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## A Transdisciplinary Collaboration and Innovation Education Model and Experience

Brian LaDuca

University of Dayton, [bladuca1@udayton.edu](mailto:bladuca1@udayton.edu)

Michelle Hayford

University of Dayton, [mhayford1@udayton.edu](mailto:mhayford1@udayton.edu)

Adrienne Ausdenmoore

University of Dayton, [aausdenmoore1@udayton.edu](mailto:aausdenmoore1@udayton.edu)

Jerome Yorke

University of Dayton, [jjyorke1@udayton.edu](mailto:jjyorke1@udayton.edu)

Kevin Hallinan

University of Dayton, [khallinan1@udayton.edu](mailto:khallinan1@udayton.edu)

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**Author(s)**

Brian LaDuca, Michelle Hayford, Adrienne Ausdenmoore, Jerome Yorke, Kevin Hallinan, Rebecca Blust, Anne R. Crecelius, Philip Appiah-Kubi, Jennifer Katz-Buonconintro, Jana Bennett, Jackie Marshall Arnold, Connie L. Bowman, and Castel Sweet

## **A transdisciplinary collaboration and innovation education model and experience**

Brian LaDuca  
Adrienne Ausdenmoore  
Kevin P. Hallinan  
Anne Crecelius  
Jennifer Katz-Buonconintro  
Jana Bennett  
Jackie Arnold  
Connie Bowman  
Castel Sweet

Michelle Hayford  
Jerome Yorke  
Rebecca Blust  
Phillip Appiah Kubi

All authors from the  
University of Dayton

### **ABSTRACT**

As the interconnectedness of the world grows, the need to prepare college students capable of addressing complexity likewise grows. In this context, the University of Dayton has developed and tested a transdisciplinary model for education. This model links multiple classes from different disciplines via a common theme and within a common space. It also employs an educational model premised on the following trajectory: disciplinary content development / transdisciplinary observation (empathy); transdisciplinary disruption leading to “A-Ha” observations which transform the disciplinary directions; and lastly transdisciplinary informed design and research. Central to this model is a 3,500 square foot common space used only by the classes participating in the experience. In this space classes share their reflections and content with other classes via both personal linkages and analog communications. The other classes respond to these from their disciplinary and personal perspectives. Thirteen classes, fourteen faculty, and over three-hundred students participated in a themed experience centered on the addiction crisis in Dayton, Ohio. Participants included faculty in applied creativity, engineering, health and sport science, education, theater, and religious studies. Also serving as co-teacher were community stakeholders. Assessment of the experience revealed variable student take-aways. Most prominent among these was student recognition that the experience had expanded their perspectives of the other disciplines. Most suggested that it had improved their ability to collaborate in a transdisciplinary environment and that it had significantly impacted their career aspirations. Fewer acknowledged the experience had improved their ability to create.

Keywords: transdisciplinary, creativity, cross-disciplinary, collaboration, humanitarian

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## BACKGROUND

### The Case for Transdisciplinary Applied Creativity

A 2015 survey of employers sponsored by the American Association of Colleges found that only 25% of graduates from all disciplines had adequate creative, critical thinking, and problem-solving skills [1]. The same survey found that, while 96% of employers felt that students should have to solve problems with students whose views are different than theirs, only 18% believed students were prepared to do this [2]. Why employers strongly value creativity is evidenced by the fact that nearly all new jobs created in the U.S. over the past 20 years have been in new and young companies [3] [4]. Assumed here is that these job-creating enterprises have gained traction through innovative practices, which ultimately derive from creativity rendering something new that has realized value to others [5].

Unfortunately, the innovativeness long associated with the U.S. appears to be lagging. Historically, the United States was considered the leading country in innovation. There has been a dramatic decrease in innovative American ideas, and with the U.S. now ranking from fourth to sixth in innovation, depending upon the study, where at one time it was ranked first [6] [7].

A 2007 study suggests that creativity can be addressed educationally by: fostering inquisitiveness or open-mindedness, helping students become comfortable with ambiguity, providing continuous practice of ideation, encouraging students to search for multiple answers, and allowing students to take risks, fail, or have ownership of the education they wish to receive, among others. This study found that virtually no university addressed these [8]. A 2009 study echoed this conclusion, faulting increasing standardization of processes throughout all business and society. Many situations require “judgement-based work” and responsiveness to changeable environments and when stakeholders value distinctive or unique output. This type of environment can require quick thinking and creativity and a true understanding of individual needs and desires [9]. University education has certainly exploited standardization of processes, especially within professional disciplines, but arguably has not prepared graduates capable of this type of responsiveness and ability to understand the value of diverse perspectives in design and research processes.

The value of creativity expressed through diverse teams is also clear. A review of 17.9 million papers spanning all scientific fields found that the highest-impact science is primarily grounded in exceptionally conventional combinations of prior work, while simultaneously featuring an intrusion of unusual combinations [10]. IDEO, a preeminent global design company, has relied upon divergent ideas coming from multidisciplinary people— “architects who have studied psychology, artists with MBAs, or engineers with marketing experience—often demonstrate this quality” [11]. De Dreu and West in comparing homogeneous to diverse teams showed that greater conflict arising from greater diversity in team make-up in innovation teams stimulated creativity and divergent thought [12]. Research by Hewlett et al. in 2013 found that employees in companies with inherent and acquired diversity are 45% likelier to report that their firm’s market share grew over the previous year and were 70% likelier to report success in capturing a new market [13]. Additionally, Hülshager et al. showed that creative conflict between people with difference is important for developing truly innovative ideas [14]. In the same vein, Jung and Lee showed that the mere act of reflection on a relational group conflict boosts creativity [15].

Models for supporting inter- and transdisciplinary education are available. Schaeffer et al. suggest that in an effective interdisciplinary environment, students must be able to: i).self-

identify their skills, knowledge, and potential project contributions to the innovations; ii).recognize the potential contributions of others to the project; iii).interact with team members during design discussions to draw out and clarify disciplinary perspectives; and iv).synthesize awareness and appreciation of other disciplines and reflect this understanding of the design products [16]. Similar curriculum at the U. of Melbourne emphasizes also that students must be able to: i). discern how important each perspective is for the issue at hand; ii). evaluate the evidence or reasons supporting each of the perspectives; iii).balance, weigh-up or accommodate the pressures from the different perspectives in order to reach a reasonable and creative decision or outcome; and iv).make a case for why this decision or outcome is better than alternatives [17].  
The Case for Humanity-Centered Innovation as Motivator for Creative Growth

Another element essential to transdisciplinary innovation success is passion. Hoffert suggests, “Without the passion there is no idea, no research, no pursuit of the new which will add to culture, transform it, and make life better” [18]. This means that each actor must have passion for the mission; passion for the team; and passion for the transdisciplinary. IDEO’s innovation philosophy emphasizes the importance of human-centered design; e.g., design which above all meets human needs to drive the passions of the design teams [19].

In 2017 Dayton, Ohio suffered the infamy of being named the epicenter of the opiate addiction crisis after experiencing 46 deaths per 1,000 people [20] [21]. Additionally, in late 2018 PBS’s Frontline documented Dayton’s demise as a city [22]. Last of all, 2016 statistics reveal that 37% of the population in Dayton does not have a high school education and currently only 28% of African-American men are graduating from high school.

The situation in Dayton reflects much of the U.S. A late 2017 report by the White House estimated that in 2015, the economic cost of the opioid crisis was \$504.0 billion, or 2.8 percent of GDP that year [23]. With over 42 million Americans having addiction to all forms of drugs and alcohol, the economic impact on the economy is certainly well higher. A recent report by the University of Washington illuminates the national cost of another problem; namely incarceration. Their report suggests that the cost of incarceration is not the \$80B/year direct costs associated with managing the prison system in the U.S. Rather the social costs associated with incarceration yield gross costs to the U.S. economy on the order \$1T/year. Having the potential to worsen these impacts are the ominous projections of the impact of automation and machine learning on jobs. A recent McKinsey Global Institute report documents that while less than 5 percent of all occupations can be automated entirely using demonstrated technologies, about 60 percent of all occupations have at least 30 percent of constituent activities that could be automated. And the jobs that are most easily automatable tend to be those in which lower income and less educated adults work. Transportation, sales, and food services jobs are the most at risk. These are exactly the types of jobs that are most prevalent for urban poor [24], [25]. Thus, their situation is likely to get worse.

## **INSTITUTIONAL BACKGROUND**

The University of Dayton’s Institute of Applied Creativity for Transformation (IACT) has developed a transdisciplinary educational framework that allows students to make mistakes, permits them to both grow relative to their own vocational directions and relative to their discipline, and progress through an ambiguity-centered, rather than content-oriented approach.. Students first ideate relative to their own individual and disciplinary perspectives. Tension is then created through engagement with other perspectives (empathy) [26]. The ideas which emerge reflect emergent themes enabled from diverse perspectives coming together. This process

is indebted to the notion of a “well-made” play; where the playwright first sets the stage, then introduces ambiguity and conflict, ultimately resulting in an ‘A-Ha’ pivot which then serves as the foundation for the remainder of the story [27].

The IACT collaboration approach integrates all disciplines together around an important social problem in the local community and transcends their traditional boundaries. Thus, many ways of doing and thinking are integrated into an applied creativity process oriented to the development of solutions to address the local social problem [28]. Students ideally enter their IACT experiences with greater passion for engaging in the transdisciplinary experience as a result of the overlying social context.

The resulting product realized from the disciplines coming together, with synthesis of the ideas into a framework and model not owned by any one discipline, is what makes the process and the learning transdisciplinary [29]. While there may be a role after merging disciplinary perspectives for single disciplinary efforts, these latter efforts have been informed by the shifting of perspective as a result of bringing the disciplines together.

Currently, more than 50 faculty and staff from all sectors of our campus serve as IACT Collective members and 17 IACT Fellows, who participated in more intensive training over the past two years, contribute to the design and teaching of the IACT curriculum. Also they commit to bringing elements of their IACT experience to the education they deliver to students within their own discipline. An IACT Undergraduate Certificate in Applied Creativity and Transformation now exists within the School of Engineering.

