An Experiment in Interdisciplinary STEM Education: Insights from the Catholic Intellectual Tradition

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ABSTRACT

The "silo effect" is a major problem today in academia, i.e. the growing tendency of disciplinary isolation both in research and teaching. "Siloing" is noted particularly in the formal, natural, and applied sciences. Yet, many areas of human inquiry require by their very nature, an interdisciplinary approach. At Seton Hall University, in the context of the Core Curriculum for undergraduate studies, serious efforts are underway to bring the sciences into dialogue with the wider Catholic intellectual tradition. By fostering a healthy exchange between philosophy, theology, mathematics, computing, and the natural sciences, upperclassmen have been able to explore topics of great personal interest and draw significant connections from content learned in diverse fields of their education. Opportunities exist to extend and adapt this approach to other university settings internationally.

Keywords: Interdisciplinary Education, Reductionism, STEM, Theology-Science Dialogue, Catholic Intellectual Tradition

1. INTRODUCTION

> Knowledge lies scattered around us, in great, unconnected pieces, like lonely mesas jutting up in a trackless waste. That this fragmentation has impoverished public discourse is a more or less common lament; that it has emaciated education, both undergraduate and graduate, is too painfully obvious a truth to dwell on. So as we try to navigate through waves of uncertainty from one disciplinary island to another, all universities, not just Catholic ones, face the challenges and dilemmas of remapping the world of learning. [1]

This quote by Professor James Turner concisely frames the challenge faced by scholars interested in interdisciplinary education, communication, and research. Unfortunately, the "scattering of knowledge" is only exacerbated by how numerous colleges, departments, and professors function. Many university faculty members are familiar with the problems that arise from academic departments operating as independent, hardened silos. When this organizational approach is taken, whether officially or not, complex, interdisciplinary research areas may be ignored or mistreated by investigators due to some form of reductionism. Professor R.T. Allen identifies three forms of reductionism relevant to educational philosophy:

1) Methodological,
2) Epistemological, and
3) Ontological

Methodological reductionism is not a problematic approach *in se*. It generally involves decomposing a topic into more intelligible subtopics or components. Once the structure and function of these units is well understood, an attempt can be made at reintegration of the parts. Then the challenge remains to explore their *integrated* functioning. This approach can only be categorized as "reductionist" in the problematic sense when the researcher assumes that the "whole" is nothing but a collection of parts.

Epistemological reductionism goes further. Allen succinctly summarizes the position as follows: "…that the conceptions, theories, and laws of one branch of science can account for and explain, without remainder, all the phenomena and processes studied by another, which therefore is denied any distinctive conceptions, theories, and laws of its own." [2] Finally, ontological reductionism denies the possibility of metaphysical emergence, reducing it to an epistemological phenomenon that is only manifest in the process of system description or analysis. Epistemological reductionism and methodological reductionism (in the restrictive sense) assume some level of ontological reductionism. Allen gives the example of scientism (i.e., "the belief that the methods of natural science, or the categories and things recognized in natural science, form the only proper elements in any philosophical or other inquiry" [3]) as a common form of epistemological reductionism that assumes a very radical form of ontological reductionism.

Allen's research shows how reductionism, in its varied forms, affects conceptions of knowledge, values, and language. For example, with reductionism requires knowledge:

1) to be quantified,
2) to be abstract and general, and
3) to be "objective" and "impersonal".

As a result, the validity of "every-day" (pre-scientific) knowledge or common sense is rejected. According to Allen, this expression of reductionism requires that:

> The table *really* is the physicist's pattern of atoms in a mostly empty space; despite our own beliefs, we are our overt behavior (Behaviorism), our genes (the socio-biology of E.O. Wilson), the extentionless,

> intersections of social roles (as implied in much sociology). Despite what we say to the contrary, our religious, moral, and political beliefs are rationalizations of childhood insecurity (Freudianism) or ideological maskings of our economic interests (Marxism). In each case, the latter formulation is the 'objective' reality behind the subjective appearance. [4]

In the context of academic silos, in which diverse expression of reductionism are present and knowledge scattering is rampant, it is very difficult, perhaps impossible, to equip students to formulate and explore profound human questions like:

1) What is the relationship of the brain, the mind, and the soul?
2) Are the theory of evolution and the Book of Genesis compatible?
3) What are the limits to knowledge for the human person, and how and where do these limitations arise?
4) What are scientifically viable and ethical approaches to relieving hunger in the third world?

Clearly, a new approach is needed.

2. SETON HALL UNIVERSITY AND ITS CORE CURRICULUM

The approach described in this paper emerged at Seton Hall University (SHU) in South Orange, New Jersey, USA. As the character and mission of the university have directly influenced the development of the courses described below, it is important to have some sense of the history and the Catholic identity of Seton Hall. Founded in 1856 by then-Bishop James Roosevelt Bayley and named after his aunt, Saint Elizabeth Ann Seton, Seton Hall is the oldest diocesan university in the United States. It includes 11 schools and colleges with an undergraduate enrollment of about 5,800 students and a graduate enrollment of about 4,400. [5] The largest of these colleges is the College of Arts and Sciences, in which all STEM departments are located.

