

# Interdisciplinary Computing: An Epistemological Examination and Proposed PLOs

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## Abstract

The increase in the number of institutions offering degrees in interdisciplinary computing raises a set of questions at the epistemological level. A set of questions is raised: is any integration of computing with some other field a representation of interdisciplinarity? What are the limits of enabling? What are the requirements of integration? Does the product of interdisciplinary computing remain computer science? These questions are urgent and answers should be provided especially that the number of such degrees is increasing accompanied by a growing demand on these jobs, as reflected on jobs and opportunities websites. A definition for interdisciplinary computing is needed. This paper attempts to answer these questions based on the huge literature available on interdisciplinarity in general, and interdisciplinary computing in specific. Special reference to career opportunities will be made. The study will be completed using document analysis examining the related documents as the data source of a qualitative research. A phenomenological study will be used to understand the meaning different schools are appropriating to interdisciplinarity. Enough documents will be consulted to extract the common themes and build a sufficient data set of emerging themes to validate the findings. While the phenomenological study aims at describing the essence interdisciplinary computing, grounded theory methods will be used to formulate a definition. As a result of this study is expected to better inform on the design and understanding of how different schools are managing their offering. Some explanatory, exploratory, or descriptive case study involving multiple types of data sources will be explored to acquire a deep understanding and provide support of the findings. The paper concludes with a proposed set of PLOs for interdisciplinary computing and reflecting its educational aspects and respecting technical norms.

**Keywords:** interdisciplinary, computing, epistemological, examination, PLOs

## 1. Introduction

The 21<sup>st</sup> century carried a change in the definition of knowledge and its dissemination. Consequently, the content of students' learning and the corresponding processes had been revised. Higher education had to acknowledge that enough knowledge lies outside traditional structures and it should be sought. Accordingly, it had to respond to its external environment without destroying its existing structures. This endeavor brought the concept of interdisciplinarity that requires working with knowledge from multiple disciplines, interacting with knowledge from different branches and its integration. This concept contributed to the production of a huge literature. Despite the relatively not short history, confusion still exists between interdisciplinarity and multidisciplinary, especially that university curricula are commonly structured by academic disciplines. Tasks like developing interdisciplinary courses, sustaining interdisciplinary initiatives, and financing interdisciplinary programs are difficult specially that faculty members in general stand more at ease in their respective disciplines and norms.

It is agreed upon that interdisciplinarity requires working with knowledge from multiple disciplines, interacting with knowledge from different branches and its integration. This concept contributed to the production of a huge literature. Despite the relatively not short history, confusion still exists between interdisciplinarity and multidisciplinary, especially that university curricula are commonly structured by academic disciplines. Tasks like developing interdisciplinary courses, sustaining interdisciplinary initiatives, and financing interdisciplinary programs are difficult specially that faculty members in general stand more at ease in their respective disciplines and norms.

In the case of computing education this actuality gets more troublesome. The reason for troubles is that many program of studies emerged from the integration of computing in traditional fields of studies. A range of enabled traditional programs appeared linked to different domains of the market, creating a demand for graduates with the field competencies enabled by non-technical computing skills, like computational thinking and systems analysis. At the end, appeared the interdisciplinary computing major. An increasing number of universities and colleges are announcing offering this field by twinning between Computer Science and some other discipline, with sometimes unexpected combinations.

At the epistemological level, a definition of interdisciplinary computing is needed. A set of questions is raised on whether any integration of computing with some other field can be considered as a representation of interdisciplinarity. The concept of computing enabling and its limits also raises questions on what differentiates interdisciplinarity from enabling. The forms and the requirements of integration of disciplines are also subjects to study and attempt to define. Many computing instructors are also concerned on whether the product of interdisciplinary computing remains computer science.