IACT course experiences have been tested over the past four years. This testing has included summer pilot programs bringing together a group of transdisciplinary student interns (25% from engineering and the rest a mix of arts, communication, and business majors) to work on applied creativity projects for external sponsors. The sponsors, mostly STEM related organizations, have been overwhelmingly positive about the processes, solutions, and learning impact on them and the participating students [30]. Of particular relevance to the transdisciplinary education experiment described in this paper is the 2017 summer experience, where students developed a transdisciplinary educational space called ‘Concourse D’. In this space, soon to be located in the UD library, faculty in every course will be able to send their students to get input from other students, faculty, and staff from across the university. Community affiliates will also be able come into the space to receive similar input.

## **METHODOLOGY**

### **Establishing the Transdisciplinary Education Experiment**

In this context, the educators involved wanted to translate the transdisciplinary summer IACT transdisciplinary internship to the curriculum. But how? Co-teaching efforts bringing faculty from two disciplines, which is common at the University of Dayton, only integrates two disciplines. Moreover, this type of course is very resource intensive, requiring two faculty to teach a regular sized class. Alternatively, bringing students from multiple disciplines into one class emphasizing transdisciplinarity would only reach a small number of students. Plus, such a course would be taught by a single faculty with experience in working in one discipline only.

The transdisciplinary experience envisioned would: engage multiple faculty and a large number of students from different disciplines; require minimal, if any, additional resources; and link to real needs in the community and ultimately contribute to transformation within the community relative to the defined needs. More practically, it needed to happen fast. Planning

began for the spring 2018 term in October 2017 after courses had already been scheduled for the spring. And a common space dedicated only to the linked classes was deemed essential. Such a space did not already exist.

Generally, these wants at a university would have translated to the development of a plan lasting one or more years. But the IACT leadership was able to convince the upper level leadership at UD about the promise of the experiment. A 3,500 square foot caged storage space was made available for use and a budget of \$10,000 was allocated for renovation of the space. For the experiment, a pilot focus was established by the IACT leadership around the theme of “disrupting the generational pattern of addiction expectancy within Dayton’s youth community.” This topic was selected in response to prior research which has shown that when children who are victims of maltreatment become adults, they tend to repeat a dysfunctional cycle and often lack mature characteristics: the ability to trust, to make healthy partner choices, to manage stress constructively, and to nurture themselves and others ([31], [32], [33], [34]). Thus, Dayton’s place as the nation’s epicenter for addiction cannot be seen to be isolated among those who are currently experiencing addiction challenges.

Then, with space identified, a commitment to renovate by the time the next semester began (less than two months into the future), IACT faculty were invited to participate by committing to use of the space, finding a way to link the theme to their already planned class, and committing to a transdisciplinary process; e.g., a process that would merge the efforts of all participating disciplines.

### **The Faculty Participants**

Despite the extreme unlikeliness of getting faculty to sign-up for the experience, a total of 14 faculty teaching 11 courses with 302 students responded to the commitment. Table 1 (Appendix) documents the faculty participation, their discipline, their course, and the number of students enrolled. Included in the UD faculty were 8 female and 4 male faculty, two of whom were racially diverse. In addition to those listed in this table, five community members served as courtesy faculty in the experience. Each of these had connection and/or interest in the addiction theme or significant personal investment in Dayton’s improvement.

As the courses had already been scheduled, there was no opportunity to coordinate which classes if any might overlap within the space. Table 2 (Appendix) documents the schedule of classes employing the shared space.

What is clear from Table 2 is that some classes overlapped others and some were isolated. Moreover, the courses with overlap may not have been perfect in terms of close collaboration. Thus, the space had to permit means to organize connections between the classes and discipline

### **The Space**

What emerged was termed the GEMnasium (“GEM” representing Growth, Education, Mindset), intended to be a “playground” for the mind. The principles guiding its design are as follows. The space needed to provide: sufficient space for multiple classes to be present at the same time; sound isolation between separate spaces; an ability to share progress via analog communication on the walls and through in-person collisions; a unique means to present student products to as many as 150 students and visitors to the space at one time; flexible work spaces and lighting; daily accessibility students; a quiet space for reflection and mindfulness; a means to prototype solutions using a variety of materials; and access to technology and WiFi.

Figure 1 (Appendix) shows a footprint of the GEMnasium, highlighting the different spaces within it. Figure 2 (Appendix) provides images of the various spaces with students in it. The features include a mix of conventional learning and teaching space with group tables arranged in a classroom setting and technology for presentation, individual break-out space, community space, and mindfulness space; all centered around a large custom-built family dining table. Additionally, to facilitate feedback between classes, a “Rebound Wall” was created. Any faculty or student could post questions requiring feedback from the other classes on this wall. All participating faculty were encouraged to have their students respond immediately to the feedback requests. The custom-built family dining table, termed the “kitchen table”, was included to especially facilitate group discussions. The numerous break-out spaces provided spaces where students could go to reduce distraction. Further, there was a bleacher section that both provided students a different place to work and a place for spectators to observe. The space included ten portable white walls and total white board wall space of about 500 square feet to enable students to collaborate and communicate their work with others. The mindfulness / quiet space was used when there were multiple classes in the space, for yoga and mindfulness sessions, for the applied theatre class physical warm-ups, and just flexible work space for students to work individually or in teams on a cushioned floor.

Figure 2 (Appendix) shows a collage of images of the GEMnasium. These images reveal much about how the space was used. It shows that the lighting was a choice. Students could opt for low light levels, conventional lighting, and even colored lighting in some of the spaces. They also reveal the flexibility of the workspace. The mindfulness space could be used for relaxed work, for presentations, and even yoga. They also show how the space enabled analog communication between classes via the ‘rebound wall.’ Finally, the collage of images shows the utility of the space in seeking input from visitors.

### **The Linkages**

As every GEMnasium course was linked to the theme of breaking the cycle of intergenerational addiction, it was essential to connect to and learn from the community involved in the addiction recovery process. Having individual community partners come to each class would be impractical and represent an unfair time commitment for the partners. But, having partners come to one event in which students and faculty representatives from all classes could attend both permitted more efficient use of partners’ time, but also questions from the multiple perspectives of the attending students and faculty.

Also, since all classes did not overlap in the space, it was essential to have numerous opportunities for students from different disciplines to come together to discuss their progress and get input beyond their disciplines. These were called collision events. These were to be facilitated by individual faculty arranging for students to cross-attend their courses or they were to be facilitated by organizing open sessions to which all students could attend. Some of the faculty required students to write reflection statements to describe their interactions with others during these events.

### **The Process**

Table 3 (Appendix) shows the general process employed for the transdisciplinary GEMnasium experience. The first phase involves planning among the faculty participating from the various disciplines. In the planning, the theme for the experience is developed. Additionally, faculty share their initial thoughts about how they will have their class address the theme. This



planning phase happens prior to the semester in which the transdisciplinary experience will be implemented.

The second stage in the process can be called disciplinary immersion with transdisciplinary observation. In this phase students are immersed in both the disciplinary content for their course, as each faculty has disciplinary expectations, and to the theme of the course. During this period, students from each class post their reflections on immersion experiences on the white spaces and walls within the GEMnasium. All faculty are expected to encourage their students to observe the postings. Students are as a result exposed to other disciplinary perspectives as they learn more about the problem.

The third phase asks students to develop content from disciplinary perspectives. This could involve the development of early designs, research, art, and even just developing questions prompted by the theme.

The fourth phase is described as the intersection of ideas / solutions or collisions. Prior to these collisions, students are asked to consider what they do not know relative to the content they have developed. The collisions then give students from other perspectives the opportunity to respond to the ambiguity, or more generally to the concept itself.

Thereafter, in the fifth phase, students develop what can be called 'transdisciplinary informed' solutions. This effort culminates in the development of a design or product which addresses in some way the driving theme.

Last of all in the sixth phase, students/student teams present their products to their peers, all faculty participants, community partners, and the broad university community.

The following presents a detailed picture of how these steps play out in the actual transdisciplinary education experience.

### ***Planning***

An early planning meeting was set for the end of November to design the space from a transdisciplinary perspective. All of the UD faculty participants were present. The process was as follows. First, the faculty designers were asked what they needed in the space for their discipline. They were also asked to consider what they did not know about the space. Then, all responded to these questions from their perspectives. For example, the Mechanical Engineering faculty (Faculty 1) said that his students needed access to WiFi and at least some conventional teaching space. The theater faculty (Faculty 9 and Faculty 10) indicated that they wanted an open space where his students could perform. The courtesy faculty interested in nutrition (S. Faculty 4) said she needed a kitchen table for students/visitors to eat at. The IACT faculty said they needed rapid prototyping materials and lots of white board wall space. Also, a number of questions emerged, including: How to facilitate communication between the classes? How to handle more than one class in the space at a time? How to provide a quiet space for students to unwind after exposed to challenging speakers? How to enable the space to bring in many visitors?

Collectively the faculty answered these questions. After a 1-½ hour session, a design concept for the space was developed. For the next six weeks, the IACT staff worked feverishly to develop it. Remarkably, the space was almost ready by the time the spring semester started and was completely finished at the end of the first week of the semester.

There were three additional planning sessions. The first introduced potential faculty participants to the problem and the experience. The next focused on how the evolving space would be used. The last meeting was called a Transdisciplinary Mapping Lab. Teams of four or five were formed, linking faculty together whose classes overlapped in day and time. In this

session, faculty were asked to develop a collective mission for addressing the theme for the GEMnasium. The faculty participants also designed how the linkages might reinforce the transdisciplinary experience of our students. Again, the IACT process was employed. Each of the faculty was asked to first imagine how they and their class could address this theme. Key words describing the envisioned focus of each faculty were integrated with the key words of the others in a team. These integrated words were used to develop a mission for each of the teams. Table 4 (Appendix) shows the integrated themes developed by the three faculty teams.