The mission statement, as approved by the Seton Hall University Board of Regents, Thursday, June 6, 1996, reads as follows:

> Seton Hall University is a major Catholic university. In a diverse and collaborative environment it focuses on academic and ethical development. Seton Hall students are prepared to be leaders in their professional and community lives in a global society and are challenged by outstanding faculty, an evolving technologically advanced setting and values-centered curricula. [6]

In accordance with this mission, an Associate Vice Provost (Monsignor Robert Coleman, J.C.D.) reports directly to the Provost and oversees the Institute of Interdisciplinary Studies which is comprised of the Department of the Core and the Department of Catholic Studies. He is also responsible for the Center for Catholic Studies and all other academic institutes and centers which focus particularly on aspects of the university's Catholic mission. The University's Core is composed of three foundation courses (two in College English and one in college skills, titled University Life) and three "signature" courses, plus a structure of proficiency requirements, ensuring that each graduating student has encountered fundamental skill sets, e.g., numeracy, writing, and critical thinking:

> Seton Hall University's Core Curriculum is an approach to general education that encourages students to become thinking, caring, communicative, and ethically responsible leaders with a commitment to service. The Core Curriculum consists of six common courses, as well as the systematic development of five academic proficiencies through the study of the liberal arts and sciences. [7]

The first signature course is entitled "Journey of Transformation." It is taken during the Freshman year and seeks to assist students in their exploration of perennial questions central to the Catholic intellectual tradition (CIT). Journey of Transformation exposes students to some of the great Catholic texts as well as those of the Jewish, Greek, Roman, and other traditions.

The second signature course, "Christianity and Culture in Dialogue," is taken during the Sophomore year. It focuses on the relationship between Catholic Christianity and culture through an approach based on principles of dialogue, development, and community. Texts from the CIT are studied alongside non-Christian sources to show points of continuity and dialogue across cultures.

The third signature (CORE III) course, "Engaging the World," is offered to Juniors and is discipline-specific. All instantiations seek to link the general principles of the CIT to the various disciplines. Topics and issues emerging from the first two signature courses find applications within or related to specific academic disciplines. Ideally, the University would like to have one or more CORE III classes in each undergraduate program.

It proved to be fairly straightforward to find a fit between the humanities and the CIT. Examples (all from the SHU undergraduate catalog [5]) include: in the Department of English, Catholic Literature and Film (CORE 3373 / CAST 2422 / ENGL 3422, where CORE is the prefix for the University Core, and CAST for Catholic Studies); in History, Medieval Italy (CORE 3426 / HIST 3234); in Classical Studies, Death and Afterlife in Antiquity (CORE 3300 / CLAS 3300); and in Philosophy, St. Augustine (CORE 3596 / PHIL 3010), all within the College of Arts & Sciences. Additional examples in the College of Communication and the Arts are Music and Theology: Historical Debates within the Catholic Church (CORE 3131 / MUHI 3131), and Propaganda, Religion, and War (CORE 3320 / COST 3101).

In the social sciences, contrasting and integrating the standard academic perspective with Catholic Social Teaching [8] and its classical and CIT antecedents, offers natural prospects, including Philanthropy and Christianity (CORE 3641 / POLS 3696), in Political Science; Roman Catholic Mystics: Anthropological Approaches (CORE 3792 / ANTH 3304), in the Department of Sociology, Anthropology and Social Work; and Neuropsychology of Religious Expression (CORE 3670 / PSYC 3695) in Psychology.

Other courses have been developed by the University's professional schools. The School of Diplomacy offers Religion, Law, and War (CORE 3851 / DIPL 3851); the College of

Nursing, Religious Values in Healthcare (CORE 3910 / NUTH 3020); the School of Business, Global Business (CORE 3101 / BINT 3001); and the College of Education and Human Services, Leadership through Service Learning (CORE 3881 / CPSY 3105).

3. STEM CORE CLASSES

While the development of CORE III courses in fields such as literature, history, classics, and political science was somewhat straightforward, the development of STEM course classes required some additional consideration and often some creativity. On the other hand, such a course can fit well with calls for integrating the arts and humanities into STEM (the STEAM movement [9]) and the need to address ethics, social concerns, and human factors in the preparation of STEM professionals (compare [10]).

Ethical issues in biology and healthcare (related to, for example, environment and ecology, birth and death, human sexuality, and genetic engineering), or historical interactions between science and religion (such as the nature of the universe) offer possibilities in the life and health sciences and in physics. Ecology and Stewardship (CORE 3243 / BIOL 3243), in the Department of Biology, is an example in the first category, and Creation and Science, discussed in Section 4, is an example of the second.

For other courses across the sciences, however, the trick is to present the topic with reasonable depth without requiring substantial prior background in science and mathematics. This would certainly be a problem, for example, for a possible course on Theology and Quantum Theory, and is in general a difficulty in the formal and natural sciences—Physics, Chemistry, Mathematics, and Computer Science. Discussion below offers a precis of a course in each of the latter three disciplines, and shows both difficulties and opportunities.

Chemistry: Science and Theology of Food

(Note that this section is largely based on the discussion in [11].)

The best approach in chemistry, in contrast, has been to find an area of applied chemistry with echoes in the CIT and if possible other areas, and with an appeal to the general population, but not covered explicitly in the Chemistry major. Food and drink is a natural match, with echoes not only in the Christian Eucharist and other religious traditions, but throughout literature, culture and society, and historical events. The resulting course, Science and Theology of Food (CORE 3252 / CHEM 3550 / THEO 3515) is currently being offered by the third author (Fr. Buonopane) through the Department of Chemistry and the Catholic Theology undergraduate program in the Immaculate Conception Seminary.

