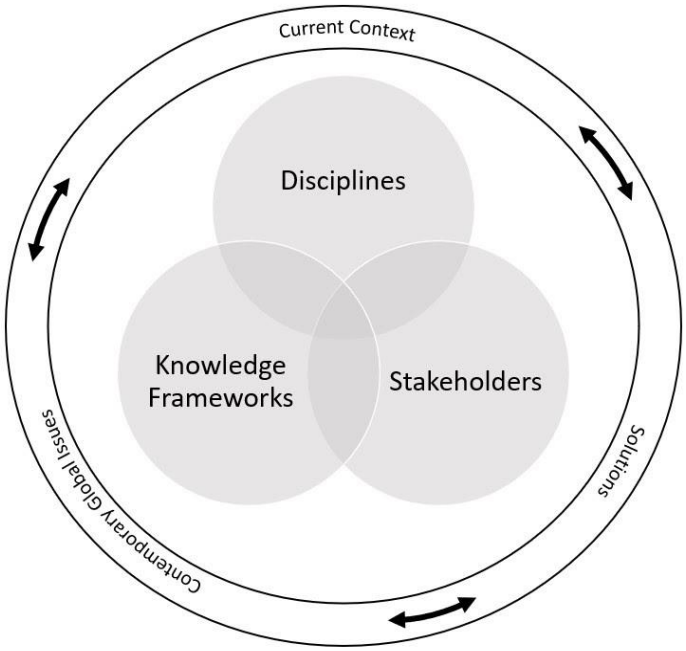
Framework

To achieve convergence in a course setting, diverse faculty provide the opportunity for traditional departments and disciplines to focus on a common problem, and in doing so, combine different methodologies, lexicons, data types, research communities, stakeholders, and knowledge frameworks, all centering on a current context. An emphasis on current issue-based learning alongside problem-solving skill development is critical and can be a springboard for future career skills and frameworks used for learning and research. Within this, a focus on the "lenses" through which students experience their world and how these perspectives can contribute to collaboration bolster a focus not only on pressing issues, but on how they are viewed through multiple perspectives.

For convergent education to be achieved, partnered and simultaneous learning across not only departments (which are traditionally represented by majors), but also across traditional academic stratification is required, and may include faculty being not only presenters of information but learners, bridging the divide of who is considered the "learner" in an educational environment. This requires both students and faculty to be responsive and engaged in an exchange of ideas, frameworks, lexicons, and experiences. Collaboration is envisioned throughout the course, and convergent education may provide for continuation of collaboration beyond the limits of a traditional term as well as beyond university settings (see Figure 1).

Figure 1

Conceptual Framework for Convergence in Education and Research.



Contemporary global issues inform the current context in which students, faculty, and non-academic stakeholders exist. These global issues demand effective solutions. Within this larger context are the central components of convergent education, which include an array of knowledge frameworks, disciplines, and stakeholders that combine to create solutions as well as identify new areas of inquiry. In this model, convergence allows for a continuous exchange between global context and inquiry that stands to build over time.

Given our above definition of the practice of convergent education, we identified three core principles of convergence to allow us to identify and evaluate the presence of convergent learning: integration, application, and vision. *Integration* refers to combining knowledge, terms, concepts, and themes from multiple fields to understand a contextual framework or even develop a new framework for "addressing scientific and societal challenges and opportunities" (Brooks, 2017; NSF, 2017; NSF, 2018). In practical terms, this means a demonstrated effective and meaningful integration across disciplines. *Application* centers around education that is driven by a specific and compelling problem that allows for students to engage with material beyond the classroom (NSF, 2017; NSF,

2018). This occurs in a manner that not only addresses a contemporary problem but does so in a manner that transcends classroom walls. *Vision* concerns the development of new theories, methodologies, data, or languages, with the potential for addressing current and future scientific and societal challenges (Herr, 2019; NSF, 2017; NSF, 2018). It may also ask new, unforeseen questions and provide insight to potential new areas of research or exploration. Our application of these definitions within the case study is described below.