Each of the UD faculty participants managed the planning for their courses somewhat differently. Some built into their syllabus the requirement of collision experiences with students from other disciplines or community members connected in some way to the local addiction crisis, requiring a reflection to describe the other disciplinary or immersive learning derived from the collision. Others had not yet worked out how they would connect their class(es) to collisions. A few sent information emails about the nature of the project that would be addressed within their class to students enrolled for the next semester. For example, the faculty teaching the capstone Mechanical Engineering modeling course sent an email to students letting them know the theme for the course and describing how the modeling would be focused on a systems model, rather than typical thermal/fluid/structural/dynamic modeling based upon fundamental Mechanical Engineering principles. In this case the steering of the course into the addiction space was a disciplinary stretch, so the faculty wanted to give students a chance to sign up for a more traditional section of the course, which was taught concurrently and was open. Interestingly, none did. A similar approach was taken by the Health and Sport Science faculty member, as there was a different section of the same course available. Again, none of the students opted out of the experience.

Overall the planning helped to establish community among the faculty and helped each faculty understand the interests that their peers had in addressing the addiction theme.

Throughout the semester planning was ongoing. The faculty collective met bi-weekly as a GEMnasium team to discuss concerns and plans for future classes and collisions. The IACT faculty maintained a common calendar highlighting all upcoming collision and community immersion events, and organized a weekly newsletter to briefly document the prominent activities in many of the classes.

### ***Disciplinary Immersion / Transdisciplinary Observation***

Students needed to better understand the addiction problem before they could begin to conceive of research, performance, or designs. So too did faculty. There were no faculty entering the GEMnasium experiment who could be said to be experts in addiction – or even close to it. Ultimately, faculty saw themselves as co-learners with students through the experience. Thus, it was essential to take time to learn about the problem. This immersion experience comprised roughly one-quarter of the semester.

The following describes how the immersion experiences were facilitated:

A number of the faculty organized preparatory classes for interfacing with people who may be in recovery from addiction. For example, Faculty 6 (Fitz Center) came to Faculty 1's and Faculty 11's respective engineering and religious studies classes to educate students about how they might talk/ behave when speaking with someone who was struggling with drug addiction or in recovery. Her session was followed by a mindfulness / yoga session organized by a community member, who also acknowledged the importance of yoga in overcoming his own addiction to drugs.

Most of the faculty organized speakers to talk about the local addiction crisis from multiple perspectives. Generally, all other faculty and students were invited to attend. Faculty 11 (REL) invited a speaker from the County Health Services to talk about Montgomery County's efforts to combat addiction. She also arranged for a maternal fetal specialist and recovering addict to speak to her classes. Faculty 5 (HSS) arranged for visits by a trained exercise scientist and founder of Adyptation, a custom health analytic company focused on improving lives of patients with chronic illnesses, as well as a University Dayton Research Institute software engineer who had developed a technology that teaches people with opioid addictions how to reduce their cravings by regaining control of their brains.

Faculty 1's Mechanical Engineering class had an open session called the Random Forest, where his students presented results from their analysis of the national SAMSHA addiction data using machine learning. The students and faculty entering the GEMnasium during the session visited various trees (within the forest of addiction) where students had used to data to answer questions like "What if all those in recovery had somehow been encouraged to begin the treatment process of their own volition? What if all of those in recovery had the opportunity to live in recovery centers for extended periods of time? How many more people would recover?"

Faculty 10 (Engineering Technology) arranged through courtesy faculty Erion, founder and Director of an organization called Families of Addicts, to have several Families of Addicts members who were in recovery attend an Applied Theatre class to share in a Story Circle with the applied theatre students. Erion also spoke to many of the classes individually about her organization.

These immersions were generally open to all students. Many of the faculty asked their students to respond to what they were seeing from their disciplinary perspectives and to communicate their response on the rebound wall or on the myriad of white boards present in the space. Students from other classes could see how students from other disciplines were responding to the speakers. In a sense, this began the transdisciplinary process, where students begin to improve their understanding of what students from other disciplines have to offer.

### ***Disciplinary content generation***

In this phase of the process, students began to develop content (ideas) from their own disciplinary perspective. Some of the classes did this in a way that was influenced by the perspectives of others. For example, the Mechanical Engineering class initiated this phase of the process by engaging in a transdisciplinary ideation process involving 25 community partners from business, governmental, addiction services, law enforcement, workforce development, and reentry services, along with 25+ GEMnasium students from other classes to ideate a recycling enterprise for people in recovery from addiction. Hundreds of ideas were developed which helped to define the broad requirements for the system they were to design.

Several other classes initiated their efforts by responding to the content and questions developed and posted by the other classes in the GEMnasium. The Health and Sports Science students were tasked with semester long group research projects addressing the topic of opioid addiction in some way. Their early work focused on what was not known, both within the literature and relative to what was identified by the other students and faculty in the GEMnasium space. The artifacts within the space were examined to determine what types of assumptions were being made, what knowledge was unknown, and how a potential project could contribute to the knowledge base. Similarly, the ACT II students were asked to review all content in the GEMnasium to identify, either individually or within groups of four or less, an

idea/concept/research developed by other students to disrupt or to develop a more empathetic understanding of the people 'problem' within their idea/concept/research.

Lastly, the Christian Ethics in Healthcare students worked to integrate learning from the immersions and the ambiguities defined by other classes with their disciplinary learning in ethics. In this stage of the process, they developed visual aids, in whichever form they wished, to represent their learning.

The other classes worked mostly in isolation during this phase. For example, the Applied Theatre students were asked to read "Dreamland: The True Tale of America's Opiate Epidemic" by San Quinones, a factual account of the opiate addiction crisis in Ohio, and "All Fall Down", a novel that details a lead protagonist who is a middle class middle-aged mother who becomes addicted to prescription opiates. The reading of these very different texts allowed the applied theatre students to see the addiction crisis from quite diverse perspectives, and specifically to understand the role of pharmaceutical corporations, unethical pill mills, Mexico's migrant drug dealers, etc. in the opiate addiction crisis, and to engage in the emotional impacts of addiction. Ultimately, this learning, along with the prior interactions with community partner Families of Addicts, established the foundation for the performance they would be developing through the semester.

The Semester of Service students familiarized themselves with the history and context of Dayton, and specifically the neighborhoods where they were placed for the semester, the history and mission of the particular organization to which they were assigned, and the population and clients they were to serve. From there, students worked with their partner organization to identify projects and/or initiatives they would contribute to for the semester.

The Project Management faculty, during this phase, introduced their students to project management from a theoretical perspective. They also linked students to the Families of Addict organization which was providing an experiential connection to the theory they were learning.

Lastly, the Teacher Education student efforts centered upon building understandings of the Social Emotional Learning components critical for young children and how to support young children who have experience and/or are experiencing trauma. Students researched and developed resources that could be used to support students going through crisis. Students also investigated the number of school counselors located in our partner schools and shared their findings.

### ***Transdisciplinary Event I - Adding Ambiguity and Tension from a Transdisciplinary Perspectives***

The early work can be said to not have been wholly uni-disciplinary. All faculty participants, because of their presence in the GEMnasium, naturally challenged their students to think beyond their own discipline. Plus the theme itself was not something any of the participating disciplines would ordinarily work on. Nevertheless opportunities were established for each of the classes to gain exposure from the other disciplines and the courtesy faculty (collisions) and to disrupt the ideas which were emerging in each of the classes.

The first of these common disruption events was termed Balance - Eyes - Elbow (grease) and Follow-through (B.E.E.F.<sup>1</sup>) Night. This two hour evening event, open to both the campus and external community, was intended to be an experience to showcase the space and the collaboration. This event was especially designed to orient all GEMnasium students to the

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<sup>1</sup> The B.E.E.F. principle in basketball is an acronym that helps novice players practice proper shooting form.

courtesy faculty. Each of these led thirty minute immersive experiences. For example, A. White led a yoga and meditation session. L. White shared learning from Indigo Life's Voices project, which is a collection of stories from people in recovery and their families and friends rising up to tell their story. Erion from Families of Addicts led a discussion of the "5 Myths of Addiction". Last of all, S. Faculty 4 (ACT II) gathered students around the kitchen table to share the same food (unhealthy first / healthy after) and experience the power of coming together at the kitchen table. Collectively, these faculty helped students personalize addiction for the attending students.

Besides this event, class collisions were organized by individual faculty from different disciplines. For example, Faculty 5 (HSS) and Faculty 1 (MEE) organized a collision event within Faculty 5's class. A number of Faculty 1's engineering students attended, entering with a sense of ambiguity about how health and wellness process could be present within the recycling enterprise they were envisioning. In the session, the HSS students taught the MEE students about the design of wellness programs in general which would include the following considerations: Frequency, Intensity, Time and Type.

Additionally, Faculty 7's education students served as a source of disruption to Faculty 10's Christian Ethics and Healthcare students' individual ideas - as young people who were participating in their first in-depth teaching experience, with many of these in underserved schools. The students presented their early project concepts to the Early Childhood students and then requested feedback. Robust conversations took place as the Early Childhood students engaged in new content they had not yet considered. They then offered feedback to the Christian Ethics and Healthcare students from the perspective of students and parents that had not yet been incorporated.

### Responding to the Ambiguity (AHa!)

A transdisciplinary effort requires that the ideas of others cause disruption of the disciplinary perspectives, ideally through a collaboration process. In a perfect world, new teams would be established with all disciplines included in the teams. However, the separation between classes in time made this type of collaboration difficult, if not impossible. Nevertheless, the Ambiguity - Tension - Empathy process did lend itself to disruption of the disciplinary ideas.

Faculty 4's ACT II class responded to the first transdisciplinary common event with a belief that their initial thinking lacked an emotional connection consistent with what they saw from the courtesy faculty sessions. His class pivoted their original theme - moving it to what Faculty 4 called "futurecasting" the epidemic, which is about forecasting an improved addiction environment in Dayton based upon the ideas / products they were developing. Their new ideas included a much stronger emphasis on establishing an emotional connection to their products / ideas. They continued to collaborate with the ideation products from the other classes in the room, and collaborated with each other in class based on tension spots they had identified. Last of all, they began to seek out active empathy with other students in the class combining their individual ideas into team ideas. Faculty 10's (REL) class likewise moved from individual ideas to combined group efforts, in which student ideas were merged.