It seeks to answer questions such as “What is food?”, “What is eating?”, “What are the social aspects of eating together?”, and “How does food fit into the philosophical and theological view of being human?” The course examines the integration and interaction of the scientific, ecological, theological, social, cultural, and ethical dimensions of food. Topics include: risk-benefit issues such as food additives or genetically-modified foods; Biblical perspectives on food and on food aid; the Holy Eucharist and other religious rites involving food in an actual or symbolic way; food taboos, fasting and feasting; social connections and obligations involving food; diets and food addictions; hunger and malnutrition; food coping mechanisms for stress; and food in literature. For most topics, readings will be taken from scientific, social science, philosophical, and theological sources; many will also be supplemented by readings from the literature and with contemporary news and political discussions.

There are six main learning objectives for this course:

1. To communicate well the relationship between reason (science) and faith (theology), as St. John Paul II described the two: “two wings on which the human spirit rises to the contemplation of truth” [12]. Students are encouraged to develop a strong understanding and appreciation of the relationship between science and faith/theology.
2. To demonstrate an understanding of food science, food chemistry and nutritional science, and to apply such knowledge to various food and nutrition topics, including diet and health, food stability and quality, food addictions, and malnutrition and hunger.
3. To formulate a comprehensive framework of food, particularly from a scientific, theological, cultural, and ethical standpoint.
4. To search and critique the peer-reviewed literature on food science and theology.
5. To develop working strategies to improve feeding the poor and hungry, enhance food security and sustainability, and provide better nutritional quality of food.
6. To contextualize critical thinking and theological reflection of food and eating for personal well-being and practical ministry. Develop and identify well-balanced diets.

Student performance in the course will be evaluated by a variety of assignments, including: several writing assignments of 3-4 pages, one of which will be an annotated bibliography on the relationship of food with one of the following: science, theology/faith, social sciences/humanities, culture, or ethics; periodic short quizzes (15-20 min.); a service project and report of their experience at a local food pantry/kitchen; a group oral presentation on a topic of choice primarily relating the scientific and theological (including the CIT) dimensions of food; a cumulative take-home final exam; and class participation.

An example of a writing assignment follows:

> Focusing on the theme of transformation and the relationship between faith and science, what Biblical food passage in the New Testament speaks to you the most? Explain how and why. Address the possible transforming effects of the subject food on you/the human person from both a physical and spiritual perspective. Your response should include a discussion of: 1) the science of the food (particularly its nutritional composition and assimilation in the body) and 2) the food’s Scriptural/theological relevance and its association with the principles of the Catholic intellectual tradition.

Computer Science: Robotics and the Human Mind

Artificial Intelligence (AI), professional ethics, and data science offer viable options related to Computer Science, although the CIT ties often seem either tenuous or tendentious.

However, understanding professional computing, information science and software engineering ethics requires substantial background in computing, while on the other hand, the interaction with the CIT, while substantial, is not deep. Likewise, a course related to data science would likely fit one of three scenarios: either it will be best understood within an application area, or it will address issues of ethics, privacy and intellectual privacy, and have somewhat of the same problem as a professional ethics course, or it will require discipline-specific prerequisites. However, as the field evolves, approaches to viable core courses in Data Science may emerge.

Artificial intelligence raises some interesting questions, the most obvious of which is of course the prospect of a sentient computer or computer-based system. AI also impacts Catholic Social Teaching via issues such as automation and the dignity of work, expert system decision making without human intervention, and (in the future) cyborgs with not only artificial hearts or kidneys but also partial robotic brains.

The first of these, artificial sentience, has clear overlaps with the Brain-Mind-Soul question, both in philosophy and theology, and in cognitive science and psychology.

Robotics and the Human Mind (CORE 3490 / CSAS 3085 / PSYC 3698) leverages faculty expertise in the Department of Mathematics and Computer Science and in the Department of Psychology. The course explores the relationship between Catholic theological investigation and scientific exploration on the question of what it means to be human, and the current state of artificial sentience. The theoretical discussion is accompanied by physically constructing and programming a variety of robots.

Mathematics: Logic, the Limits to Knowledge, and Christianity

(Note that this section is largely based on discussion in [13].)

Finding an appropriate mathematics course faced three challenges. First, mathematics curricula are almost inherently hierarchical, and a junior-level course without mathematical prerequisites seemed hard to justify. Second, modern mathematics is largely a creation of the 17th through 20th centuries and does not directly dealt with issues of significant theological or religious concern. Thus, third, it would seem difficult to find an area of mathematics that could be naturally and easily related to the questions of the CIT.

The solution to this dilemma arose organically when the second author began discussions with colleagues about logic, reasoning, unsolvable problems, and the need for logic to be placed in a wider context, while the first author was teaching courses in the Department of Mathematics and Computer Science, the Department of Systematic Theology, and the Department of Catholic Studies.

The first realization was that logic offered an opportunity to interweave history, philosophy, and theology. The philosophical logic of Aristotle and his successors has had a long and substantial influence on Catholic and other Christian theologians and philosophers. Since before St. Thomas Aquinas and through the present day, Catholic thinkers, especially clergy, have contributed to its development in Europe since at least the 11th century.

