Increasing Student Engagement Through the Development of Interdisciplinary Courses:

Linking Engineering and Technology, the Sciences, and the Humanities

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Abstract — **The changes in the defining ideas of the contemporary world, the exponential growth of knowledge, and the expansion of technological innovations have created a need for a critical examination of the convergences and connections between the Sciences, Engineering, and the Humanities. Today, there are areas of study so complex that they go beyond the confines of a single discipline. Examples of such areas include (1) the comparative study of concepts of mind, consciousness, and machines, (2) the critique of the technological culture through appropriate and alternative technology approaches, and (3) the questions surrounding cosmology, evolution, and beliefs. In response to this, we have developed interdisciplinary, team-taught, general education courses on artificial intelligence, appropriate technology, and the origins of the universe that respond to the above challenges, while fostering the ability of our students to use skill sets and concepts from different and divergent disciplines in order to examine such complex areas of study. The preliminary results indicate that, while there is a need for continuous retooling of the course model to better reflects the General Education goals and the university culture, this is a successful course model for our institution. The data also suggests that this type of interdisciplinary intervention in the beginning years of university study positively impacts the development of students' abilities in these areas.**

Index Terms — interdisciplinary courses, student engagement, first year experiences, critical thinking, integrative learning

I. Introduction

The past few decades have witnessed an explosion in information in science and technology that directly impact our lives and call for an examination of the connections between Science, Technology, and the Humanities. These intersections form the crux of critiques of artificial intelligence, the appropriate use of technology, and the origins of life; three areas which influence our conceptions and our place in society and the world. While, technology and science are integral and formative parts of our culture, not neutral entities, they have the ability to alter how our senses inform us about the external world and help form one's own view of reality, structures of meaning, and identity [1]. Very few of the University of Puerto Rico, Mayaguez's (UPRM) General Education (GE) requirements examine the reciprocal relationships between science/technology and society/culture or the associated convergences. To remedy this situation, our educational project, "The Convergence of Science, Technology, and the Humanities", aims to examine the convergences in our culture through a set of interdisciplinary team-taught, theme-based GE courses that enable students to explore the links between the sciences and the humanities, with the goal of improving our students' engagement in their own learning. Given the complexity of the three above areas, an interdisciplinary approach is needed for the study of their diverse elements [2 - 7], with Klein and Newell [3] indicating that such a format provides a base and process for examining topics, questions, or problems that are too broad to be dealt with by a single discipline or profession [3].

Scholars [8 - 11] indicate that colleges and universities are using interdisciplinary courses to enhance and focus on developing students' integrative skills, while addressing topics that are by their very nature intrinsically broad, multi-faceted and, therefore, beyond the scope of a single discipline. To be successful, these courses depend upon the integration of perspectives and tools from multiple disciplines for a more complete inquiry of the subject matter [9, 11, 12]. While there are concerns about the effectiveness and problems associated with team-teaching [9, 10, 13], in our project it became clear that if a teaching team maintains good communication lines and the members seek a deep collaborative experience, the development and offering of the course flows more smoothly.

Because UPRM is mostly a Science/Engineering university, the creation of interdisciplinary GE courses that examine the above mentioned intersections is an important addition to our GE curriculum. Professors from widely diverse disciplines are collaborating to develop and offer three interdisciplinary, thematic, team-taught GE courses that contextualize current debates and questions that inquire about (1) the expanse and limits of artificial intelligence (AI); (2) the ethical, social, and technical choices that distinguishes appropriate use of technology (AT); and (3) the theological, social, and scientific debates that arise in connection with the study of cosmology, evolution, and belief (CEB). Given the depth and complexity of these areas, an interdisciplinary, team taught approach is well suited and provides the best tools for considering these

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topics [7- 9, 11, 13].

II. Course Designs and Outcomes

A team of three professors was assigned to each of the three thematic areas. Each team began designing the course format, syllabus, readings, assignments, and evaluation rubrics at least one year prior to offering the course. As part of this process, each team hosted a conference of visiting scholars who had expertise in both the specific theme and in pedagogical methods for interdisciplinary education. This included use of such interdisciplinary pedagogical methods as writing for learning, case studies, group research, and student led discussions [13 - 14]. The visiting scholars were presented with annotated draft syllabi of the courses for their responses, which further engaged the team members in a critical dialogue on course content, design, and pedagogy.