Case Study

The social, political, and global events of 2020, each layered with inequality and injustice, provided the opportunity to create a course designed around addressing current context using convergence principles. In the course, which was entitled "Imagining our Futures: Sense Making in the Light of COVID-19, Black Lives Matter, and Climate Change," 23 faculty from 12 different departments (see Table 1) aimed to intentionally connect three contemporary challenges, predominantly within an academic environment: COVID-19 as a zoonotic disease that caused a global pandemic; systemic racial injustice within the United States highlighted by recent police brutality; and climate change impacts made particularly visible by West Coast wildfires in 2020.

Table 1

Departments Represented by Faculty Members and Topic of Focus in Order of Presentation Throughout the 2020, 14-Week Course

Week	Faculty Department	Presentation Focus
1	Communication Studies, Gender and Women Studies, Psychological Sciences	Introduction BLM and Racial Justice
2	Biology, Nursing	The Biology of COVID-19
3	Environmental Studies	Climate Change
4	Communication Studies, International Language and Culture, Gender and Women Studies	The Anthropocene, Race, and Nonhuman Animals
5	Psychological Sciences	Impacts of Racism and Scarcity on Psychological Functioning and Physical Health

Week	Faculty Department	Presentation Focus
6	Economics	Economics and Race Inequities
7	Economics, Mathematics, Environmental Studies	Economics and Transformative Change
8	Biology, Environmental Studies, Communication Studies, Gender and Women Studies	Wet Markets and Wildlife Tourism
9	Engineering, Biology, Environmental Studies	Racial Disparity in Water Resources
10	Environmental Studies	Climate and Racial Disparities
11	Biology, Environmental Studies	Race, Disease, and Health
12	Environmental Studies	Climate, Adaptation, and the “Global South”
13	Theology, Philosophy, Environmental Studies	Ethics
14	Communication Studies	The Meaning of it All

These problems arrested the attention of our students, especially given our geographic context. COVID-19 profoundly impacted our community following the gubernatorial declaration of a state of emergency on March 8, 2020, and our university leadership pivoting to remote learning on March 12. Portland was also the site of major racial justice protests, many explicitly aligned with the Black Lives Matter movement, following the murder of George Floyd. Described by *The New York Times* as the “center of B.L.M. protests” (Fuller, 2020), Portland’s protests were notable in part for the sheer numbers of participants (Haas & van der Haart, 2020; Wallner, 2020) and their longevity (Levinson, 2021). Further, civil unrest was characterized by clashes between combinations of protestors aligning themselves with Black Lives Matter, members of right-wing groups, members of left-wing groups and anti-fascists, anarchists, police, and federal agents (Baker, Bogel-Burroughs, & Gillespie, 2020; Mogelson, 2020).

2020 also represented one of the worst years on record for wildfires in Oregon, with over a million acres burned. While Portland escaped major fire damage, air quality was severely impacted by wildfire smoke. The city had never before scored worse than “Unhealthy” on the Air Quality Index but registered as “Very Unhealthy” on three days and

"Hazardous" on five in 2020 (Loew, 2021), at one point in September recording the worst air quality out of any major city in the world (Green, 2020).

Thus, we identified the topics of racial justice, COVID-19, and climate crisis as highly salient to our students. Current curricula, and STEMM curricula in particular, lack formal structures to explore interlinkages between these critical challenges, but we hypothesized that a more holistic understanding of these challenges could be achieved through a course centered on their relationships.

Our course took place at University of Portland, a private, comprehensive, regional university with roughly 4,000 undergraduate students across forty undergraduate programs. We opted to create an elective Massive Open Online Course (MOOC), as the university was operating largely remotely due to COVID-19, and so that students of any major could participate asynchronously. Ultimately, approximately 250 students spanning 24 different majors (see Table 2) enrolled and completed the course. The course was the largest ever to be taught at the University. Each week included readings, 20-60 minutes of recorded material, a 10-question multiple choice quiz covering week-specific material, and peer discussion.