Second, it was realized that, although all junior mathematics and computer science majors will have seen logic in discrete mathematics or computer architecture, and many other students will have taken a philosophy course in Logic or Symbolic Logic, there were no advanced courses in logic. This presented an opportunity for an advanced course in a major area in mathematics in which the mathematical prerequisites could remain implicit.

Finally, there is an enormous body of intellectual content beyond simple propositional and predicate logic in the mathematical sciences: in mathematics, sets, relations and functions, plus axiom systems and proofs in linear and abstract algebra; in computer science, reasoning and natural language understanding in artificial intelligence, undecidability and incomputability in algorithms and theory, and the use of logic in databases and in data science, as well as the use of temporal and modal logics and abstraction in the analysis of program specification and design, and of the correctness of computer programs. Moreover, both directly and through mathematical modeling, computing, and more recently data science, logic and its extensions have had a major impact on the sciences, social sciences including economics, and even the humanities.

Further, setting the course in the context of logic and philosophy would allow discussion of the nature of mathematics, logic and science, and their relationship to language, philosophy, and reality. This provided not only the disciplinary content we needed, but also opportunities to relate the course material to the experience of the students, and to encourage the internalization and integration of concepts from the course.

Course content was guided by these reflections, beginning with historical development—Greek, Islamic, and Christian—and the relation of logic and natural language, looking at formalizations and extensions, exploring its use and generalizations in artificial intelligence and data science, and ending with limitations, inherently logical (Gödel and Turing), systematic (Arrow and cellular automata), and scientific (quantum theory, chaos, and second-order cybernetics). Interactions with the CIT were considered throughout, beginning with the medieval philosophers and Thomas Aquinas, through the Renaissance and Enlightenment, to the Neo-Thomists, Stanley Jaki, and Bernard Lonergan. More detail can be found in [14].

4. CREATION AND SCIENCE: A CASE STUDY

Creation and Science (STHO 6585 / CAST 3003 / CORE 3983 / THEO 3585) is a unique course that seeks to deepen a student's understanding of the relationship between the Catholic theology of creation and contemporary empirical science. Its development was funded by the Science in Seminaries program funded by the John Templeton Foundation and coordinated by scholars at John Carroll University. Topics covered include the birth of science, the historical-

philosophical environment of this birth, the interventions of recent Popes on the issue, the specificity of the cosmos as shown by current science, the unity of the cosmos and its beauty, the importance of philosophical realism, the doctrine of creation *ex nihilo et cum tempore*, the theory of the Big Bang, the theory of evolution, the role of contemporary mathematics in the natural sciences, the fundamentals of climate science and ecology, and the relationship between theological anthropology and modern psychology.

Inspired by the extensive historical research of Fr. Stanley Jaki, O.S.B. (1924 – 2009), [15], this course shows how early Christian thought built upon the accomplishments of Jewish, Greek, Roman, Egyptian, Islamic, Chinese, Indian, and Mesopotamian insights into the natural world and how modern empirical science emerged. It also shows how the development of empirical science in Europe is the direct result of the fruitful dialog of Aristotelian metaphysical and epistemological insights and the Christian doctrine of creation *ex nihilo et cum tempore*. It references the Old and New Testaments, the proceedings of Ecumenical Councils, the writings of pre-Christian civilizations in Mesoamerica, India, Egypt, China, Mesopotamia, Greece, Rome, and the Arab world.

There are five main objectives for this course:

1. To introduce students to the history of the development of the natural sciences.
2. To explicate the Christian theology of creation.
3. To communicate the Papal Magisterium of the 19th, 20th, and 21st centuries on creation and science.
4. To clarify the structure of the scientific method and its relationship with method in theology.
5. To introduces the fundamentals of big bang cosmology, Biblical cosmology, the theory of Evolution, climate science, and psychological theories of personality.

Before each class, students are assigned a reading from a scientist, philosopher, or theologian relevant to the class topic such as Charles Darwin, Viktor Frankl, George Coyne, Michael Heller, Stanley Jaki, Paul Haffner, John Paul II, Benedict XVI, and others. The lecture experience is enhanced by guest faculty from a variety of disciplines. In a the most recent offering of this course, students had the opportunity to learn from mathematician Carlo Lancellotti, chemist Gerald Buonopane, physicist José Lopez, and Biblicist James Platania.

A key philosophical issue emphasized in Creation and Science is the role of "moderate realism," a crucial component of Aristotle's epistemology. The approach of moderate realism "declares that there are universal concepts representing faithfully realities that are not universal." [16] That is, universals exist insofar as they are instantiated in specific entities, e.g. "bird" is a valid universal as it is instantiated in the various animals that exhibit "birdness." Moderate realism may be placed on a spectrum between exaggerated realism and nominalism. Exaggerated realism "holds that there are universal concepts in the mind and universal things in nature" [16] as suggested by Plato's ideal forms. On the other hand, nominalism "denies the existence of abstract and universal concepts, and refuses to admit that the intellect has the power of engendering them." [16]

Moderate realism is an important foundation both for the Catholic theology of creation as well as the philosophy of science. It