Faculty 4's and Faculty 10's (ACT II and REL) classes because of their natural transdisciplinary composition helped to advance disruption. The teams that emerged were inherently disruptive by bringing students from different disciplines together.

Faculty 1's Mechanical Engineering students were likewise impacted by the emotional experience of the first transdisciplinary event; although it was difficult for them to articulate. After this experience, they challenged each other to both improve the emotional connection to

people within the enterprise they were imagining and in communicating their design with others. Additionally, to further strengthen this connection, a local female social entrepreneur was invited to speak about her fifteen year journey through addiction to being sober for now over eight years. Faculty 10's class attended also. The speaker's emotional delivery really did disrupt students in both classes.

Faculty Health and Sports Science research course had put on display the efforts of early collisions with Faculty 4's ACT II course. These collisions had focused on the "who, what, why" of asking certain questions related to the opioid epidemic and relating it to the population, data, and purpose of a research project. The other collision had approached the idea of "stigma" and how environment may or may not impact one's development. At this event, the student response to these collisions were shared and attendees, who were asked to add their own "who, what, why" comments and provide feedback on the initial research questions posed by these students.

The Project Management students applied their observations at this first transdisciplinary event and their detailed interactions with Families of Addicts to define their project focus, which was to design a more effective space for this organization and a training handbook for their newly developed "Hotline" program.

### ***Transdisciplinary Event II (Alley Oop)***

In a second common transdisciplinary event, all students and campus and community guests were again invited to assist the students/student teams in getting their final ideas, projects, research and deliverables to the 'proverbial' finish line. This session was termed the Alley Oop.

At this event, Applied Theater faculty, Faculty 8 and Faculty 10, led an applied theatre physical warm-up and story-sharing exercise that allowed for safe pair-sharing of how one has been impacted by addiction.

Most of the classes presenting at this event solicited specific feedback relative to the products they were developing. Faculty 1's Mechanical Engineering students presented a system schematic of their evolving recycling enterprise. Their identified system included the on-boarding and training of workers, health and wellness integrated into the work, work operations, resource requirements (training, employment salaries, facilities, equipment, and transportation), and funding resources. The engineering students were seeking responses to specific questions like "How many clients can one case worker support?" and "How many weeks does it take to help a person get tangible benefit from yoga?" in order to complete their designs.

The Health and Sports Science research teams presented their work by concisely writing out who they were, what they were asking, how they were doing it, and why they were interested. Attendees were then prompted to offer questions or free-form comments, or suggest resources her teams could access. This feedback was then able to be taken into consideration as students were moving into the data collection portion of their projects. The Christian Ethics in Healthcare students had prepared infographics describing their original research ideas. They likewise were seeking general feedback.

The ACT II class at the presented their ongoing concept. Attendees were challenged to explore and respond specifically to the four M's characterizing their concept. These included:

- Mechanisms - The drivers and influencers for action
- Mechanics - The parts that come together to make it work
- Modes - The ways in which the concept/idea/strategy can be engaged with
- Motivators - The elements that encourage participation

Lastly, the education students displayed their findings concerning the number of guidance counselors in elementary schools. Students also displayed community resources that could be utilized by teachers as well as a bibliographies of picture books. These books could foster read 'alouds', story-telling, reflection, or performance. Attendees gave feedback on the need for more guidance counselors in schools and recommended additional resources for the students to consider.

### ***Transdisciplinary Informed Innovation***

After the second transdisciplinary event, the classes integrated the feedback they had received into their products and began planning for their final presentation at the GEMnasium Summit Slam organized for the end of the semester.

The Christian Ethics in Health Care student teams continued prototyping their group ideas. Their prototype had to potentially aid the opioid epidemic through the themes of healthcare, religion, or both and by targeting a singular audience. The diversity of themes emerging from the prototypes was striking. One team focused on developing long-term workshops, worship and community activities for mothers and babies who are recovering addicts. Another team developed a series of short videos aimed at peers health care majors to educate them about addiction and addiction and emphasize the personhood of each addict. A third team designed "Freedom Kitchen," a place where recovering addicts could develop employable skills in hospitality, and where they could receive support from like-minded peers. The diversity of themes emerging almost certainly was influenced by the transdisciplinary nature of the GEMnasium experience.

The Health and Sport Science Capstone Research class worked to incorporate feedback from the second transdisciplinary event into their project. For example, one group was interested in how pre-service teachers were prepared or not prepared to face students that might be impacted by the opioid crises. Feedback from pre-service teachers yielded additional questions to include in a survey they had developed to assess health care professional understanding of the addiction crisis.

The capstone Mechanical Engineering modeling class moved on from a schematic representations of their system model of the recycling enterprise concept to a quantitative systems model to validate the economic viability of the enterprise which ultimately would providing mentoring, health and wellness, life skills education, training, and dignified work for people in recovery and/or reentering society post-incarceration. Their enterprise concept breadth and human principles were clearly indebted to the transdisciplinary interactions in the GEMnasium.

For the ACT II class, feedback from the second transdisciplinary event had great influence on the products they were developing. One cohort made up of three students in entrepreneurship, sports management, and communication, who had developed what they called a Maturity VR (Virtual Reality) Experience, a virtual reality experience helping children learn about drug addiction, heard from attendees concern about what each child would be experiencing in the VR simulations. Their A-Ha was described as follows. "We realized we could have the child at the age of six create an imaginary friend, or avatar, of themselves along with adding things they are interested in such as sports, arts, and hobbies that they would follow over the years in their experience." This specific innovative concept would end up being a well-received by the public at the GEMnasium culminating summit.

Teacher Education students participated in research being conducted with Health and Sport Science students. Pre-service teachers (n=165) completed a survey designed to assess their opinions and confidence levels on drug education based on their student-teaching experiences as well as the knowledge and skills they have gained throughout college. One result of the survey, presented by the Health and Sport Science students was a relationship between students' personal connection to drug-related topics and their confidence in being able to provide drug education. There were also differences in survey responses based upon their educational concentration (e.g, early childhood education vs adolescent and young adult).

The Applied Theatre students scripted a series of short plays based on their research, reading, story circle event, and story pair-share. Each script was written to be performed inside a car. The car plays each had characters that were in some way connected to one another. As the audience made its way through each car, sitting in the backseat to witness the "scene" in the front seats, they came to understand how the characters from each car knew the characters from the other cars. The car plays, called "Highjacked," performed the various stages of opioid addiction, as well as the diversity of those who are affected by the opioid crisis [35]. Audience members (students from other courses) moved from car to car, revealing the connections between characters in each car. Audience members moved through each car twice. The second time through represented a period of time five years later than the first act. This play was open to a select few on a first come basis. The audience included GEMnasium faculty, Families of Addicts, and GEMnasium students. A video was also made in order to share with a wider audience.

### *Capstone Presentation (Summit Slam)*

The capstone presentation, termed the Summit Slam, was the culminating experience for each of the classes, taking place on the last day of the semester over a two hour time block. All students from all classes were expected to attend and be part of their individual, group and class presentations. Additionally, the event was open to the entire campus. Further, all community members who had attended prior events were invited. In total, the event drew an estimated audience of 150 people.

Each visitor was given 3 sticky dots for voting which of the ideas would be moved into the summer 2018 IACT Collaborator Accelerator internship program. The two or three most highly voted projects were to be moved into this program..

## **RESULTS**

Our evaluation of the GEMnasium experience is predicated on two primary sources of input - namely faculty input and student input. The fundamental question for faculty was this: "Did the GEMnasium experience change the disciplinary deliverables, and if so how?" The faculty sought to understand the specific ways in which they valued (or did not) the interactions with other students and perspectives; their perception of how the GEMnasium space affected their experience; how the GEMnasium experience enhanced or diminished their disciplinary learning; what problems they encountered through the experience; and what impact the GEMnasium experience had on their future vocational vision. The following documents these results.



## Faculty Assessment of How the Experience Changed the Disciplinary Deliverables from Their Courses

Each instructor was asked to reflect on how the GEMnasium interactions changed their disciplinary deliverables. There was one common response from the faculty. The very nature of the opiate addiction topic forced students to include transdisciplinary considerations in their design and research. There was no class with disciplinary grounding in this topic. A good example of this is the work of the Applied Theater class. The students in this class reported feeling that they had learned a great deal about the opioid crisis from a research and fact-based perspective, as well as an empathic understanding. They were proud of the scripts they created, and were challenged to bring authenticity to the characters they were performing in “Highjacked.” It was difficult to embody and perform characters struggling with addiction, but by doing so, the students felt that they were able to relate to and understand the struggles of those dealing with addiction in our community. They also came to appreciate the need to advocate for more social service supports for those in our community dealing with addiction.

Secondly, the designs/products developed owed substantially to transdisciplinary influences. For example, Faculty 1’s Mechanical Engineering capstone modeling class’s recycling enterprise for recovering addicts accounted for numerous human related themes. Their enterprise would offer at-risk workers jobs with meaning (sustainability, education, community health, community arts), and include numerous activities to promote health and opportunity for the long-term, such as yoga, clown and stand-up comedy training, coding training, and life-skills development. Their collective systems design could not have emerged except as a result of the transdisciplinary ecosystem enabled within the GEMnasium. The Project Management class’s project solutions for the FOA organization likewise included human dimensions not typically present in this class’s solutions.