Table 2

Majors Represented by Students Enrolled in the Course

Major		
Accounting	General Studies	Secondary Education
Biology	German Studies	Social Work
Business Administration	History	Sociology
Communication	Marketing	Spanish
Economics	Mathematics	
Elementary Education	Mechanical Engineering	
English	Nursing	
Environmental Ethics and Policy	Organizational Communication	
Environmental Science	Philosophy	
Finance	Political Science	

Faculty members volunteered to take part in the course and were charged with stepping out of their disciplinary silos and making explicit connections to explore how the three issues are deeply interwoven. This design intentionally blurred traditional academic boundaries. Examples of topics included: “Racial Disparities in Water Resources”; “Climate, Adaptation, and the Global South”; and “The Anthropocene, Race, and Nonhuman Animals” (for a full list of course topics, see Table 1). We also sought to re-structure the traditional lecture model by removing the faculty as the center of student dialogue. As part of course learning outcomes, students were expected to think convergently and problem-solve macro and micro concepts; reimagine possibilities for our daily routines and interactions; and confront implicit bias and the often invisible, embedded ways that inequity and racism continue to shape the United States.

Importantly, the course itself was not initially designed specifically as a convergent education case study. While the initial design and learning outcomes do, in large part, fall in line with convergent education, the central focus of the design was to address the particular context in which our students and faculty were finding themselves and provide a platform for which to explore these problems through an array of lenses. During the course it came to light that convergence education was occurring, but a framework was needed to identify it and analyze its outcomes.

Data Collection and Analysis

We created three units (each lasting four to five weeks) and assigned each student to an online group (~10 students per group). Group composition was rearranged after each unit to encourage interaction with a new group of peers. Students were required to initiate topic threads for discussion and respond to at least three topics started by peers. Students rated each other’s posts anonymously on perceived quality relative to other students within the group, on a scale from 1 to 100. Once students posted all required threads and rated their group members posts, they received 100% for the completion of the peer activity. This peer component was responsible for the bulk (60%) of each student’s course grade.

While quizzes documented comprehension of week-specific material, it was the forum posts that presented an unexpected quality and quantity, and could demonstrate a linking

of themes across weeks, disciplinary specialties, and faculty presentations. In total, there were 2,405 threads initiated by students and 8,164 total forum posts (totaling over 1.3 million words) throughout the semester, averaging 32 posts per student. In an effort to not only apply the framework broadly, but also to identify and evaluate potential differences in convergent learning between STEMM and non-STEMM students, a central gap within convergent education research, we randomly selected 24 STEMM majors and 24 non-STEMM majors from the total number of enrolled students who had at least posted the median number of responses (26) and new threads (12). We then categorized all individual forum posts into one of four indicator categories: integration, application, vision, or non-convergent learning.

The research received ethical approval through the University's Institutional Review Board (IRB), which allowed for analysis of data collected, provided that the analysis was first de-identified by an individual not taking part in the analysis. For accuracy and anonymity, four teams of two faculty researchers read an anonymized subset of student posts and determined the classification for each post. The teams compared results and resolved differences in analysis. All posts categorized as convergence were analysed an additional time by the entire research team to ensure all were correctly classified. Data were analysed by major (STEMM vs. non-STEMM), student year, and gender. Gender was determined based on first names as students were not asked to self-identify for the course, so some gender attributions are incorrect or incomplete. For each of the categories, we carried out chi-square tests to determine whether there was a significantly different number of posts for each category ($p<0.05$).

Convergence Indicators

Integration is a demonstrated effective and meaningful synthesis of knowledge across disciplines. It requires students from diverse departments or fields to communicate surrounding current problems, issues, and ideas. Students and instructors link topics that are frequently seen as disparate, or are housed in different departments, enabling novel connections and insights. To determine that integration has occurred, we evaluated student forum posts with a focus on the intermingling of language used across disciplines, student-led connections between disciplines or diverse concepts, and successful communication between disciplines on these concepts.

Evidence of the integration component of convergent learning included posts that synthesized across academic disciplines through specific references. For example, “The material from this week reminded me of how in my biology class we thought about…,” “I read a paper for my economics class that relates to this week’s discussion of…,” or “As a philosophy major, I applied Occam’s Razor to COVID.” We also included posts that incorporated outside resources or published works as they related to the course material. Example posts showing integration include:

> I've learned more about how all of these topics are interconnected. I didn't really think there was before this course. But all of these three topics can be connected to every topic in the world: food, philosophy, religion, health, animals, wildlife, etc.
>
> In my development economics class, we talked about something called a critical juncture. Basically, societies and people are path dependent, meaning history controls or has a major impact on a country's future. However, when a critical juncture occurs, this path dependency is changed. With this change in path dependency, there are major shifts in regulations, societal thinking, etc. I think this moment we are in right now is a critical juncture.

