Mind and Machine: Interdisciplinarity

Daegene Song

ABSTRACT

As the world becomes more sophisticated and socio-economically complex, interdisciplinarity (collaboration among two or more disciplines) has become ever more important. In particular, in the field of education, interdisciplinarity is known to enhance creativity and the capacity of people to work together. However, some drawbacks, such as the lack of solid expertise in one specific discipline, have also been exposed. A simple and efficient way of implementing an interdisciplinary study is reported to be one that combines areas that are computable (i.e., science and engineering) and non-computable (i.e., emotions or abstractions often found in the arts and humanities). This approach has been verified in studies conducted in the last four years on mostly first- and second-year undergraduate students with different majors, with close to 1,000 participants, and has successfully shown to yield diverse mixing between different disciplines, with approximately 300 different outcomes. This particular approach to interdisciplinarity is easy and simple to implement, yields different interconnections among various disciplines, exhibits clear measures of success, and can be done along with expertise training in a traditional field.

Key Words: Computable, Non-computable, Interdisciplinarity

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Introduction

The importance of interdisciplinary studies is well known in academia (Lattuca, 2001; Van Noorden 2015) (also see (Dreyfus *et al.,* 2014; Lindsey, 2014)). Numerous cases have had fruitful outcomes resulting from collaboration among two or more traditional disciplines. For example, recent success in quantum information processing (Veldhorst *et al.,* 2015) has resulted from collaboration among multiple disciplines, including quantum physics and computer science. Indeed, this collaborative effort has provided completely new and efficient ways of processing information, such as quantum computation (Deutsch, 1985) and quantum cryptography (Bennett *et al.,* 1984).

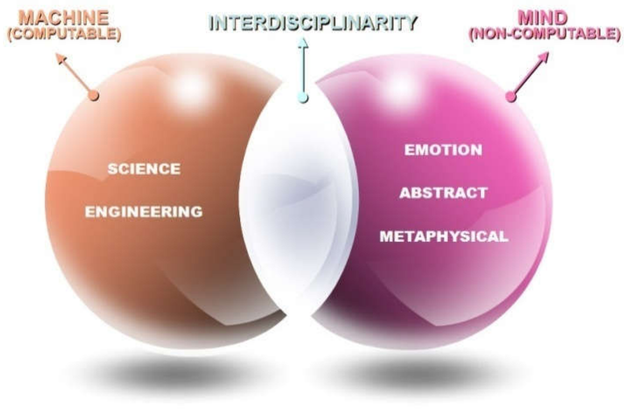

Figure 1. Interdisciplinarity between areas of inquiry that are computable (science and engineering) and non-computable (emotional, abstract, or metaphysical elements, which are often found in disciplines such as music, the humanities, etc.). This approach yields a simple and diverse way of interdisciplinary education. Moreover, it can be done as a complementary approach to training in a traditional field of study.

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In particular, in education, it is widely believed that interdisciplinarity is strongly associated with creativity (Rhoten *et al.,* 2006; Brown *et al.,* 2015). For instance, while someone trained in one particular field is often not able to see outside the box, an outsider may find an undetected opportunity in the traditional field. While the creative idea often resulting from interdisciplinarity can be useful, this may work against interdisciplinary studies as well. One of the weaknesses of interdisciplinarity involves the possible lack of competence in one particular field (Rylance, 2015). This is sometimes seen in the case of students with interdisciplinary majors, where they may graduate without solid expertise, which is one of the essential ingredients in college education.

On the other hand, another benefit of interdisciplinarity involves a problem-centered approach (Johnson, 1999; O'Grady, 2012; Ledford, 2015; Brown *et al.,* 2015). That is, with modern real-world problems, a single discipline simply is often not enough to solve them. For example, the goal of sustainable development is to protect the environment while maintaining economic growth (Giddings *et al.*, 2002; Hopwood *et al.*, 2005). This critical and important problem requires collaboration from many different disciplines, such as economics, environmental engineering, ecology, sociology, and so on. While a problem-centered interdisciplinary approach can be useful, its actual implementation in the field of education can be rather difficult. This is because the approach often requires each participant to have thorough pre-knowledge in one particular field. This can be a major obstacle in interdisciplinarity for students who are still in the middle of training. This letter offers an interdisciplinary study that involves different disciplines in producing a creative and useful outcome, with students not necessarily having the prerequisite expertise in one particular field. This can be particularly useful for students in terms of delving into interdisciplinarity while being trained in one particular area of expertise. This could help students to be equipped with both a major, in which they can develop expertise, and with interdisciplinarity, which is the capacity to collaborate with others in different disciplines.