Two formats for the course were designed, both of which are based upon the mega-section concept and are cost neutral in terms of the number of students per professor. The first format, which was used in the AI and CEB courses, divided the students (up to 30 students per professor) into three separate sections. Each professor then met separately with each section on an alternating basis, with some general meetings for all participants scheduled during the course of the semester. The second format, used in the AT course and employed at some point in the other two, convened the entire class in a large classroom or auditorium. In all cases, for accounting and grading purposes each teaching team member was assigned up to thirty (30) students.

Due to the differences between the courses, the following presentation of the results (description, design, results) will be divided by course topic.

A. *AI: Mind, Consciousness, and Machines*

Core theoretical questions in AI research (and contemporary computer science and cognitive science in general) are core theoretical questions in the modern history of psychology and the philosophy of mind. An interdisciplinary course on AI, team-taught by a Computer Engineer, a Philosopher and a Psychologist, introduced a class of undergraduate students from diverse disciplines to the main areas that influence AI research, such as the rationalist/empiricist divide [15], the nativist/operationalist debate in psychology [16 - 17], classical computationalist models vs. connectionist models in Computer Science [18], neural nets and debates in Neurophysiology [19 - 20], as well as the basic premises of Computer Science [21 - 22], evolutionary Biology [23], Linguistics [24], Philosophy [25 - 26], Psychology [27 - 29], and Robotics [21, 30 -31]. This course has been offered twice (2010 and 2012). In the second offering, there were 17 enrolled students, with 80% of the students being from Engineering and the remaining from the Natural Sciences.

One of this course's main objectives was, through an introduction to diverse disciplinary perspectives on the topic of AI, to develop the students' critical thinking skills. Students were introduced not only to established paradigms, but to current debates and movements in the field, while the professors' job was conceived more as a facilitator to raise questions, rather than as a dispenser to introduce the students to conventional professional wisdom. The professors quickly realized that the students needed instruction on general critical thinking skills. Forensic debates (in which the student was not aware ahead of time of which thesis they would be defending), mutual student grading and, of course, professorial debates were particularly well-matched to the interdisciplinary environment. The final grade distribution 29% -A, 5%-B, 12%-C, 18%-D, 0-F, (5 withdrawals, 1 incomplete) highlight both the benefits and the problems associated with this type of course.

The final course assessment activity was a general meeting with the students about the course. The students indicated that their writing skills had improved and that they developed greater understanding of what needed to be done to establish and defend a point of view. This is supported by the final grades in the class (i.e., the relatively high number of A's) and the professors' own observations. This was exciting, as professors initially thought that the most significant pedagogical achievement would be an increase in comprehension (owing to the diversity of the material). Increased comprehension was also evident, particularly in student reports, but they also developed a greater appreciation of the range of diversity in professional opinions; that academic and scientific disciplines generate disagreement as frequently and as productively as they do consensus, both inside particular disciplines and, of course, across them. This seemed to be a particularly valuable lesson so far as the students were concerned. The students also reported that they enjoyed seeing the professors interact and that the professorial debates were favorite class periods.

It was difficult to arrange the distribution of credit hours and classroom time, as well as registration, grading, and course organization for a team-taught, inter-departmental course. As the first group to offer a course, professors struggled with organization and subsequent courses learned as much from what went wrong as from what worked. The first time this course was offered, in 2010, it was organized around the concept that the students would meet separately with each professor for one of the scheduled class periods of the week, with periodic meetings of the complete group for the interdisciplinary discussions. The first course evaluation results, halfway through the semester, clearly indicated that the students preferred to meet with all three professors at the same time. This is the format that was followed in the second half of the 2010 course and the whole of the 2012 offering. The feedback from the students strongly indicated that this is the preferred meeting format.

B. *AT: Alternative and Appropriate Technologies: Technology for What? Technology for Whom?*

The overall goal of this course was to foster critical thinking about the humanity/technology relationship, and to inspire creative thinking about alternatives. The course enrolled 72 students (64 engineering, 8 non-engineering; 30 1st year, 22 2nd–3rd yr., 20 4th yr. or beyond) and was taught by faculty from Philosophy, Electrical Engineering, and General Engineering.

Using Schumacher's concept of Appropriate Technology [32] and elaborations by Willoughby [33] as the central theoretical framework, students critiqued practices of technology both in the global North and in the global South. Additional ideas from Philosophy of Technology and elementary science were interwoven to encourage students to construct views beyond any single framework, and to elicit diverse views on what constitutes human progress.