Third, the topics addressed in relation to the opiate problem were highly influenced by other disciplines. For example, each of Faculty 10’s Christian Ethics and Healthcare student projects emerged entirely in response to the content developed by other students in the GEMnasium. The fact that the Freedom Kitchen project theme of one of her student teams was framed as an enterprise reveals influence from the Engineering Analysis class. Similarly, in Faculty 5’ Health and Sports Science Research course, a few students who had attended a guest speaker brought in by Faculty 10 who discussed addiction as a medical disease, rather than a moral failing which it is commonly portrayed as, led them to study beliefs of the campus student community about addiction as a moral or medical issue. The resulting campus-wide survey they developed also enabled another team comprised of pre-health professionals to assess the knowledge-level of UD peers was on opioids in general. Another student team’s project emerged as a result of them establishing an emotional connection to the real life stories of addiction. In their project they sought to assess how messaging of the opiate addiction might influence response. They did this by showing two different brief video clips of recovering addicts (one that was fairly optimistic, one that was not) to groups of students and qualitatively assessing the impact it had on attitudes towards the opioid crisis. Only one project resembled what typically occurs as an outcome of the course; namely a quantitative study of pain tolerance. Interestingly, the instructor (Faculty 5) had to encourage at least one group to pursue this experimental, human-based, quantitative approach, whereas in previous semesters, this project represented the typical study design.

## Evaluation of Student End of Course Reflection

At the end of the spring 2018 semester, students from all classes were asked to complete a survey that included both demographic questions about the students and queries requiring textual response to a series of questions about the experience. The demographic questions foremost asked students to identify which class they were part of and their major. In total, 108 students responded to the survey, roughly 33% of the total enrollment.

The following describes the questions asked and analyzes the responses. All responses were tallied, word frequency groupings were established, and counts within these grouping were made.

### *Defining the GEMnasium*

Figure 3 (Appendix) summarizes student responses to the question “What is the GEMnasium in one sentence?” From this figure, it is clear that several categories stood out among the students. Foremost, the students saw the GEMnasium as a place for collaboration, and particularly collaboration across disciplines. Secondly, they saw it as a place for creativity; growing and applying it. Third, it was also about the space. The students recognized the linkage between the collaborative and creative environment established in the GEMnasium and the space in which the collaboration and creativity took place. While not appearing quite as much, many students understood the GEMnasium was about a theme connected to humanity-centered design that brought everyone together.

Appearing less than one-half the frequency of collaboration, creativity, and space were categories associated with: the GEMnasium processes (not as many students associated the GEMnasium with the processes employed), the emotions engendered by being in the GEMnasium, the potential impact of the solutions, and the relaxing environment offered by the space. It is clear that student perception of the GEMnasium courses was quite varied, even within classes. Thus, students were taking away different things from the experience.

#### The value of working with other disciplines/courses in the GEMnasium

Figure 4 (Appendix) shows the relative frequency of response categories to the prompt “Please articulate any specific valuable aspects of working with other disciplines/courses in the GEMnasium.” It is evident from this figure that the observations drawn from the previous question are mirrored here. 41% of the word groupings are associated with comments about valuing the perspectives of the other students (and community partners). These perspectives helped them learn (18%) mostly by developing new perspectives and finding ways to combine the perspectives of others into their solution(s)/research (16%). 10% acknowledged that they had valued collaborating closely with the other disciplines. Most of these responders, it appears, had the opportunity to do this deeply, something that was accessible to only a small fraction of the students. Some also acknowledged that it aided the creative solutions emerging - helping to develop solutions that would not be accessible from a single discipline (8%). Others noted the real value obtained in communicating and networking with other disciplines (3% each).

Examples of responses to this question from students follow. Relative to growing perspective, an Education student commented that the experience “expanded my thinking and opened my views to other approaches and ways of knowing.” A Health and Sports Science student had a similar observation, saying “I believe it helped me expand my thinking and see different points of view.... I was able to get a different look at this serious issue and see how people of other disciplines see the issue.” Another commented that the experience “encouraged

me to think differently than I normally do and apply different ideas.” A Mechanical Engineering student echoed these statements, saying “I became more conscious of other concerns from other points of view other than an engineering point of view. It introduced me to a new lens to view problems.” A Christian Ethics in Healthcare student noted likewise that the GEMnasium experience “opened my eyes to different approaches to problem solving.”

Student valuation of the transdisciplinary innovation process are exemplified by the following student responses. One interesting take-away from some of the Mechanical Engineering student responses is that transdisciplinary included the input from community partners who were involved in their brainstorming and review processes. To this type of response, a Health and Sports Science student offered “Working closely with engineer majors and fine arts majors made me realize that I think in a certain way. I liked other students challenging me to think outside my comfort zone.” A Mechanical Engineering student offered “Working in a transdisciplinary environment helped me realize how to break out of the traditional mold of learning. It's okay to ask questions, fail at a few approaches, etc. A typical teaching method feeds you the path you're supposed to take - this was more realistic.”

The following comments illustrate the awareness some students had gained about communicating with other disciplines. One Mechanical Engineering student said “I was more encouraged to present the projects that we worked on in a different way knowing that other classes and other community partners would be seeing it all, instead of just another engineer or engineering professor.” Another said “Working across disciplines enabled me to find ways to simplify my methods and models so that people from other subjects could understand them easily.” Lastly, a Christian Ethics and Healthcare student offered “I would say it made me think twice about everything I produced for the GEMnasium knowing others would be seeing it and potentially using it for their own products.”

### ***Impact on disciplinary knowledge***

Students were asked to respond to this question, “Did your experience in the GEMnasium impact your own disciplinary knowledge?” The most important disciplinary take-away for the education students was that the experience improved their understanding of how addiction affects the lives of their students and their families. This knowledge was deemed nearly universally to be important to their future disciplinary practice as teachers.

The Health and Sports Science and health related students in the general courses (REL 367, UDI 372) drew similar collective benefit. The GEMnasium experience particularly helped them grow in their understanding of addiction and helped them envision the value that their future profession might have in the treatment of this problem. One future physical therapist noted:

“As a pre-physical therapy student, I was very interested to learn how physical therapy is used as an alternative pain management therapy to prescription opioids. It made me realize that physical therapy can be utilized for more than just a physical injury or disability. I think it would be very interesting to further research how PT could be used as an alternative way to manage pain so that less opioid drugs need to be prescribed.”

Addiction almost never intersects the lives of mechanical engineers from a professional standpoint. Thus, it is not surprising that one-third of these students noted that the GEMnasium experience did not apply to their profession. However, the remainder of the students noted a myriad of different takeaways. Two especially valued the opportunity to design new enterprises (“I plan to use some of the enterprise creating aspects I learned and apply it to creating my own

program. This class really inspired me!”) A number credited the experience with helping them understand the value of their professional experience in addressing different problems (“It gave me a better understanding of how the engineering process can be applied to a variety of challenges/problems that are not solely mechanical or design based.”). Many acknowledged the teamwork, leadership, and project management value of the course (“I also learned a lot about teamwork. So much can get done when everyone is focused on the same project. But along with that comes a SERIOUS need for organization and communication.”). A number of these students said that the brainstorming processes employed in the class would have relevance to their future disciplinary practice (“It allowed me to learn about data analysis and system modeling in a creative way.” “This class gave me strong analytical tools to apply to my practice.”).

### **Identified challenges for the GEMnasium**

Figure 5 (Appendix) addresses the frequency of responses to the prompt, “Please articulate any specific challenges you encountered working with other disciplines/courses in the GEMnasium”. The prominent challenge identified was primarily noted by students in classes meeting simultaneously in the GEMnasium - that the environment was distracting and loud (21%). The next five-word categories were suggested about half as much as the distraction concern. This included disconnectedness of the different class efforts, difficulty in valuing the work of others or feeling one’s viewpoint was not valued, not understanding the background or language of the other disciplines, not knowing how to communicate with the other disciplinary perspectives, and not having enough opportunities to interface with others or the inaccessibility of the collision events for their schedules. Some students observed a lack of commitment of some of the different disciplines to the problem (8%). Overload or overstimulation was identified as being a concern (6%). Interestingly all faculty participating in the GEMnasium echoed this concern at the end of the semester. The last four-word categories, while comprising only 3% of the total words, were nevertheless somewhat concerning. Some of the classes felt that the connections with other disciplines were one-way, meaning that they provided input to others but did not get any response in return. Several noted deep concern with the lack of sensitivity of some of their peers in other disciplines to those with addiction problems. Others noted difficulty in meshing, particularly in the big collision events, where students generally moved around the space with peers they were most comfortable with in their own discipline. Lastly, a number of students had difficulty understanding the purpose of the collision events. They did not feel that these had been articulated as well.

### **Impact on career aspirations and directions**

Figure 6 (Appendix) summarizes the responses to the question “Has your experience in the GEMnasium impacted your sense of vocation and/or future career path? If so, how?” Included in this analysis were only the responses only from students in the fully engaged classes. Each student’s response was classified into one of the categories shown. Thus, the percentages associated with the groupings reflect the percentage of students whose responses were classified in the assigned category.

Roughly one-third of the students said that the experience had no impact on their future career. Our sense is that those who responded in this way were only considering the linkage to addiction, not any of the other aspects of the experience (collaboration across disciplines, collaboration, etc..). Striking is that collectively 22% of the students now acknowledge that they

are seeking a vocation which enables them to address deep seed social problems in society or in their communities (14% general, 8% addiction). Additionally, another 8% noted that the experience had strengthened their commitment to a vocation which has human impact or addresses addiction. Combined, these account for nearly 1 and 3 students. Frankly, it is difficult to imagine few classes at the university involved in the study or anywhere having this kind of impact.

Additionally, a good number of students' vocations were affected by the processes employed in the GEMnasium. Eleven percent of the students now say that they are seeking a profession emphasizing transdisciplinary collaboration, creativity, and freedom.

Some examples of engendering a pivot to a more meaningful, human-centered vocation follow. A Mechanical Engineering student offered this. "I would certainly like to apply my education in a more meaningful way, trying to impact the community that I live in the way that this experience has. I now feel a deeper responsibility to give back and serve my community in some way, whether it be my career or alongside my career." An education major noted "I met an associate dean for the counseling education department, and I now am thinking about going into counseling rather than teaching at this moment." Lastly an ACT II student offered. "I want my vocation to be humanity centered design. I changed majors (from business) and switched into the arts so I could be in a more humanity centered career."

Illustrations of students who say that the experience strengthened their previously selected vocation follow. A majority of these were already pursuing careers in health, wellness, or education. A Health and Sports Science student offered this perspective. "As a student who had been considering pursuing a public health degree in grad school, working in the GEMnasium gave me some real experience on a real public health issue, and affirmed for me that I am interested in combatting public health issues." Another offered, "It has continued my appreciation for the social needs of patients I will be seeing in my future career." Lastly, an ACT II student said "The GEMnasium continued to engage my interests in working with people who have addictions through my work as a music therapist."