Another problem that is often found with interdisciplinarity is the ambiguity in measuring success. For instance, this is often seen in the case with team teaching, a method where two or more instructors from different disciplines are involved in a single class. While team teaching may provide an excellent way of implementing interdisciplinarity, it may in fact involve two different fields simply put into a single class, often resulting in students with shortcomings in both fields. Thus, a method of interdisciplinarity that is not only easy to implement but also provides clear measurements of the results of mixing among different disciplines will be discussed.

2. The Model

To conceptualize the specific interdisciplinarity model, the notion of computable and non-computable are discussed: In a strict sense, the definition of computable can be discussed using the notion of Turing machines and, in such case, non-computable corresponds to a non-algorithmic process (Turing, 1936; Song, 2007; Goldreich, 2008). However, for our purpose of discussing interdisciplinarity, it is sufficient to assume that by computable refers to something that can be calculated, mathematically modeled, or numerically quantified and predicted. The disciplines that are in this category may include science, engineering, mathematics, and so on. For example, the path of the moon, the mass of a proton, the price of a smartphone, and the economic growth rate may be considered as computable. On the other hand, non-computable items involve abstract, metaphysical, emotional, and other elements that are often found in the humanities or arts. In some sense, the entire world and its associated problems fall into either one of these two categories; that is, everything may be considered either computable or non-computable. This simple categorization connotes one of the great advantages of interdisciplinarity (Fig. 1), as will be discussed.

The interdisciplinary study merging computable and non-computable areas may proceed as follows: As shown in Fig. 2, the project initiates as by first finding a non-computable topic (i.e., a topic associated with emotion or an abstraction). It is often the case that these topics are related with disciplines such as arts, music, or humanities. In the second phase, mathematical or numerical methods are applied to analyze the chosen problem. For instance, one may choose to numerically compare liberal versus conservative political views, mathematical modeling of idealistic versus realistic approaches to various agendas, or an algorithmic evaluation of paintings, music compositions, poetry, or literature. Finally, it is certainly necessary to check the validity of the established numerical and mathematical model based on preexisting data and to modify or update the model accordingly. This procedure is extremely simple, but it requires a lot of imagination and creativity and provides a great opportunity to yield something useful.

3. Implementations and Advantages

From 2012 to 2015, interdisciplinary projects were established by the author at the Korea University of Technology and Education (KoreaTech) and Chungbuk National University. They were performed during mathematics classes, including pre-calculus, calculus, and business statistics, along with lectures on traditional mathematics materials, for mostly engineering and business major students in their first and second years. Approximately 300 projects were initiated, and close to 1,000 students participated. As shown in Fig. 3, the projects involved various disciplines; that is, mathematical and computational methods were applied in fields associated with psychology, movies/media, cuisine, cosmetics, interior design, marketing, and history.

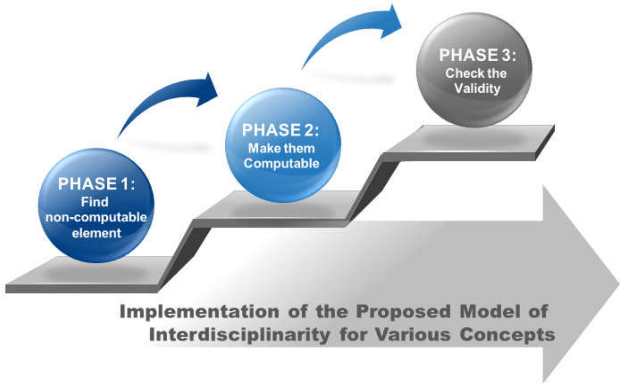

Figure 2. The implementation of interdisciplinarity between computable and non-computable issues may be done by following three phases: First, a non-computable problem is chosen. Second, a mathematical and numerical method is applied to the chosen problem. Finally, the validity of the model is checked based on the previously existing data.