Forum posts that simply expanded upon a previously existing theme or idea did not count as integration, even if they incorporated novel information.

Application is the demonstration of on-going engagement beyond the classroom with regards to the specific problems being addressed in the current context. Application indicates that students are not only engaged in specific problems but are engaged in a manner that transcends classroom walls, recognizing problems as not academic or synthesized, but relevant to day-to-day life. Students may continue the conversation across class time and non-class time.

Evidence of application includes a focus on course material, specifically one of the three focal problems, shown within forum posts with references to how these problems tangibly impact a student's life experience. This included times when a student relates the specific course material to personal experience. For example, “At work, this concept appears as…,” or “Growing up in a traditional Vietnamese household, I experienced similar issues…” Application also included times when a student described or shared information

from the course with people they were close to (e.g., family or roommates), related course topics to non-academic areas of their lives, or discussed how the course as a whole is relevant to their non-academic life, indicating sustained interactions across multiple communities. While in some ways this indicator is imposed by the structure of the course and its weekly forums, this could also include posts that reference previously held conversations within or outside of the course. Examples of application include:

> I personally know a lot of my peers have legal names that are more in line with their culture but introduce themselves with a different common name when talking to higher-ups. For my own family, my grandparents and parents were very aware of the discrimination behind our culture's name and made it a point to name all of their children with common western names.
>
> I can recall being in first grade and having kids transfer into my class because they had to evacuate New Orleans due to Hurricane Katrina. Up until reading this article, I didn't consider that I had already witnessed migration due to climate disaster. I now realize that this is going to be an ever-increasing problem that needs to be addressed immediately.

Examples that highlighted recognition of privilege or highlight a previously established behavior or practices (e.g., becoming vegetarian years prior) did not count within our definition of application.

Vision refers to the development of new theories, potential solutions, methodologies, data forms, or lexical terms with potential for addressing current and future scientific and societal challenges. It is the demonstrated ability to understand current context and think beyond it. Evidence for vision includes students demonstrating development of a new toolset to address pressing issues, addressing pressing issues with methodologies or language that were previously foreign to them, and suggesting new theories or solutions. This includes directly proposing novel ideas, but also novel questions or new avenues of inquiry.

Evidence of vision included specific, concrete solutions regarding a societal or scientific problem. This required an enumeration of the means through which a desired outcome could be achieved, regardless of how simple the proposed solution. For example, “The

campus dining hall could cease to offer meat on a particular day…" suggests a tangible, enactable solution to a problem. Vision also included specific applications to a student's ideation of future self, profession, or societal role as part of a future vision: "As a future medical professional…" or "as a future educator…" Examples of vision include:

> In my opinion, I think a good middle ground would be to maybe pick one or two food groups to take out of your diet. Maybe you're going to stop eating cheese, and beef, for example.
>
> Imagine what resources we could free up if we launched a marketing campaign to popularize systems for collecting and treating water for the home. If we replicated the popularization of solar panels, eventually rain collection and treatment would become so mainstream that we would only have to rely on aquifers during dry seasons.

Posts that did not contain any of the three indicators, while potentially still inter- or trans-disciplinary, were considered "non-convergent".

Results

Of total course participants,19% are represented within the results. Figure 2 illustrates analysed posts by type. Nearly one third (n = 660) of the posts demonstrated convergent learning through application, integration, or vision. Across the total sample of posts demonstrating convergent learning, application and vision appeared nearly twice as frequently as integration.

In the analysis of posts by major (STEMM vs. non-STEMM), we found significant differences in both integration and vision (see Figure 3). Non-STEMM majors contributed significantly more posts identified as integration, whereas STEMM majors contributed significantly more posts identified as vision. The difference in integration is particularly noteworthy as STEMM students only posted 27% of the total integration posts. The percentages are much closer to 50% for both groups for application and vision. There were no differences by major for posts classified as application ($p > 0.05$).