Several Mechanical Engineering students noted how important the experience was for them in valuing the ideas and roles of others (non-engineers). These comments are especially illustrative of this change. One offered "This experience causes me to look at co-workers in new light." Another said "My experience in GEMnasium has helped me to understand the importance of teamwork. It has shown me that no matter what a person's job is, they can be a real benefit to almost any project. I know I will be more mindful about the composition of my team and my own biases entering into a project."

Lastly a number of students noted that the experience had awakened in them a desire to work in collaborative transdisciplinary and creative environments. One Mechanical Engineering student's response to this question illustrates this. They said "Yes, I see myself pursuing a career where innovation and collaboration are emphasized."

## CONCLUSIONS

It is clear from the spring 2018 assessment results from the GEMnasium that the experience was successful in achieving the objectives of the study. Students have clearly been impacted by the experience. The greatest impact from the experience was student valuation of the perspectives of students from other majors. . This evolved empathy for others' perspectives has been identified by others as vital to collaborative innovation [13] [19] [26] [36]. The act of bringing together students from all disciplines, providing opportunities to share their perspectives

with other majors, and faculty advocacy of the value of these perspectives was highly effective in realizing this sought outcome. This empathy of others' perspectives clearly influenced the product of a majority of students.

Additionally, most students judged the GEMnasium experience to be highly effective in promoting collaboration, creativity, and freedom. The flexible space itself was deemed crucial for promoting collaboration, primarily within individual classes. But, the freedom associated with student ownership of their learning and their ideation is what stood out the most in the GEMnasium. We truly gave students opportunities to deal with ambiguity, define the problem/question they would address, develop multiple answers, and take risks and even fail, qualities that Kazerounian and Foley indicated as essential for helping to develop creativity [8].

But, the assessment also points to many things that could be improved. The participating faculty strongly believed that somehow students must be immersed more strongly in the community. This first GEMnasium saw very few students getting off-campus to interface with community members - particularly those who have experienced addiction. Humanity centered innovation above all requires connection to people, and expects that the people served are involved in the innovation process. While our courtesy faculty served this role to some extent, all faculty involved in the GEMnasium agreed that future instances of the GEMnasium must involve more meaningful immersions in the community. Additionally, a liability was the accessibility of community partners relative to the schedules of students. Other researchers have noted this issue [37]. In the future, we will be looking to explore the inclusion in every class of trained and hired peer-to-peer researchers formed of community members actually affected by the thematic problem addressed by the classes. This approach has three additional significant impacts. First, it recognizes through pay the educational value of these persons to students. Second, it brings a community voice to every class and perhaps even every day. Third, it involves community members as co-designers with students and faculty of the products being realized [38].

Second, a number of students suggested that there needs to be an increased frequency of interactions between the majors. Several suggested the need for more independent interaction.

Third, information overload was often observed as problematic. For many, the space was overstimulating. With some classes emphasizing individual work (albeit informed by others) rather than team work, the amount of material present on the walls can be immense. Often there is just too much to review, limiting commitment of students and faculty to provide response. Moreover, sometimes the posted information remained up for others to see for long periods of time. It was not always clear if the postings had just been left up, or if the students/classes were still seeking response. While the openness of the space is clearly highly conducive to collaboration, future GEMnasium experiences must likewise offer undistracted spaces, both visually and sound-wise [39]. These spaces must offer a means for individual students and student teams to isolate themselves from the often noisy and visually stimulating environment.

Fourth, communication across disciplines must be more strongly emphasized. Only one of the classes noted the value of the space in terms of improving the ability of student communication to other disciplines (Mechanical Engineering). However, the limited intersection between most of the classes in the GEMnasium is a real impediment to realizing successful communication to the disciplines. Pennington notes that effective communication across disciplines requires more than empathy for the ideas and ways of doing of others. It takes time. Students communicating across disciplines need to know each other to be able to have comfort in asking questions to better understand [40]. We have imagined future GEMnasium experiences to

have disciplinary-based courses along with parallel transdisciplinary laboratories integrating students from the various classes.

More interactions between the disciplines should both help the students see the difficulty in communicating across disciplines; but if there is empathy for the other's knowledge and way of knowing and doing, then, there will be greater willingness to work on the communications. They can even ask what they could do to communicate better.

Fifth, the space didn't work for all classes all of the time. For example, the video presentation of the Applied Theater class's final performance "Highjacked" could not be heard.

Last of all, the first GEMnasium had an impact on students' views of their career. This was not exactly envisioned a priori. But, it is now clear that vocational growth from the experience is an IMPORTANT aspect of the experience. In the future, more effort can be put forth to ensure that students' individual vocations are being brought to bear on the project in the research, work, problem-solving, and creativity they are involved in. Teams can be formed based upon their vocations and the difference individual team members have.

Further, the processes employed need study and evaluation. There are a number of unanswered questions relative to the transdisciplinary mechanisms employed. What vehicles are working best and at what time? From which experiences are students more likely to identify the knowledge and project contributions of students from other disciplines? How are students articulating the value of their own disciplinary knowledge in these experiences? What communication obstacles are experienced in these settings? What factors engender greater comprehension of others' perspectives? Which of these experiences are forcing students to develop judgement about the importance of the different perspectives? Further, what evidence or reasons are students using to judge this importance? Last of all, as transdisciplinary solutions emerge, what evidence or reasons are students using to support the value of these solutions relative to what they may have come up with on their own? Future research is needed to answer these questions.

## APPENDIX

Table 1. Faculty/student participation

UD Faculty	Course	Disciplinary Course Expectations	Enrollment
Faculty 1, Mech. and Aero. Engin.	MEE 460 - Engineering Analysis	Capstone Mechanical Engineering modeling course.	32
Faculty 2 / Faculty 3, Engineering Technology	IET 323 - Project Management	Solving social problems with Project Management tools	25
Faculty 4	UD 372 - ACT II	Applied creativity for innovative change in solving social, commercial, professional and academic challenges.	24+21 = 45 total
Faculty 4, Health and Sport Science	HSS 428 Health and Sport Science Research Capstone	Application and practice of research in student's chosen profession and vocation.	28
Faculty 5, Fitz Center for Community Leadership	UDI 393 - Semester of Service mini course	Community Service Internship course is designed to support the Semester of Service nonprofit community service experience.	10
Faculty 6, Teacher Education	EDT 453 - Literacy in Early Childhood	Required literacy methods course for all Early Childhood students.	25+36 = 61 total
Faculty 7, Teacher Education	EDT 436 - Capstone for Early Childhood Educators	Developing resources to use with primary students promoting positive lifestyles	60
Faculty 8 / Faculty 9, Theatre, Dance, and Performance Technology	THR 352 - Applied Theater	Addresses practical applications of theatre and prepares the theatre practitioner to create performance for social justice	7
Faculty 10	REL 367 - Christian Ethics and Health Care	Focus on the problems and challenges related to health care ethics	25+10=35 total



Table 2. Schedule of classes committed to themed class

Time	Mon	Wed	Time	Tu	Th
9:00 - 12:00 p.m.		UDI 393 (Faculty 6)	8:00 a.m. - 12:15 p.m.	EDT 453 (Faculty 7)	EDT 453 (Faculty 7)
			9:30 - 10:45 a.m.	MEE 460 (Faculty 1)	MEE 460 (Faculty 1)
			9:30 - 10:45 a.m.	REL 367 (Faculty 11)	REL 367 (Faculty 11)
			12:30 - 1:45 p.m.	IET 323 (Faculty 3 and Faculty 2)	IET 323 (Faculty 3 and Faculty 2)
			3:35 - 4:50 p.m.	REL 367 (Faculty 11)	REL 367 (Faculty 11)
			4:30 - 7:10 p.m.		THR 352 (Faculty 9 and Faculty 10)
5:00 - 7:30 p.m.		HSS 428 (Faculty 5)	4:30 - 7:10 p.m.		EDT 436 (Faculty 8)
5:05 - 6:20 p.m.		UDI 372/ACT II (Faculty 4)	5:05 - 6:20 p.m.	UDI 372/ACT II (Faculty 4)	

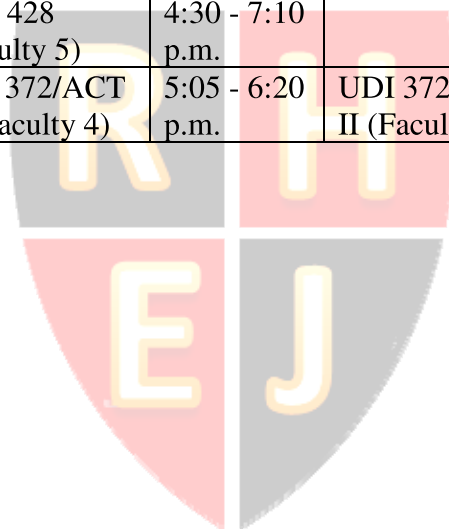


Table 3. Transdisciplinary Innovation Education Process

Phase	Process	Description
I	Transdisciplinary Course Planning	Faculty team define the theme; share their initial thoughts on how they will address; identify potential linkages
II	Disciplinary Immersion/ Transdisc. Observation	All classes immerse in disciplinary requirements and the theme for the course
III	Disciplinary Content Development	Students develop content (research, designs, questions, art, etc...) from disciplinary perspectives
IV	Transdisciplinary Collision	Students identify what they do not know about their ideas; students from other disciplines respond
V	Transdisciplinary Informed Innovation	Students incorporate ideas of others into class product(s)
VI	GEM Symposium	Students present their products innovatively to other classes, community partners, the university community

Table 4. Faculty teams and the curricular purposes established from the Transdisciplinary Mapping Lab

Faculty Team Members	Integrated Theme
Team 1	To develop an open and authentic form of communication to advocate for an overall healthy lifestyle
Team 2	To advocate for understanding of the unique experience of people with addiction and their communities in order to serve
Team 3	To create an innovative space to advocate authentic self-exploration while finding one's purpose