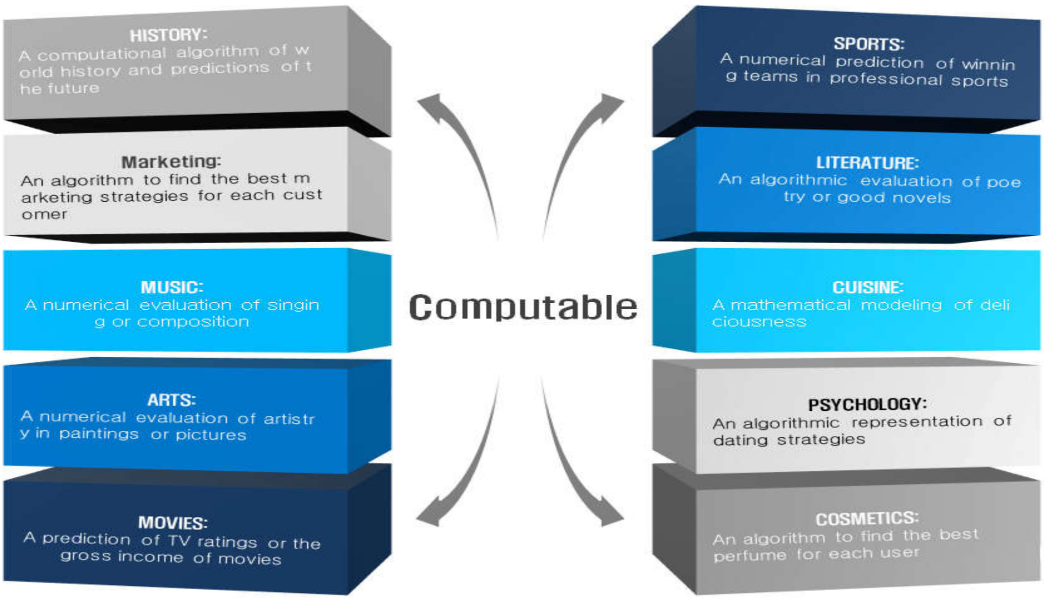

Figure 3. From 2012 to 2015, over 300 interdisciplinary projects were carried out, yielding algorithmic analyses of various disciplines, ranging from humanities to sports.

Figure 4. The proposed model yields the following advantages: It is simple to implement, it results in diverse outcomes, it is easy to measure the success of the actual mixing between two or more disciplines, and it may be applied not only to college but also to secondary school students.

The proposed approach to interdisciplinarity yielded the following advantages (Fig. 4):

Simplicity

One of the difficulties in implementing interdisciplinarity for both instructors and students has been finding a proper interdisciplinary problem. This is because one generally needs a relatively thorough knowledge in multiple fields to present the problem, which is not easy for any instructor or student. However, the proposed approach of interdisciplinarity between computable and non-computable areas provides an extremely simple way of coming up with a problem. For instance, in the last four years of the projects described above, almost all the students were able to come up with their own creative interdisciplinary problems.

One group of students (Seung-Hyung Lee, Kyu-Tae Kim, Kwang-Il Kim, Jae-Hong Min, and Ho-Kyung Shin) seeking first-year undergraduate business majors at KoreaTech decided to numerically quantify the taste of coffee. They were motivated by the fact that people often have difficulties in ordering coffee because there are so many different types. They decided it would be useful to quantify the taste, so customers could anticipate the taste before ordering. They analyzed the taste based on the richness of espresso, water, milk foam, whipping cream, sugar, chocolate syrup, caramel syrup, gelato, and so on. They then applied this analysis to the top ten best-selling coffees, including espresso, americano, cappuccino, and others, and established an ordering process such that the softer and smoother flavors could be predicted. The result in this group was particularly interesting in the way that it numerically analyzed a concept that is often considered to be non-computable, namely, the taste of coffee. The interdisciplinary topic of the coffee taste was simple to find because coffee was familiar to the students. This result can be useful to the customers at the coffee shop such that they can have a wider choice of coffee. Moreover, this may help coffee chains to develop an analytic evaluation of their menus.

Diversity

The proposed scheme yields a very diverse interconnected outcome. This approach has indeed resulted in an interdisciplinary study that may have the most potential to connect previously unthinkable areas. For example, an interdisciplinary study between engineering and mathematics, where both are in the computable category, might be interesting, but there are already many established interconnections between the two, and it would be rather difficult for students to come up with an interdisciplinary problem on their own. A similar story goes with interdisciplinarity among non-computable areas. Although it may be the most difficult area, interdisciplinarity between computable and non-computable could be the most rewarding and has the potential to bear creative and useful outcomes.