Instead of attempting a detailed description of the course, professors provided a brief tour using electronic devices and media as a cross-cutting case. The students entered largely sharing the common view that technology is morally and politically neutral. This instrumentalist view is challenged by Albert Borgmann's theory on the endangerment of "focal things and practices" due to what he calls the "device paradigm" in which technologies provide goods and services invisibly, hiding the many consequences of our behaviors (e.g., we do not directly see carbon emissions when we turn on the lights) and erode lifestyles that reflect unity of effort engender human commitment [34]. A related idea elaborated by Héctor Huyke [35] is that over-availability of such devices produces distance between people, rather than nearness (e.g., think of a family at dinner, with each person on the phone rather than conversing with each other). Accordingly, the design of technology should take into consideration the strengthening of close human ties and foster meaning in life's activities [34]. Yet, introducing electronic devices in developing communities is often considered to be an "appropriate technology" [36]. However, the proliferation of these devices and their necessary infrastructure is generally managed by multinational companies whose principal motives are profit, raising questions such as those posed by Riley (e.g., should engineers resist global neoliberal economic policies?) [37], Practical Action (e.g., how is the community's wellbeing considered?) [38 - 39] and Willoughby (e.g., is the technology at a scale commensurate with the community's ability to manage and use it?) [33]. Parallel to these questions, mini lessons and exercises were presented to explore technical details of power requirements for operating such devices, and the broader environmental implications of diverse technologies for producing energy. In sum, students were able to reflect on the relative merits of seeking technological parity with the developed world, procuring better technological alternatives, and effecting behavioral changes to best promote quality of life and genuine wellbeing.

The principal assignments consisted of three written essays, in which students needed to apply critical thinking skills to (1) explain an important aspect of a theoretical framework on the humanity/technology relationship; (2) analyze a case from the perspective of that framework; (3) discuss a possible weakness of that framework; and (4) deliberate for or against the validity of the framework in a specific context. To evaluate students' critical thinking skills, an assessment rubric was developed based on these four elements. After the first essay was graded, students had an entire class session work in small groups to discuss the rubric with samples of their graded works, and a second class session for a plenary discussion summarizing the small group discussions.

Based on the rubric (10 pts. max.), the average scores on Essays 1 and 2 were as follows: Essay 1: (6.4, 6.6, 6.9); Essay 2: (7.1, 7.9, 6.9), where each triplet represents scores ordered by cohort (1st yr., 2nd–3rd yr., 4th yr. or beyond). For Essay 3, a group essay, the average scores were (8.0, 7.6), where the pair represents scores ordered by groups with a (majority, minority) of 1st year students. These results suggest that there was general improvement in students' critical thinking skills as the course progressed, and that this improvement was most (least) demonstrated by lower class (upper class) students. We speculate that by being less encumbered by years of compartmentalized learning and teaching, entry level students are more motivated to freely investigate interdisciplinary questions critically. Although we are unaware of any studies that directly support this conclusion, our results cohere with those from a study of First-year Interest Group (FYIG) participants at UW-Madison, in which first year students choose to enroll in a set of theme-based courses. According to this study, "Faculty have also remarked that their FYIG students *often* outperform their upper class, and in some cases, even graduate students on some critical thinking tasks" [40, p. 248, emphasis on 'often' added].

Another positive outcome of the course is that several students were motivated to continue to be active in Appropriate Technology. Two students from our class took a special topics class about structural mechanics and building with bamboo [41]; one student started a "social business" with a limited profit motive and a commitment to employing fair labor and environmental practices [42]; one student plans a capstone design project in Electrical Engineering incorporating ideas of appropriate technology applied to the irrigation of a local bamboo farm; and nearly a dozen science and engineering students have subsequently chosen to take classes in Philosophy of Technology, Engineering Ethics, and general Ethics.

C. CEB: Cosmology, Evolution, and Belief

The course, "Cosmology, Evolution, and Belief," provides an introductory examination of the dynamic process of evolution of three different objects: the Cosmos (with their fundamental constituents and natural laws) [43], Life (from its origin to human beings) [44 - 45] and Belief [46 - 47] (from primitive cultures and ancient civilizations to present societies). In this course professors from Physics, Biology, and Humanities collaborated to present, discuss, and clarify these topics. The course is designed for first or second year university students. There were 64 total students enrolled in the course with 56% from the Natural Sciences, 21% from Engineering, and the remaining 23% from the Humanities. The student evaluation system was based on two exams (8th and 15th weeks), class participation, quizzes, homework, and attendance. Each professor used the last three evaluation methods differently.