## **2. Interdisciplinarity**

### **2.1. History of the term**

David L. Sills in the International encyclopedia of the social sciences (1986) refers the first use of the term “interdisciplinarity” to the mid of 1920’s. While he clarifies that he could not assure whether the founder of the term was the American Council of Learned Societies or the Social Science Research Council, he assures based on the study of the corresponding archives that The International Union of Academies encouraged “collective researches,” while 1925 Annual Report of the Social Science Research Council asserted that “ordinarily the Council will deal only with such problems as involve two or more disciplines.” As Sills continues in his research, he states that at 1930 Hanover conference, the board of the Social Science Research Council adopted a statement expressing the “Council’s interest will continue to run strongly in the direction of these interdiscipline inquiries.” (A Note on the Origin of “Interdisciplinary”)

The Merriam Webster (n.d.) defines interdisciplinary as “involving two or more academic, scientific, or artistic disciplines”. It states that the first known use of the term “interdisciplinary’ gets back to 1926.

Deriving from this simplified definition is that by Klein and Newell (1998) which is widely-quoted as a definition of interdisciplinary studies: “A process of answering a question, solving a problem, or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline or profession... [It] draws on disciplinary perspectives and integrates their insights through construction of a more comprehensive perspective.”

In addition, a tightly similar definition of interdisciplinary research is offered by the National Academies (2004) and is broadly used: “Interdisciplinary research (IDR) is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice.”

### **2.2. Disciplinarity**

The concept of interdisciplinarity historically depends on disciplinarity. Scholar Louis Menand (2001) considers that “interdisciplinarity is not only completely consistent with disciplinarity - the concept that each academic field has its own distinctive program of inquiry - it actually depends on the concept”.

Studies suggest that each major area of knowledge consists of multiple disciplines that might correspond to some school subject or university major or department. Joe Moran gives a brief definition of discipline as follows: “a particular branch of learning or body of knowledge” (2002, p. 2). While Julie Thompson Klein (1990) offers a more

comprehensive and more popular definition: “The term discipline signifies the tools, methods, procedures, examples, concepts, and theories that account coherently for a set of objects or subjects. Over time they are shaped and reshaped by external contingencies and internal intellectual demands. In this manner a discipline comes to organize and concentrate experience into a particular ‘worldview.’”. (p. 104)

William H. Newell (1998) writes that “understanding the role of disciplines in interdisciplinary studies should be central to a full understanding of interdisciplinarity” (p. 541). This emphasizes the importance of knowing that the two concepts of interdisciplinarity and disciplinarity are strongly linked. This in turn highlights the importance of understanding the emergence of interdisciplinary studies through the formation of involved disciplines.

### **2.3. Multidisciplinarity**

Youngblood (2007) defines multidisciplinarity in a simple way as “what happens when members of two or more disciplines cooperate, using the tools and knowledge of their disciplines in new ways to consider multifaceted problems that have at least one tentacle in another area of study”.

Zaman and Goschin (2010) state that “multidisciplinarity results as a simple aggregation of different disciplines that preserve unchanged their specific perspectives. They share a relationship that is not interactive but rather cumulative and may work together to collaboratively create a more complex image of the reality. The subject of research can better reveal its various features when examined by different perspectives, using the methods and insights offered by several established disciplines.”

### **2.4. The confusion and distinction**

The definitions of disciplinarity and multidisciplinarity were cited above in order to show the difference between these concepts and interdisciplinarity. Although interdisciplinarity depends on disciplinarity it is a wider and more complicated concept in theory and application.

Study of literature shows that the terms multidisciplinary and interdisciplinary are used in many cases interchangeably or confusingly.

Zaman and Goschin (2010) determine the main distinction between multidisciplinarity and interdisciplinarity “in the relationship that the disciplines share: multidisciplinarity simply reunites a range of disciplines independently contributing to the investigation, while interdisciplinarity blends their methods generating new and improved tools, better adapted to the research topic.”

### **2.5. Definition of interdisciplinarity**

Augsburg (2006) states that interdisciplinarity refers to the general phenomenon of combining or integrating disciplinary perspectives.

Klein (1990) offers a more comprehensive definition: “as a methodology, a concept, a process, a way of thinking, a philosophy, and a reflexive ideology. It has been linked with attempts to expose the dangers of fragmentation, to reestablish old connections, to explore emerging relations, and to create new subjects adequate to handle our practical and conceptual needs. Cutting across all these theories is one recurring idea. Interdisciplinarity is a means of solving problems and answering questions that cannot be satisfactorily addressed using single methods or approaches”.