1) affirms universal concepts – against nominalism;
2) affirms that reality extends beyond that which empirical science can measure – against positivism and empiricism;
3) affirms the value of the scientific method in se – against the instrumentalism that maintains the merely practical value in the field of scientific research;
4) affirms the objective existence of the external world – against idealism;
5) affirms that reality has meaning – against nihilism; and
6) affirms the unity of being – against existentialism which asserts that related entities are totally disconnected from each other. [17]

The father of Big Bang cosmology, Monsignor Georges Lemaître (1894 – 1866), is given special attention in the course. His writings make clear how physical cosmology studies *change*, and *creation* is not a change. Indeed, as the contemporary British theologian, William E. Carroll, succinctly points out, the fact that the empirical sciences study change "excludes an absolute beginning of the universe from their purview, since such a beginning could not be a change. Any change presupposes some reality which is there to change." [18] Empirical science offers a mathematical description of nature but, as the French historian of science, Pierre Duhem (1861 – 1916) said, "science does not explain." [19] Expanding on this thought, the contemporary Italian-American mathematician, Carlo Lancellotti, stated in an address at Baylor University:

> [Science] does not address the metaphysical question of how the object can be and [how it can] be formed. Rather, in Scholastic terminology, science only knows the object *qua* a certain aspect of its being. This is where trouble can begin, if the abstraction is not recognized as such and claims to exhaust the intelligibility of the object. [20]

Another significant scholar in the Creation and Science course is Pope Emeritus Benedict XVI (Joseph Ratzinger). In his theological writings, e.g. [21], one finds an exceptionally clear articulation of Christian thought, rooted in a total openness to the full capabilities of human rationality. This reason respects the mathematical structure of the material universe and the method of natural science, while also appreciating the metaphysical aspects of creation and Creator. Through his further development of the theology of creation and charitable dialogue with philosophers and scientists with differing or no religious belief, the fruitful relationship of the Catholic faith with the natural sciences has been clarified and strengthened. Students from a variety of backgrounds have connected strongly with Benedict's writings.

5. TOWARD A KNOWLEDGE MAP

In light of academic silos, reductionist educational philosophies, and the general fragmentation of knowledge, one may ask if is there a logical way to move toward greater interdisciplinarity, more systemic educational philosophy, and knowledge synthesis? Seton Hall's Director of the Center for Catholic Studies, Monsignor Richard Liddy, suggests that it might be possible to develop a "knowledge map" utilizing the philosophical insights of Father Bernard Lonergan, S.J. Father Lonergan, (1904-1984) was a Canadian philosopher and theologian with a strong background in mathematics as well as classical literature. The map envisioned by Liddy would seek

to provide a way of knowing how the diverse fields of knowledge are related and whether our quest for interdisciplinary communication was headed in the right direction. He goes on to point out how this was the goal of Lonergan's 1957 book, *Insight: A Study of Human Understanding*: "This work aims at 'an insight into insight'—an explanatory understanding of the dynamics of human understanding, that is, the basic 'method' followed by the human spirit at the basis of all other methods…" [22]

Liddy further explains how Lonergan analyzed "the concrete unfolding of mathematical, scientific, and philosophical methods, paying attention, as Einstein cautioned, to what scientists do rather than to what they say they do. In his 1972 *Method in Theology*, Lonergan extended his analysis to scholarly historical methods of understanding and how they can be functionally linked to theological methods." [22] In *Method in Theology*, Lonergan analyzes the dynamics of cognition through the basic levels of experiencing, understanding, and judging. He points out how in scientific research these fundamental stages take place through the processes of experimentation, hypothesis formation, and verification. Lonergan also makes a connection with archival/historical scholarship by identifying the basic processes of research, interpretation, and historical judgment.

For the proposed knowledge map, a key chapter of *Insight* is "The Self-affirmation of the Knower." In it, Lonergan asks readers to reflect on the operations of their own mind and discern whether or not his analysis of the fundamental method of the human cognition, i.e., experiencing, understanding, and judging, is accurate. If Lonergan's method is consistent with reader's own mental operations, Liddy suggests that it may provide "the basis for the integration of all areas of knowing. An accurate account of human interiority as it manifests itself in the various methods employed by the human spirit is the basis for a philosophical vision strong enough to integrate the various scientific and scholarly methods." [22]

We refer here to Lonergan's Generalized Empirical Method (GEM), which Fr. Lonergan describes as "a normative pattern of recurrent and related operations yielding cumulative and progressive results. The GEM is a transcendental method, for the results envisaged are not confined categorically to some particular field or subject, but regard any result that could be intended by the completely open transcendental notions." [23] The GEM calls for an interdisciplinary and collaborative approach to learning.

Fr. Buonopane is a GEM Fellow in the Praxis Program of the Advanced Seminar on Mission at Seton Hall. The program provides practical application of Lonergan's GEM as an effective way to apply the mission of the University to the various disciplines/professions. In the Spring 2016 semester Fr. Buonopane, as member of Cohort IV of the Praxis Program, developed an ATM (Applying The Method of Lonergan) to his work as a professor of chemistry and biochemistry. The ATM title is: "Utilization of GEM in Teaching an Applied Science (Food Chemistry) in Seton Hall's Chemistry and Biochemistry Curriculum."

Because of GEM's interdisciplinary nature it can be applied to various disciplines, those in science as well as in the humanities and arts. In the Spring semester 2017, Fr. Buonopane implemented his ATM in his existing Food Chemistry course (CHEM 4518 / 6518). Thirteen students were enrolled in the course – eight graduate students (6518) and five undergraduates (4518). All of the students were strict chemistry or biochemistry majors. None of the students previously had completed a course in food or nutrition. In addition, none of the students had previously studied Lonergan.