With regards to the academic results, the average grades on partial and final exams, quizzes-works, and participation for the students who completed the course (there were three withdrawals) were 24/30 (exam 1), 21/30 (exam 2), 22/30 (other assignments), 9/10 (attendance), with an overall total average of 76%. All three areas utilized many bibliographic and audio visual references. The cosmology section used 12 references, which included the textbook *Introduction to Cosmology* [43], which was written specially for the course. The evolution component used 22 references, ranging from scientific articles to book fragments; and the belief section employed 12 references.

Formal quantitative assessment was not developed for this course. Although, professors offered an assessment test to gather students' background about the course topics. They also offered a survey at the end of the course to probe students' degree of satisfaction. The majority of the students were highly satisfied with the course. Some of them were more engaged with a specific subject matter, depending on their personal interests. Critical thinking and integration of topics were assessed on exams questions. Most students were able to integrate different views presented in class about the topics, which translates into the 76% grade average. However, a few failed to develop critical arguments in their exams, or refused to answer the questions altogether.

The course design was similar to the 2010 iteration of the AI course, in that it was originally divided into three separate sections with each professor rotating through each section and offering his lectures three times (during weeks 2-7 and 9-14). The interdisciplinary discussions were to take place in weeks 1, 8, and 15, when all registered students and professors would meet together to discuss, analyze and synthesize ideas. However, once professors concluded the first cycle in the eighth week, they decided to adopt a different approach for the remaining weeks of the course. All three sections were fused together and the professors attended all lectures. This new format promoted interesting discussions among students and all three professors during the classes. In the final course assessment, 75% of the students expressed that they preferred this second format. During the course, all three perspectives were taken into consideration while analyzing specific issues. For example, professors discussed the ethical and biological impact of transhumanisms and technology on the continued evolution of the human species [48 - 49].

III. Conclusions

The project's original goals were that an interdisciplinary perspective would help increase our students' engagement in their learning and, subsequently, their critical thinking skills, as well as the understanding of the links between the Sciences, Technology, and the Humanities and the preliminary results support this. While the assessment only measured the work during the course of one semester for each course, the students did demonstrate improvements in their critical and integrative skills during that time. This was observed in all three courses, through the use of class discussions and assignments.

All three courses surveyed the students at the end of each associated semester in order to gather information regarding their degree of satisfaction with the course format and subject matters and their views of their own understandings of the areas of study. The majority of the students were highly satisfied, with some going so far as to say that "For the first time in my 6 years in college I found a piece [of] hope for the system, thanks to you [for] having developed this course" and "It was an overall great experience and I'm glad we all had some part in it" (in reference to the CEB course). The students agreed on the positive impact of discovering the intimate relationship between the disciplines included in each of the three courses.

The team-taught format also demonstrated positive results in regards to the level of student engagement. In all three courses, student engagement was high, which was supported by the increased level of class participation and fewer students using electronic devices during the class period. This was especially noted by professors in the 2010 iteration of the AI course and the CEB course. By changing the format of the classes from meeting in separate sections (with occasional interdisciplinary interventions), to one of all participants meeting together in one single section, not only were the students better able to perceive the convergences and divergences of the topics, but their levels of engagement in the class noticeably increased. As one of the professors observed, there was a notable increase in student attention, attendance, and participation as soon as they began meeting as a single section, instead of in separate sections.

However, organizing this type of course does present various difficulties during the course design and its subsequent offering. First of all, it requires extensive pre-course development, as well as good communications skills between the participating professors and the teaching teams needed to meet on a continual basis during the academic year before offering the course. In addition, each team of professors experienced a fairly steep learning curve to understand and learn each other's professional language, attitudes, and core beliefs. Further complicating the situation we confronted obstacles in regards to the administrative aspects. To offer such a course, a university needs to have well defined administrative procedures in regards to 1) teaching load, 2) publicity of the courses, and 3) student registration. We observed this while working on the course preparation and student registration for the course. Regardless of the obstacles, the whole process proved to be enriching, with one faculty member even remarking that he felt that the experience was like having an internal sabbatical.

IV. The Future

We envision that this model will be employed throughout the University to enrich the curricula and support better student engagement. To this end, professors from the Schools of Agricultural Sciences, Engineering and Business Administration are designing interdisciplinary courses along these lines. These curricular innovations will result in interdisciplinary team-taught courses between Engineering and Business, as well as a new multidisciplinary capstone course, which are scheduled for implementation on August 2015.

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