Figure 2

Forum Posts by Category: Non-convergent Learning, Integration, Application, and Vision

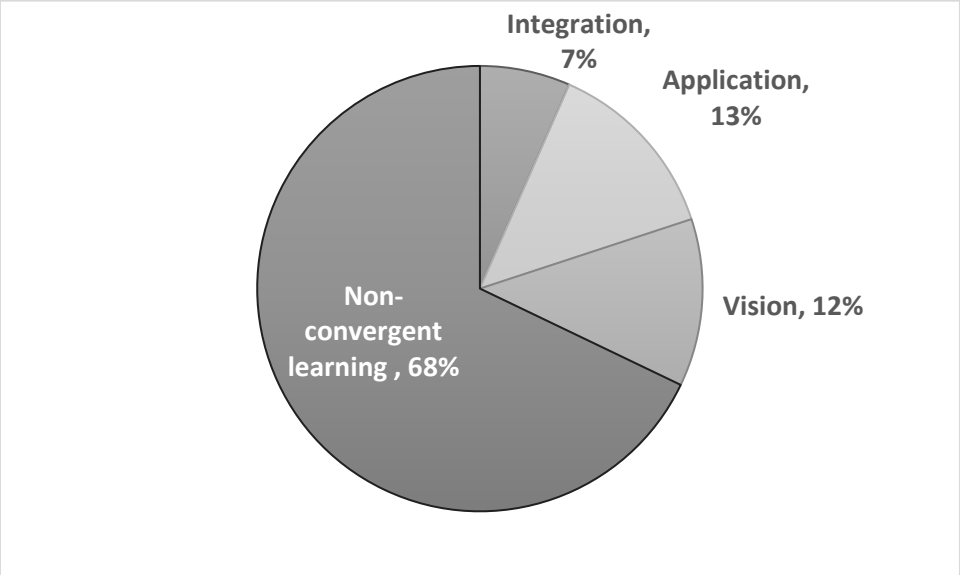
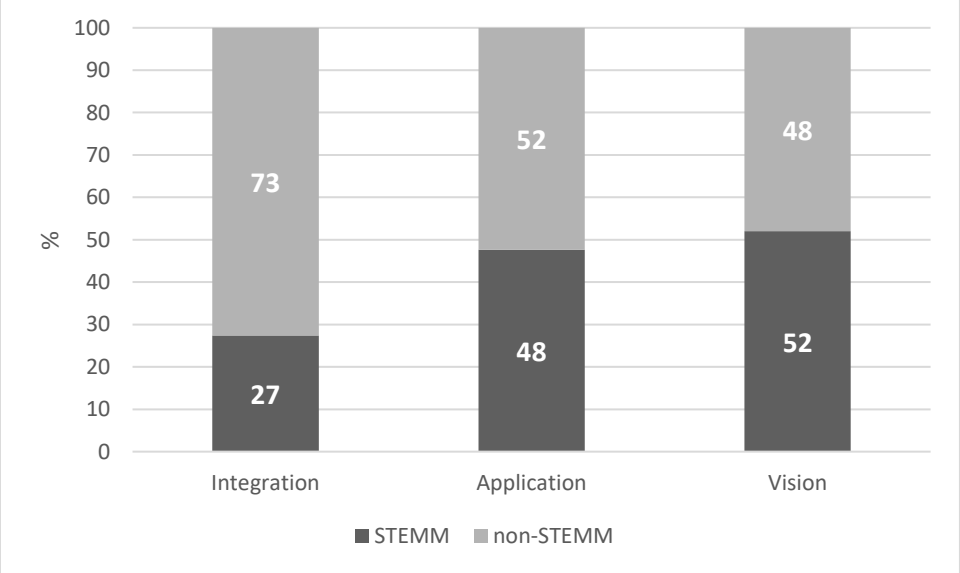