Another definition can also be taken from Rhoten & al. (2009) emphasizing that interdisciplinarity: “as both a process and a practice by which a set of purposive arrangements and a sense of community are established and ultimately integrates ideas with others to form an end product” (Rhoten, O’Connor, & Hackett, 2009, p. 87).

As a conclusion, for the purpose of our study, the adopted definition of interdisciplinarity is as follows: “An endeavor involving more than one discipline to address problems that can not be solved without the integration of the corresponding perspectives, methods and approaches of the involved disciplines”.

### **3. Interdisciplinary Computing**

#### **3.1. Development**

Since 1976, William W. Agresti from the University of Michigan-Dearborn, spoke about computer science as an interdisciplinary study. In a paper presented at the sixth SIGCSE technical symposium on Computer science education, Agresti described the organization of computer science education as an interdisciplinary program tracing the various relationships among disciplines and explaining the features of interdisciplinarity. Among the advantages of this program, he cites a lower cost program, a higher level of adaptation and a better interfacing between computer science and the other areas. Argesti called, at that time, to consider the interdisciplinary approach especially by colleges which want to offer a computer science degree but have limited funds.

Dabu (2017) considers that “in the formation of future specialists, computer science education cannot ignore the reality of a society in which research and technological progress are based primarily on interdisciplinarity and transdisciplinarity”. For Dabu and for other theorists, including the Computing Research Association, computer science contributed in the development of classical sciences while it is evolving. This relation between classical sciences and computer science led to the emergence of new border sciences and the progress of others. Accordingly, there are calls to adapt to this trend and perform computer science education in an interdisciplinary manner. An increasing number of schools are announcing the delivery of interdisciplinary computing programs.

The National Research Council (2011) reports an ongoing debate about whether Computer Science should be introduced as a standalone subject or though an

integrative approach. Deitrick & al. (2017) report a set of national initiatives contributing to the rooting of interdisciplinary computing in the curriculum. They also report that including computing in other subjects reflects professional practice and presents computing as applicable and relevant to learners' interests. In addition, interdisciplinary computing activities are often collaborative in groups.

With the increase in problems scope, computing provides new tools to deal with scale and complexity what makes computing a team challenge. Students working in groups represents an alignment with sociocultural perspectives that highlight the value of participation in communities for learning. On the other hand, collaboration provides career preparation (Deitrick & al., 2017).

In parallel to the development of interdisciplinary computing programs, the volume of the related literature, research and textbooks, is increasing. Volumes on interdisciplinary computer science in this or that language are published, and many textbooks are revised and re-published reflecting an interdisciplinary approach.

### **3.2.Literature review**

Like interdisciplinarity, a variety of definitions are given to interdisciplinary computing and interdisciplinary computer science. In what follows, a set of selected quotations will be exposed taken from offered programs. It is noteworthy that a large number of programs descriptions do not define interdisciplinarity nor the program and go directly to an overview of the content or education process. The term is used to denote a variety of meanings ranging from simple collaboration to integration.

#### **3.2.1 Programs**

- The overview of the Interdisciplinary Computing major at the Trinity College, Hartford, states: "This interdisciplinary major is designed for students who wish to combine the study of computing and computers with another academic discipline. Students can combine the study of computing with traditional academic disciplines, such as physics, chemistry, sociology, or biology, and with emerging fields that involve a substantial computing component, such as bioinformatics, cognitive science, and digital arts."
- (<https://www.trincoll.edu/Academics/MajorsAndMinors/Computer/Pages/InterdisciplinaryComputing.aspx>).
- The learning goals include: developing problem-solving skills, becoming proficient in programming, attaining an in-depth knowledge in computing systems, understanding the fundamental principles of computing, cultivating general intellectual skills in liberal arts education in relation to computing, and gaining a broad exposure to topics in computing and its related disciplines.
- The MIT Course Catalog 2018-2019 lists, under "Interdisciplinary Programs", a set of undergraduate and graduate programs. There is no text that reflect

the MIT view of interdisciplinarity. Among the undergraduate programs, 2 that interest this research: Computer Science and Molecular Biology and Computer Science, Economics, and Data Science. Logging into the corresponding pages, there is no mentioning of the term “interdisciplinary” or any derivative. One description that describes the interdisciplinary approach is the following: “The curriculum provides strong foundations in both biology and computer science and features innovative, integrative, capstone, and elective subjects. The goal is to produce an entirely new cadre of graduates who are uniquely qualified to address the challenges and opportunities at the interface of computational and molecular biology. Students in the program are full members of both departments and of two schools, Science and Engineering, with one academic advisor from each department.”