Food chemistry (a subtopic of food science) is an applied and interdisciplinary scientific discipline that draws knowledge from numerous subjects, including food science, chemistry, biochemistry, nutrition, biology, microbiology, physics and engineering, as well as from the social sciences and humanities, such as psychology, sociology, anthropology, and even theology. Thus, the interdisciplinary GEM can be effectively applied to an interdisciplinary subject like food chemistry. After all, food itself is strongly and richly interdisciplinary. The beauty in following the GEM is that it allows individuals to speak across disciplines. For example, the chemist speaks to the food scientist or the food scientist speaks to the social scientist or the nutritionist to the psychologist, and so on.

At the start of his GEM-infused food chemistry course, Fr. Buonopane presented an overview of Lonergan's cognitional structure, i.e., Lonergan's philosophy and language for thinking, questioning, and knowing. The syllabus provided a description of GEM. Following this (and unlike what Fr. Buonopane had previously done with the course when he would jump right into chemical topics of food), he began with a discussion about the interdisciplinary nature of food. "What is food?" "Who studies food?" Something so ubiquitous, we all "know" about food – from eating it, drinking it. We like some foods, dislike others. But, do we truly know what food is and the origins of the enormity and diversity of foods that we see in the marketplace? This basic introduction allowed everyone to begin at the same point.

Throughout the course Buonopane followed GEM activities of experiencing, questioning, understanding, formulating, and judging/deciding. Pertinent questions were asked as the class moved towards judgment. He and the students developed insights, grasped ideas, and formulated concepts and judgments. Images/pictures of foods, food processing equipment, chemical structures, etc., enhanced learning. The class reflected on their insights by assessing the connection between evidence (e.g. research data) and conclusions. The current food chemistry literature was explored and established (believed) concepts were confirmed or refuted. Students learned how they learned, i.e. how they came to know. Everyone – teacher and student – learned from each other and experienced intellectual conversion. Although the students were novices in the study of Lonergan's GEM, they found it to be a helpful approach in learning.

It should be noted that there is a CORE III course, The Philosophy and Theology of Bernard Lonergan (CORE 3749 / CAST 3749). However, the integration of Lonergan's perspective in other, more discipline-focused courses offers a means of reaching more students, particularly those in technical disciplines, in ways that connect directly to their interests and fields of study.

Finally, there have been important, if somewhat accidental, by-products from development of CORE III courses, both in STEM and across the University. First, it has encouraged a number of cross-departmental faculty collaborations, including

that of this paper's authors, extending beyond course development into research. Second, it has in several cases assisted in and sometimes prompted the development of minors and certificates in Catholic Studies, including the Faith and Science minor dealing with the interaction between STEM and the CIT, for which all of the above STEM CORE III courses are electives. And third, it has resulted in improved student appreciation for general education requirements and the University Core, as students see material from other disciplines integrated with their own interests and fields of study.

6. A GENERAL PROPOSAL FOR INTERDISCPLINARY EDUCATION

The key elements of the four STEM courses profiled above — and indeed of most of the CORE III courses at SHU — are

- The elaboration of the synthetic and analytical content of the first two courses, viewed in a disciplinary or issue-oriented context. At SHU, this is primarily the Catholic Intellectual Tradition and its relation to culture and secular learning from the Classical period through to modern times, but includes additional readings from other faith traditions and relevant readings from other disciplines.
- The integration of serious disciplinary or issue-oriented content, typically with a particular focus, with this body of knowledge, learning and practice.
- An exploration of connections of broad areas of learning, often touching on much of a student's general education curriculum, and their interaction with the both of these.
- Enrichment of a student's education and (ideally) ability to learn, including in a student's major program, through enhancement of habits of thought, of learning, of research and presentation, and of consideration of alternative viewpoints and perspectives.
- Offering opportunities for students to undertake their own reflections, explorations, and integration of content from these three areas, and to use these to modify or enhance their own approaches to learning and to life.

There are two models to consider in attempting to generalize this approach: adapting the three-course or two-course model, or using a single course to meet similar objectives.

The authors firmly believe that the benefits of this approach are best achieved in a two- or three-course model, with the first courses intended to provide content and, to extend a metaphor, plant seeds for trees that will be harvested together with the fruits of other branches of knowledge, in the culminating course. Moreover, even for the single-course model, they believe that the last course should be for upperclass students, who presumably have greater experience and maturity, and in addition a body of disciplinary knowledge, rather than freshmen or sophomores. From experience, students are astonished when they find that the isolated, "siloed" information that they have not only fits with but enhances their own discipline and much of the rest of their general education. In contrast, most freshmen lack knowledge or context, and for many of these, the promise that everything will fit together is vague, sounds like much other educational propaganda, and will not be remembered or internalized.