Figure 3

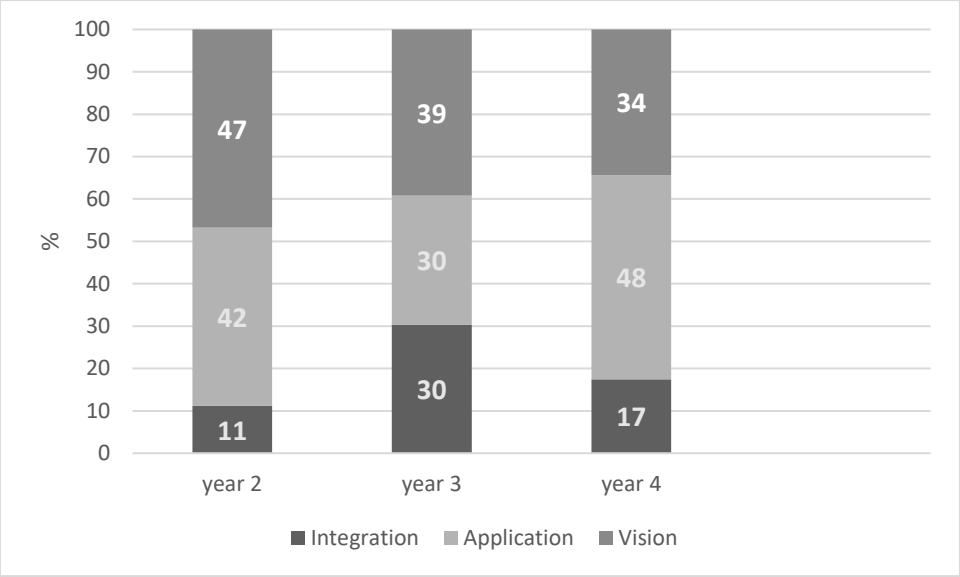
Integration, Application and Vision Posts by STEMM and Non-STEMM Majors.



The analysis by year also showed interesting patterns (see Figure 4). We had no posts by first year students as these did not enroll in the course due to having limited options for electives in their first semester at the university. The data show a decrease over time with regards to posts identified as vision. Application decreases from year 2 to year 3, before increasing again among year 4 students. We determined significant differences for year 2 and year 3 relative to the other years, but the underlying reason is unclear.

Figure 4

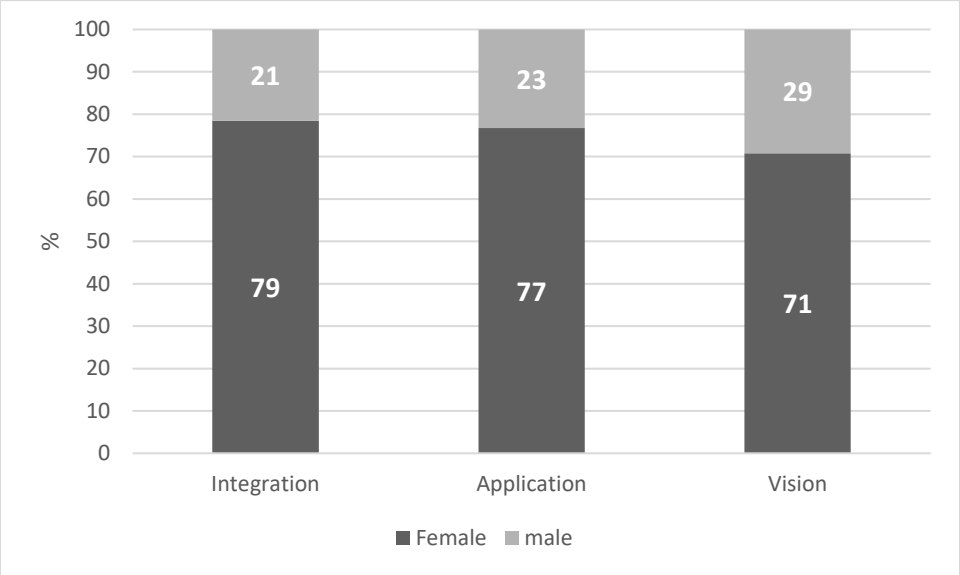
Differences in Posts across Years, as Well as Significant Differences for One Year Versus the Other Years



Finally, Figure 5 shows posts by gender. While it appears that female students posted somewhat more integration and application posts, with male students' posts falling more often into the vision category, gender did not significantly impact the type of convergent learning observed in our case study class.

Figure 5

Posts by Gender for each Category (Integration, Application, Vision)



Note. There were no statistically significant differences by gender in the distribution of posts across categories ($p > 0.05$).