- (<http://catalog.mit.edu/interdisciplinary/undergraduate-programs/degrees/computer-science-molecular-biology/>)
- The University of Kansas in its 2019-20 Academic Catalog cites a B.S. in Interdisciplinary Computing Program. In the overview of the program, it is stated that students “Graduates will have exercised shared responsibilities through activities such as contributions to multiperson or multidisciplinary technical projects, participation in professional society/organization functions, or performing collaborative research. In all such cases, graduates will have contributed to documentation of the collaborative activities.”
- The Interdisciplinary Computing and the Arts major at the University of California San Diego “draws upon and aims to bring together ideas and paradigms from computer science, art, and cultural theory. The goals of the program are to prepare the next generation of artists who will be functioning in a computer-mediated culture; to give students necessary technical, theoretical and historical backgrounds so they can contribute to the development of new aesthetics for computer media; to prepare students to mediate between the worlds of computer science and technology, the arts, and the culture at large by being equally proficient with computing and cultural concepts; and to give students sufficient understanding of the trajectories of development in computing so they can anticipate and work with the emerging trends, rather than being locked in particular software currently available on the market.” (<https://visarts.ucsd.edu/undergrad/major-req/icam.html>)

### 3.2.2 Textbooks and literature

- Robert Sedgewick and Kevin Wayne, in their popular textbook “Computer Science: An Interdisciplinary Approach” declare that “This book is an interdisciplinary approach to the traditional CS1 curriculum, in that we highlight the role of computing in other disciplines, from materials science to genomics to astrophysics to network systems. This approach reinforces for

students the essential idea that mathematics, science, engineering, and computing are intertwined in the modern world.” (p. xiii).

- The summary on the “Discovering Computer Science: Interdisciplinary Problems, Principles, and Python Programming” book website, it is stated that the book “introduces computational problem solving as a vehicle of discovery in a wide variety of disciplines.” this is achieved by the textbook “organized around interdisciplinary problem domains, rather than programming language features”. The textbook includes “independent projects that encourage students to explore questions across disciplinary boundaries.”
- The “Interdisciplinary Computing In Java Programming” website compares the textbook to other books on computation in the marketplace that tend to discuss the topics within specific fields, while it “introduces readers of different backgrounds to the beauty of the selected algorithms.”

### **3.3. Phenomenological study**

In phenomenology, the aim is “to describe as accurately as possible the phenomenon, refraining from any pre-framework, but remaining true to the essence as seen from the perspectives of the people involved” (Abakpa & al., 2017). The adopted type in this study is the descriptive or hermeneutical phenomenology which “refers to the study of personal experience and requires a description or interpretation of the meanings of phenomena experienced by participants in an investigation” (Padilla-Díaz, 2015). Purposive sampling was used to determine the samples using the self declaration as interdisciplinary as criteria. A list of significant statements was developed from the data, according to Creswell’s phenomenological methodology (2013) using structural analysis.

More emphasis was placed on structural analysis than on textual. Textual analysis deals with the provided description of interdisciplinarity, while structural analysis deals with the interpretation of how interdisciplinarity is expressed by documents.

#### **3.3.1 Significant Statements**

The documents were consulted to extract the common themes and build a sufficient data set of emerging themes, that can be expressed through the significant statements advised by Creswell. These significant statements, extracted through structural analysis, can be grouped into 3 groups:

- Statements on the program:
  - Combining the study of computing with traditional academic disciplines and with emerging fields that involve a substantial computing component
  - Providing strong foundations in both a field and computer science and featuring innovative, integrative, capstone, and elective subjects