A number of institutions, particularly those with a strong liberal arts focus, require all freshmen to take an interdisciplinary seminar with similar aims, and a very few, such as the University of Chicago [24], have in the past asked all or most students to take a series of "Great Books" or similar courses for the first years of their curriculum. Other institutions require all students to take a capstone course with some interdisciplinary content. Each of these goes some way toward providing a comparable experience, but

- The freshman seminar may be premature for most students at the typical institution, and for that reason does not provide an opportunity for most students to engage in reflection, or to integrate knowledge.
- A Great Books-like program can be too narrowly focused on the humanities, possibly together with the social sciences, and not appeal, for example, to STEM or professional school students.
- Capstone courses that derive from a student's major have a risk of focusing too closely on that major, or on a set of related majors, and focusing too much on career-relevant or research skills, while those that are not closely related to a student's major program or interests are likely not to connect with many of the students.

The key difficulties in implementing a program such as Seton Hall's are two-fold: first, in selecting the focus and content of the initial courses, or in the case of a single course, student preparation for the course; and second, in encouraging departments and faculty to develop proper culminating courses, and in assuring that those courses are designed to meet (most of) the objectives outlined at the start of this section.

It should be clear that a similar program could be implemented at another university affiliated to a religion or denomination with a tradition of scholarship extending beyond religion and theology itself, together with a fairly broad understanding of the nature and content of academic study and debate. Many of the same questions considered in SHU's University Core could be addressed with different (but not completely distinct) sets of readings and reflections in, say, the Anglican, Jewish, or other traditions. A similar statement seems to the authors to hold true for many universities religiously affiliated to non-Judaeo-Christian traditions, but is left for those schools and religions to determine.

The content and the structure will be affected, and the specific questions of interest may vary, but the areas of fundamental concern will largely be the same: ethics, values, responsibility, and community; sentience, cognition, identity, and spirituality; epistemology, learning, and communication; and metaphysics and questions of existence, individual, conceptual, or universal. Most or all of these should be addressed in the initial course(s), and several should be a major focus of the culminating course. In addition, where possible, one or more should be addressed in disciplinary courses (compare to recent calls to include frequent discussion of ethics in the study of computer science or data science [10]).

The same program at a secular university in the United States or Canada, especially a public university, will need to be tailored in a different way, with a set of readings expressing a greater diversity of views. This will most likely result in smaller changes in the culminating course than in the initial course(s), where the difficulty lies in matching these to a purpose that faculty and administrators can endorse, and students can accept, preferably tied to the university mission or a common statement of purpose. Nonetheless, religious, theological, and philosophical readings are important to many

possible topics, and a course that omitted or downplayed these would be incomplete.

In the developed world, and much of the developing world, outside the USA and Canada, there are several additional challenges and one compensation.

The main challenge is that secondary education, access to which is often limited, has greater disciplinary content, to the extent that a high school diploma (or local equivalent) is often the equivalent of a US Associate's two-year degree, so that a university degree often has very little in the way of general education requirements, and more in terms of disciplinary content, offering fewer opportunities, especially for the initial courses described above. (In some countries, there may be a general education requirement for courses in local history and/or religion, or courses in English as the language of business and scholarship, but these most often also offer little opportunity for such a program.)

Another, although this appears to be changing, is that relatively few undergraduate classes are conducted in an open, interactive, and exploratory mode. Alternatively, as in Great Britain and some other countries, interaction may occur in individual (as opposed to group) tutoring sessions, eliminating student-to-student interaction, and—depending on the tutor—even exploratory interactions between student and tutor.

On the other hand, most developed countries do not have the same narrow view of the use of religious and theological works as seems to pertain in most American public institutions, and issues including ethics, individual existence, and the nature of the universe can be addressed with both secular and religious perspectives.

7. CONCLUSIONS

A program is presented for interdisciplinary STEM education that allows a student to build on and integrate their disciplinary knowledge, general education, and a focus developed in specified previous courses. The four courses profiled here illustrate how a CIT-focused interdisciplinary approach can be integrated into a serious upper-level course even in the formal and natural sciences. The structure and content of each course, and the route taken in its development, reflect both the nature of the discipline and the background and interests of the developers. Nonetheless, there are strong commonalities in their interactive and discursive style, a focus on the "big questions," and an emphasis on concepts and reflection.

The result, from the authors' experience, is a deeper student comprehension of their own disciplines and the role of their liberal arts education, better understanding of the role and purpose of technical language and its meanings, improved ability to learn, think, integrate, and present, and more awareness of some of the great philosophical and theological issues and questions.

While the program originated as a way of including a required exposure to the Catholic Intellectual Tradition for all Seton Hall University undergraduate students, it has also offered, in STEM, at least, an opportunity to move instruction and understanding from STEM to STEAM. One can expect, based on student feedback and instructor observation, this integration of disciplines to result in better modeling, design, and solution of problems in the formal, natural, and health sciences, embracing as appropriate philosophical and social concerns, such as ethics and issues of privacy.

In addition to its impact on students, collaboration in the development or teaching of these courses have created or enriched faculty and department connections, and have led to collaborative research and publications. We will consider use in the future of additional faculty guest speakers or discussants to increase and enhance these cross-disciplinary connections.

Through its influence on both students and faculty, theses CORE III STEM courses, can start to address C. P. Snow's concerns [25] of an increasing gap between the humanities and social sciences on the one hand, and (modernizing) STEM fields on the other, and to bridge "the gap of mutual incomprehension," at least by sensitizing STEM students to connections with philosophy and theology, the other humanities, and the social sciences including economics. In the process, a possible new intellectual and academic gap, between researchers in and practitioners of the mathematical sciences [26], may be in part ameliorated or avoided through broader understanding by the mathematical scientists.