Discussion

The aim of convergent education is to meet the needs of today's society, which calls for professionals who are comfortable thinking across traditional boundaries and addressing issues that are central to and concurrent with a student's present experience. Convergent education moves away from siloization toward an emphasis on creative problem solving that spans traditional academic and institutional boundaries and is simultaneously embedded in the contemporary context. Based on our framework, our results indicate that our case study course did achieve convergent learning through student demonstration of integration, application, and vision, even if not across all cases.

In the absence of a longitudinal analysis, it is difficult to determine the degree to which convergence was produced solely by the course itself, versus pre-determined tendencies

in student thinking. However, the implementation of the framework allows us to identify when and where convergence is present and to subsequently turn to identifying potential differences between the convergent learning experiences of STEMM and non-STEMM majors.

The presence of convergent learning was most apparent within all the forum posts in the form of vision. The nature of the course strongly encouraged an orientation towards the future and problem solving. In fact, although the course was titled, “Imagining Our Futures”, it was often referred to as, “Re-Imagining our Futures”, by students and faculty. However, our results suggest a disparity in the extent to which STEMM and non-STEMM majors engage in vision, with greater frequency of vision posts by STEMM majors. This significant finding not only emphasizes the potentially entrenched nature of the boundary between STEMM and non-STEMM majors but suggests that perhaps the skillsets highlighted within these majors creates limits for students and future professionals.

We speculate that evidence of vision within STEMM majors may be linked to the solution-driven nature of science and technology and the significant emphasis on problem solving. This may have been particularly amplified for all students, but for STEMM students in particular, by the central focus of the course being at least partly on issues such as climate change and the global pandemic, for which solutions are desperately needed. The national and global narrative of technology as a savior of societal problems is pervasive and may influence the lens through which STEMM majors in particular see their role in addressing these problems.

Non-STEMM majors demonstrated integration at significantly higher levels than STEMM majors. This may be attributable to non-STEMM fields’ emphasis or incentivization of thinking across rather than within disciplinary boundaries. Non-STEMM majors may also be more commonly asked to think in interdisciplinary fashion by taking courses spanning multiple departments within humanities and social sciences, such as English, Philosophy, or Sociology. We hypothesize that the diminished level of integration for STEMM majors might suggest a pattern in which STEMM majors are discouraged from the non-STEMM practice of crossing disciplinary boundaries and/or have fewer options to take classes outside of particular academic tracks. For example, a biology major may need to center their academic trajectory on a series of pre-designated course offerings surrounding

predominately biology-related courses, with little room left for electives. Flexibility can disappear entirely in programs like mechanical engineering, where all 130 required credits are prescribed by core curriculum, general engineering requirements, and specific mechanical engineering requirements.

This emphasis away from transcending disciplines was reflected in our institutional culture and practices as two STEMM departments opted out of having the course "count" for their majors during the second iteration in 2021, citing concerns over how much science was covered, the need to meet enrollment numbers in department courses, or the step away from department-specific learning outcomes. While these are pragmatic considerations, they also highlight the institutionalized siloing of STEMM disciplines and, whereas non-STEMM majors may welcome breadth, STEMM majors may emphasize depth.

As a second hypothesis, integration may also appear more commonly amongst non-STEMM forum posts because a central component of the course focused on racial justice in current context. It is probable, and often expressed in forum posts, that non-STEMM majors are more likely than STEMM majors to have taken or be concurrently enrolled in courses that address issues of racism and social justice, presenting a more direct avenue for integration with our convergent-based course. Additionally, even in courses without an explicit focus on racial justice, non-STEMM faculty may see racial justice as more relevant or more easily integrated into course content than STEMM faculty, giving non-STEMM majors an advantage in racial justice conversations.

In terms of student year, our results showed that year four students engaged in application significantly more than other years. This may reflect that as students advance, increased experience allows for increased application. This experience does not necessarily imply solely academic and coursework, but also lived experience beyond classrooms, such as work, family, internship, or other community experiences. This focus on application may also reflect students' attention to their own lives as they prepare to transition out of college. However, in comparing results across student year, additional observations including having first year students in the data set, are necessary to approach differences between years.