- Draws upon and aims to bring together ideas and paradigms from computer science and humanities, art, and cultural theory
- Adopting an interdisciplinary approach to highlight the role of computing in other disciplines, from materials science to genomics to astrophysics to network systems
- Understanding computational problem solving as a vehicle of discovery in a wide variety of disciplines
- Organization around problems involving multiple domains, rather than programming language features
- Including independent projects that encourage students to explore questions across disciplinary boundaries.
- Statements on the enrolled students
  - Students in the program are full members of all the collaborating departments
  - Students stack sufficient understanding of the trajectories of development in computing so they can anticipate and work with the emerging trends, rather than being locked in particular software currently available on the market.
- Statements on the prospective graduates
  - Graduates qualified to address the challenges and opportunities at the interface of computational and other fields
  - Graduates will have exercised shared responsibilities through activities such as contributions to multiperson or multidisciplinary technical projects or performing collaborative research
  - To prepare the next generation of specialists who will be functioning in a computer-mediated culture
  - To prepare students to mediate between the worlds of computer science and technology, the arts, and the culture by being equally proficient with computing and cultural concepts.

#### **4. Grounded Theory**

The techniques for data-gathering and analysis in the grounded theory were designed to allow concepts and categories to emerge from the data. Data is approached without preconceptions to avoid imposition of meanings. The aim is to produce theories that are truly grounded in the data that do not depend on any external concept. Potential knowledge is to be captured by taking a positivist approach to knowledge production.

Grounded theory merges the processes of data collection and analysis in order to achieve theoretical saturation. As a result, there is no fixed series of steps to be followed. (Charmaz, 2006, p. 101)

#### **4.1. Grounded theory justification**

Since this study is based on a document analysis. The research started from the lack of a fixed definition of interdisciplinary computing but progressively evolved throughout the research process to open the way to more research questions. The cyclical nature of the method serves well since the aim is to define. So, it was possible to start the readings, proceed to extracting the significant statements, work generalization of the statements, then derive a definition of interdisciplinary computing.

#### **4.2. From phenomenological study to grounded theory**

The use of both phenomenological study and grounded theory in this qualitative research is highly compatible with the paradigm from which the research evolved, which is interdisciplinarity.

The similarity between the two approaches, especially at the goal and product levels made it also possible to use a combined methodology. The goal of phenomenological study is to describe the meaning of the lived experience of a phenomenon, while the goal of grounded theory is to develop an explanatory theory of the basic processes. The product of phenomenology is a thematic description of the pre-given “essence” and structures of lived experiences, while that of grounded theory is to generate theory from the range of the participants’ experience.

### **5. Definition of interdisciplinary Computing**

Interdisciplinary computing is a field of study combining the study of computing at least one other academic discipline, being traditional or emerging, that involves a substantial computing component. This study provides a strong foundation in both fields featuring innovative, integrative, capstone, and elective subjects, bringing together ideas and paradigms from both fields, adopting an interdisciplinary approach to highlight the role of computing in the other disciplines. The program supports understanding computational problem solving as a vehicle of discovery in a wide variety of disciplines and is organized around problems involving the involved domains, rather than programming language features, through independent projects that encourage students to explore questions across disciplinary boundaries.

Administratively, students in the program are full members of all the collaborating departments in order to stack sufficient understanding of the trajectories of development in computing and develop the ability of anticipating and working with the emerging trends, rather than being locked in particular software available on the market.

Graduates of interdisciplinary computing programs are qualified to address the challenges and opportunities at the interface of computational and other fields, and to mediate between the worlds of computer science and the other fields. Their background should prove them exercised in shared responsibilities through activities such as they have contributed to multiperson or multidisciplinary technical projects or performed collaborative research. Those graduates are the next generation of specialists who will be functioning in a computer-mediated world.

## 6. Proposed Program Learning Outcomes

As an application of the definition adopted above, the following set of program learning outcomes of a typical interdisciplinary computing program is proposed. The mapping exercise should take into consideration the specific characteristics of the non-computing disciplines involved in the program.

- The integration of knowledge and modes of thinking drawn from at least 2 disciplines: Computer Science and the other twining discipline(s)
- Producing an interdisciplinary understanding of a complex problem or intellectual question
- Engaging in experiential learning in prospective career or academic field by serving effectively in some internship
- Demonstrating advanced critical thinking skills at levels required for effective performance in professional and other social or cultural contexts
- Demonstrating advanced communication skills (written, spoken, computer-assisted) at levels required for effective performance in professional and other social or cultural contexts.

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