As with many other institutions, Seton Hall will also seek to bridge the gap in the other direction. Efforts and plans across the nation and the world are based on developing STEAM-based instruction for primary and secondary grades, encouraging students to develop coding and information expertise, and creating courses and programs in the Digital Humanities and in Data Science/Big Data that involve students from the humanities, the arts, the social sciences, and the professional schools. However, at Seton Hall, these efforts are strengthened by the University Core program, and in particular its CORE III classes, and by offerings such as the minor in the Faith and Science offered by the Catholic Studies program.

While this program was developed at a Catholic university, and relies on the Catholic Intellectual Tradition as its underlying matrix, the structure provides a template that can be adapted to many other situations, deepening the education of STEM students, and their preparation for career and life.

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9. REFERENCES

[1] J. Turner, "The Catholic University in Modern Academe: Challenge and Dilemma," **Catholic Education: A Journal of Inquiry and Practice**, Vol. 1, No. 3, 1998, p. 255.

[2] R.T. Allen, "Reductionism in Education," **Paideusis**, Vol. 5, No. 1, 1991, p. 20.

[3] S. Blackburn, "Scientism," **The Oxford Dictionary of Philosophy**, Oxford: Oxford University Press, 2005, pp. 331–32.

[4] R.T. Allen, pp. 22-23.

[5] "Seton Hall Undergraduate Catalog," Retrieved September 5, 2017 from https://www.shu.edu/academics/upload/Undergraduate-Catalogue-2016-17.pdf

[6] "Seton Hall University Mission Statement," Retrieved September 5, 2017 from https://www.shu.edu/mission.cfm

[7] "About the Seton Hall Core Curriculum," Retrieved September 5, 2017 from https://www.shu.edu/core-curriculum/about.cfm

[8] United States Conference of Catholic Bishops, "Catholic Social Teaching," Retrieved September 5, 2017 from http://www.usccb.org/beliefs-and-teachings/what-we-believe/catholic-social-teaching/.

[9] A. Jolly, "STEM to STEAM: Do the Arts Belong?", **Education Week Teacher**, Retrieved September 5, 2017 from http://www.edweek.org/tm/articles/2014/11/18/ctq-jolly-stem-vs-steam.html.

[10] B. Friedman and P.H. Kahn, Jr., "Human Values, Ethics, and Design," **The Human-Computer Interaction Handbook**, Julie A. Jacko and Andrew Sears, eds., Hillsdale: L. Erlbaum Associates Inc., 2002.

[11] G.J. Buonopane, T.J. Marlowe, J.R. Laracy, "Development of an Integrated Course in Science and Theology of Food: Nourishment for Body, Mind, and Soul," **The Seminary Journal**, submitted August 2017.

[12] John Paul II, **Fides et Ratio**, Vatican: Libreria Editrice Vaticana, 1998.

[13] T.J. Marlowe, J.R. Laracy, "An Integrated Course in Logic, Philosophy, History, and Theology: Extensions of Logic and the Limits to Knowledge," **Proceedings of WMSCI 2017**, Orlando, FL USA, July 2017, pp. 349-354.

[14] T.J. Marlowe, J.R. Laracy, "Logic as a Key to Interdisciplinary Integration", **Journal of Systems, Cybernetics and Informatics**, submitted September 2017.

[15] S.L. Jaki, **Science and Creation**, Lanham: University Press of America, 1990.

[16] M. De Wulf, "Nominalism, Realism, Conceptualism," **The Catholic Encyclopedia**, New York: Robert Appleton Company, 1911, Retrieved September 5, 2017 from http://www.newadvent.org/cathen/11090c.htm.

[17] P. Haffner, **Mystery of Creation**, Leominster: Gracewing, 2010, pp. 2-6.

[18] W.E. Carroll, "Creation, Evolution, and Thomas Aquinas," **Revue des Questions Scientifiques** Vol. 171, No. 4, 2000, Retrieved September 5, 2017 from http://www.catholiceducation.org/articles/sc0035.html.

[19] P. Duhem, **Le Systeme Du Monde: Histoire Des Doctrines Cosmologiques De Platon a Copernic, vol. I**, Paris: Librarie Scientifique A. Hermann et Fils, 1913.

[20] C. Lancellotti, "Science, Contemplation, and Ideology," **Proceedings of The World and Christian Imagination Conference**, Baylor University, Nov. 9-11, 2006, p. 5.

[21] J. Ratzinger, **In the Beginning**, London: Burns & Oates, 2013.

[22] R. Liddy, "Bernard Lonergan On A Catholic Liberal Arts Education," **Catholic Education: A Journal of Inquiry and Practice**, Vol. 3, No. 4, 200, p. 523.

[23] B.J.F. Lonergan, **Method in Theology**, Toronto: University of Toronto Press, 1971, pp. 13-14.

[24] "Great Books Program (College)," **Wikipedia**, Retrieved September 5, 2017 from https://en.wikipedia.org/wiki/Great_books.

[25] C.P. Snow, **The Two Cultures**, New York: Oxford University Press, 1998, pp. 3-4.

[26] T.J. Marlowe, "Has Informatics Changed the Intellectual Landscape? A Reflection on Siloing and the Mathematical Sciences", **Journal of Systems, Cybernetics, and Informatics**, submitted September 2017.