The absence of convergence in a large portion of the participant posts may be a product of the factors discussed above or may reflect a larger trend towards favoring discipline specific education. It is possible that in a university setting in which convergence (or even inter- or transdisciplinary) is infrequently implemented, students are not predisposed to think in a convergent manner or, especially in the case of first year students, maintain pre-developed habits.

Overall, the divide in major (STEMM versus non-STEMM) presents the most significant differences in convergent learning within our case study. This may emphasize that the type of education on either side of this boundary differs in a manner that it should not. The outcome of this differentiation then is an imbalance and limitation to achieving the aims of convergent learning. Future work looking at changes in student perspectives across the lifespan of the course is needed to better understand the degree to which STEMM versus non-STEMM students build a convergent skill set. The current imbalance presents the opportunity for a course like ours to re-frame traditional boundaries and provide a map towards successful convergent education.

As previously mentioned, the course was not specifically designed as a convergent case study, as such intentionality was somewhat lacking with regards to faculty participation, course design, and learning outcomes. A convergent learning environment is likely to be one in which faculty also blur disciplinary and departmental boundaries and avoid the appearance of sequential, disparate “guest lectures”. With the difference between STEMM and non-STEMM majors coming to the surface, faculty are presented with an opportunity to intentionally assist in bridging an important disciplinary gap. Having faculty work with colleagues outside their discipline and department to understand perspectives, lexicons, knowledge frameworks, and lenses through which current context is viewed, should enhance convergent education opportunities and limit barriers. The inclusion of non-academic stakeholders, absent from this case study, could provide similar opportunities.

Though demographic data was not collected for the purposes of our study, future insights could be gleaned by collecting this information alongside forum posts. The same is likely true for other student characteristics such as specific major or professional aspirations.

In sum, we found the application successful in the identification of convergent education and found the structure of the course and its participants did produce convergent education outcomes, even if not across all student participants. Application of the framework allowed for clear identification of convergent education in a manner that mirrors the definition of convergence within the literature (Brooks, 2017; NSF, 2017; 2018). Future application of this framework could further define the indicators, particularly within the analysis of outcomes, to better understand diversity in student experience.

Conclusion

Our work developed a framework in which to define, identify, and evaluate convergent learning in a university course structure. While we relied predominantly on forum posts, the framework developed is readily applied in any course involving student assessment (e.g., exams, essays, or discussions). As of the time of publication, no other researchers have developed an implementable framework that is transferable across university settings. The framework, as well as the structure of our case study course, can be carried into other university settings allowing for convergent education to be identified, implemented, and evaluated, particularly with regards to student outcomes. In addition to the development of a framework, using integration, application, and vision as indicators of convergence, we demonstrated significant differences between STEMM and non-STEMM students when it comes to convergent learning outcomes.

While it is possible that this implies that convergent education should be applied differently for these groups to produce outcomes, it is more likely that this difference is an artifact of traditional disciplinary academic structure, best overcome by continuous offering of convergent education opportunities. Despite the ready need for and applicability of convergent-based education, more traditional academic structures predispose both students and educators towards educational outcomes that remain largely siloed, particularly in the divide between STEMM and non-STEMM majors. As we aim to transition from traditional to convergent education, this may appear initially in the form of convergent education that targets identified weak points in the STEMM and non-STEMM divide, and transforms into more universal convergent learning outcomes as the traditional divide is increasingly blurred.

Meeting the needs of today's inherently convergent society requires addressing gaps that remain in traditional education. Much more work is needed to span the gap between STEMM and non-STEMM curricula, especially with regards to connecting STEMM course material with social justice issues. The year 2020 provided an opportunity to recognize that many of the most pressing problems and their solutions are embedded within social and cultural contexts that often are associated with elements of inequity, injustice, and limits to accessibility. Incorporating social justice themes across traditional disciplinary spheres is required to address any contemporary problem. There is a vast opportunity for future courses to repeat our aims towards convergent education and build upon our framework. Future similar courses would allow for a more robust analysis of convergent learning processes and outcomes, and comparison of convergent learning across courses and university campuses. This would help define ways in which outcomes of convergent learning could best be achieved at the undergraduate level.

Declaration of Interest Statement: The authors report there are no competing interests to declare.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author, [KA]. The data are not publicly available due to their containing information that could compromise the privacy of research participants.

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