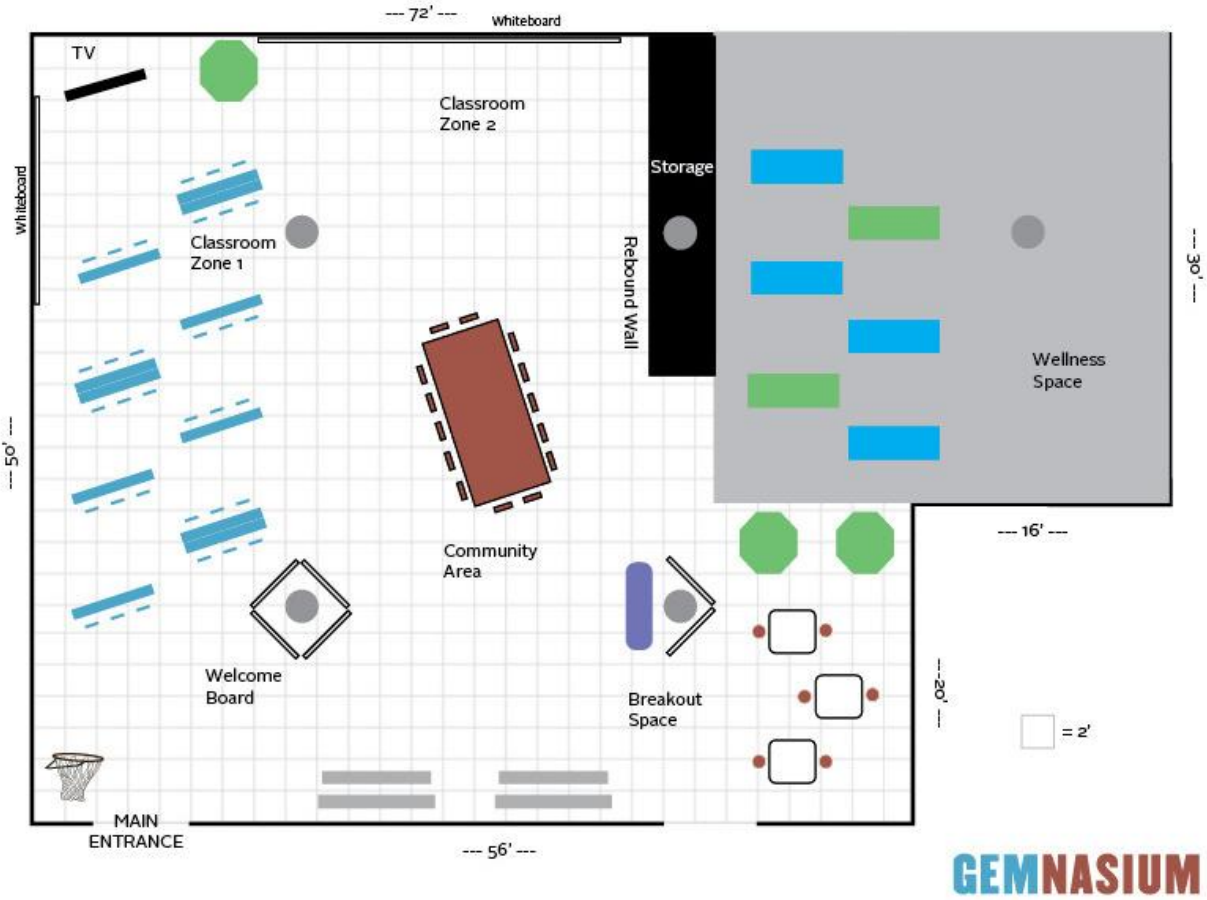


Figure 1. Footprint of the GEMnasium





Figure 2. Images of the GEMnasium spaces in use

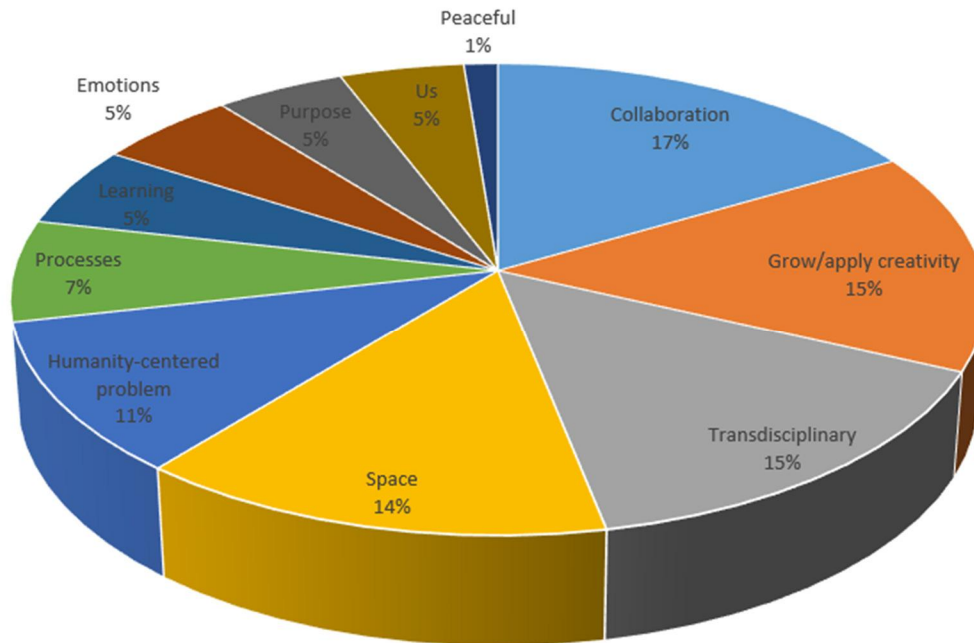


Figure 3. Pie chart showing percentage of words classified in each grouping in response to the question “What is the GEMnasium in one sentence?”

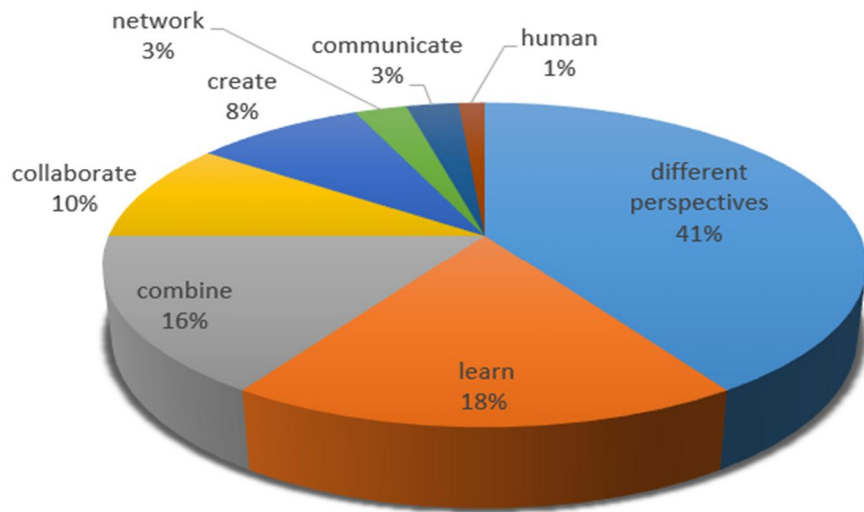


Figure 4. Relative frequency of student responses to the prompting “Please articulate any specific valuable aspects of working with other disciplines/courses in the GEMnasium” in grouped word categories.

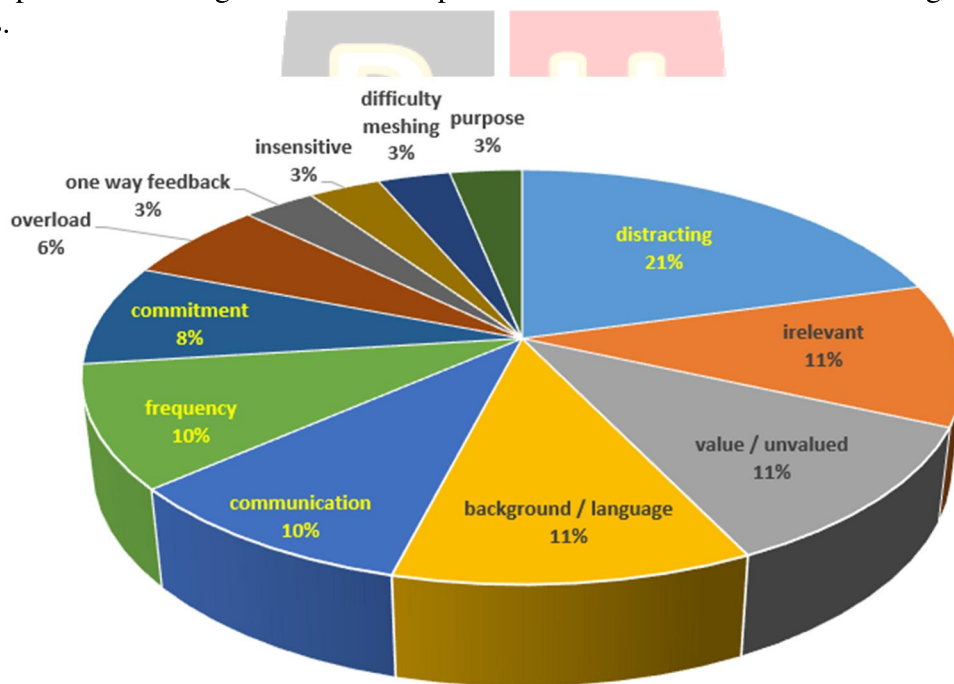


Figure 5. Relative frequency of student responses to the prompting “Please articulate any specific challenges you encountered working with other disciplines/courses in the GEMnasium” in grouped word categories.

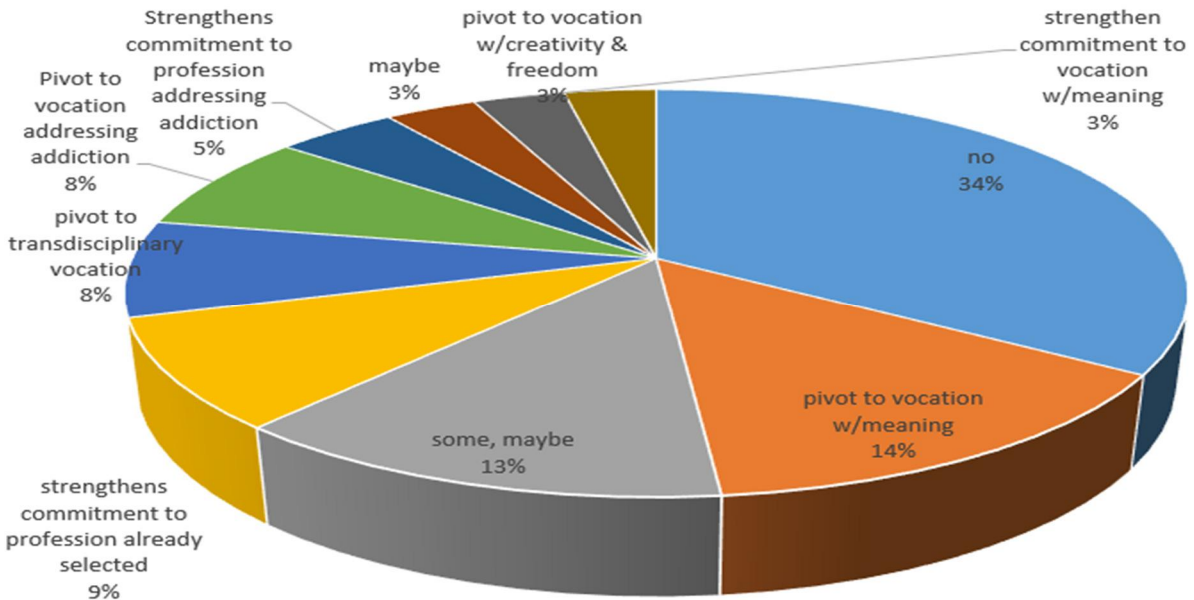


Figure 6. Relative frequency of student responses to the question “Has your experience in the GEMnasium impacted your sense of vocation and/or future career path? If so, how?” in grouped word categories.



**BIBLIOGRAPHY**

- [1] S. Jaschik, "Well Prepared in Their Eyes," *Inside Higher Education*, 21 Jan. 2015.
- [2] American Association of Colleges and Universities, "Well Prepared in Their Eyes," *Inside Higher Education*, 7 Nov. 2015.
- [3] R. Florida, *The Rise of the Creative Class*, New York, New York: Basic Books, 2001.
- [4] K. Foundation., "The Importance of Young Firms for Economic Growth," *Entrepreneurship Policy Digest*, 14 Sept. 2015.
- [5] S. Hunter, *Out Think: How Innovative Leaders Drive Exceptional Outcomes*, Wiley, 2013.
- [6] Bloomberg, "Bloomberg Innovation Index," [Online]. Available: <https://www.bloomberg.com/graphics/2015-innovative-countries/>. [Accessed 2017].
- [7] World Intellectual Property Organization, "Global Innovation Index 2016: Switzerland, Sweden, UK, U.S., Finland, Singapore Lead; China Joins Top 25," 2016.
- [8] K. Kazerounian and S. Foley, "Barriers to creativity in engineering education: A study of instructors and students perceptions," *Journal of Mechanical Design*, vol. 129, pp. 761-768, 2007.
- [9] J. Hall and M. E. Johnson, "When Should a Process Be Art, Not Science?," *Harvard Business Review*, March 2009.
- [10] B. Uzzi, S. Mukherjee, M. Stringer and B. Jones, "Atypical Combinations and Scientific Impact, Science," *Science*, vol. 342, no. 6157, pp. 468-478, 2013.
- [11] T. Brown and J. Wyatt, "Design Thinking for Social Innovation," *Stanford Social Innovation Review*, no. (Winter), pp. 31-35, 2010.
- [12] C. Dreu, W. De and M. A. West, "Minority Dissent and Team Innovation: The Importance of Participation in Decision Making," *Journal of Applied Psychology*, vol. 86, no. 6., pp. 1191-1201, 2001.
- [13] S. Hewlett, M. Marshall and L. Sherbin, "How Diversity Can Drive Innovation," *Harvard Business Review*, December 2013.
- [14] U. R. Hülsheger, N. Anderson and J. F. Salgado, "Team-level predictors of innovation at work: A comprehensive meta-analysis spanning three decades of research," *Journal of Applied Psychology*, vol. 94, p. 1128-1145, 2009.
- [15] E. JUNG and S. LEE, "THE COMBINED EFFECTS OF RELATIONSHIP CONFLICT AND THE RELATIONAL SELF ON CREATIVITY, IN ORGANIZATIONAL BEHAVIOR AND HUMAN DECISION PROCESSES," *ORGANIZATIONAL BEHAVIOR AND HUMAN DECISION PROCESSES*, vol. 130, pp. 44-57, 2015.
- [16] S. Schaffer, X. Chean, X. Zhu and W. Oakes, "Self-Efficacy for Cross-Disciplinary Learning in Project-Based Teams," *J. of Engineering Education*, pp. 84-92, 2012.
- [17] C. Golding, "Integrating the Disciplines: Successful Interdisciplinary Subjects," Centers for the Study of Higher Education, 2009.
- [18] B. Hoffert, "Innovation and Conflict: Finding Creative Solutions to Social Problems," 2006.
- [19] J. Fulton-Suri and S. G. Howard, *EMPATHY ON THE EDGE SCALING AND SUSTAINING A HUMAN-CENTERED APPROACH IN THE EVOLVING PRACTICE OF DESIGN*, 2015.
- [20] M. Bowman, "Opioid Abuse and Death: Thoughts From Dayton," *Fam Med.*, vol. 50, no. 6, pp. 420-422, 2018.
- [21] Dayton and Montgomery County Public Health, "Accidental Overdose Deaths," 20 9 2018. [Online]. Available: <https://www.phdmc.org/coat/158-accidental-overdose-death-totals>. [Accessed 25 9 2018].

- [22] P. -. Frontline, "Left Behind America," 11 Sept 2018. [Online]. Available: <https://www.pbs.org/wgbh/frontline/film/left-behind-america/>. [Accessed 15 Sept 2018].
- [23] Council of Economic Advisors, "The Underestimated Cost of the Opioid Crisis," Washington, DC, 2017.
- [24] McKinsey Global Institute, "A FUTURE THAT WORKS: Automation, Employment, and Productivity," 2017.
- [25] C. B. Frey and M. A. Osborne, "The Future of Employment: How Susceptible Are Jobs to Computerization," 2013.
- [26] S. Perry, "What's Empathy Got to Do with Creativity? Everything (If You Want to Do Either 'Right')!," *Thrive Global*, 15 Nov. 2017.
- [27] B. LaDuca, "Social Innovation through Purpose, Performance, and Story," in *Performing Arts as High Impact Practice*, Palgrave Macmillan, 2018, pp. 82-95.
- [28] B. Choi and A. Pak, "Multidisciplinarity, interdisciplinarity and transdisciplinarity in health research, services, education and policy: 1. Definitions, objectives, and evidence of effectiveness," *Clin Invest Med.*, vol. 29, no. 6, pp. 351-64, 2006.
- [29] S. W. Aboelela, L. E. S. Bakken, O. Carrasquillo, A. Formicola, S. A. Glied, J. Haas and K. M. Gebbie, "Defining Interdisciplinary Research: Conclusions from a Critical Review of the Literature," *Health Services Research*, vol. 42, p. 329-346, 2007.
- [30] B. Laduca, A. Ausdenmoore, J. Katz-Buonincontro, K. Hallinan and K. Marshall, "An Arts-Based Instructional Model for Student Creativity in Engineering Design," *J. Engineering Pedagogy*, vol. 7, no. 1, pp. 34-51, 2017.
- [31] S. Magura and A. B. Laudet, "Parental substance abuse and child maltreatment: Review and implications for intervention," *Children and Youth Services Review*, vol. 18, no. 3, pp. 193-220, 1996.
- [32] L. Feig, "Understanding the Problem: The Gap Between Substance Abuse and Welfare Services," in *Substance Abuse, Family Violence, and Welfare Services: Bridging Perspectives*, Thousand Oaks, CA, Sage Publications, 1998, pp. 62-95.
- [33] V. Felitti, R. Anda, D. Nordenberg, D. Williamson, A. Spitz and V. Edwards, "Relationship of childhood abuse and household dysfunction to many of the leading causes of death in adults," *American J. of Preventative Medicine*, vol. 14, no. 4, pp. 245-258, 1998.
- [34] C. Whitfield, *Healing the child within: discovery and recovery for adult children of dysfunctional families*, Pompano Beach, Fla: Health Communications, 1987.
- [35] M. Hayford and J. Yorke, Directors, *Highjacked*. [Film]. University of Dayton, 2018.
- [36] C. Dreu, W. De and M. A. West, "Minority Dissent and Team Innovation: The Importance of Participation in Decision Making," *Journal of Applied Psychology*, vol. 86, no. 6., pp. 1191-1201, 2001.
- [37] D. Comeau, N. Palacios, C. Talley, E. Walker, C. Escoffery, W. Thompson and D. Lang, "Community-Engaged Learning in Public Health: An Evaluation of Utilization and Value of Student Projects for Community Partners," *Pedagogy in Health Promotion*, vol. 5, no. 1, pp. 3-13, 2019.
- [38] B. Roche, A. Guta and S. Flicker, *Peer Research in Action: Models of Practice*, New York, NY: Wellesley Institute, 2010.
- [39] Haworth Research, "Designing for Focus Work," Haworth, Inc., 2016.
- [40] D. Pennington, "Cross-disciplinary collaboration and learning.," *Ecology and Society*, vol. 13, no. 2, 2018.