It is known that weather affects people's personalities, especially over a long period of time. One can see this phenomenon in regions with different weather conditions, where people often tend to be more outgoing or introverted. A group of computer engineering students KoreaTech (Yong-Suk Lee, Dong-Kyu Kim, Mi-Young Shin, and Gil-Seok Ha) tried to link weather change with people's emotions and attempted to relate this to colors and to cafe interiors. They defined 12 different preferred colors and assigned them to different aspects of weather. They then formulated this result to be encoded in the RGB (i.e., red, green, and blue) spectrum. This analysis was then applied this concept to determine different interior tones. For example, they applied this in the case of optimal interior color for snowy, warm, and cold days. The novelty of this approach was to connect weather, color, emotion, and the optimization of interior design.

Complementarity

As pointed out earlier, one of the most common challenges facing interdisciplinarity is overcoming the problem of implementing an interdisciplinary study without necessarily sacrificing traditional education and expertise in one specific field. The proposed method has been mostly applied to first- and second-year undergraduate students who were pursuing their own majors along as well as interdisciplinary projects. Students with a high school only background or at the first-year college level were able to apply computational techniques to successfully analyze non-computable concepts.

In fact, there is often a misconception that it is better to use more advanced or complicated math or computing methods to analyze non-computable problems. However, using the simplest possible technique for different problems is actually the most effective and efficient approach. Not only is it easy to use, but it is also useful for other people in terms of finding related applications. This is often seen in the history of physics, where extremely simple formulas, such as Newton's three laws, have a huge number of applications.

One group of KoreaTech business students (Ji-Na Kim, Kyung-Hee Yoon, Ju-Hee Lee, and Na-Young Lee) took a college math class as one of the requirements for completing their majors. When given the task of merging non-computable and computable subjects, they thought of social media, such as Facebook or Twitter, and attempted to come up with a way to numerically estimate how active one is with his or her social networking interaction. They searched for possibilities and noticed something called an impact factor, which is often cited in academic journals. They also noticed that an impact factor is associated with a very simple formula. It is so easy that only basic arithmetic knowledge would be needed to formulate it. Similar to an impact factor, they used the number of retweets and tweets and the number of followings and followers to formulate a very simple formula to indicate the activeness of one's social media. They then calculated a social media index for one of the team members and for one celebrity to estimate the validity of the index they had invented. One novelty of this approach was that the students came up with a very simple mathematical equation to estimate something that was non-computable (estimating one's activeness on the Internet).

Measurability

The proposed interdisciplinarity model also presents a clear way of measuring the success of convergence. As noted earlier, it is often the case that interdisciplinarity simply displays two different disconnected disciplines in a single frame, rather than the two being interconnected so as to produce something new, creative, and useful. However, the proposed approach presents a clear way of measuring if the interconnection is indeed being realized. That is, the students and instructors are able to clearly see that something previously non-computable actually becomes computable. This can be advantageous in overcoming the ambiguity that is often seen in interdisciplinary studies.

Can one numerically estimate someone's mood or emotion? This question was asked by the group of KoreaTech computer engineering students (Young-Mi Han, Bong-Woo Cho, In-Soo Choi, and Jong-Hun Park). In particular, they attempted to numerically evaluate the bright and dark aspects of a given piece of music. To do that, they used tempo, time, harmony, pitch, and other measures as variables and came up with a simple formula after a number of trials. They then applied this method to different songs to check the validity of their equation such that it approximated the mood of the song, given the piece of music yielding the affirmative response. This project showed that students were able to clearly measure the success of interdisciplinarity by numerically evaluating the previously non-computable element of the subjective emotion associated with music.

Applicability

Finally, the proposed model is simple and easy enough so that it can be applied at secondary schools as well. In 2014, the proposed program was applied during an interdisciplinarity field trip in Hong Kong for students aged from 10 to 16 years old attending elementary, middle, and high schools. These young students understood the interdisciplinarity model of computable and non-computable concepts well and successfully pursued their own project during the five-day trip. This can be particularly useful in STEAM (Kerr *et al.*, 2008; Connor *et al.*, 2015; Song, 2015), an interdisciplinary education involving science, technology, engineering, arts, and mathematics, which is being implemented in secondary schools around the world. The proposed scheme would correspond to the convergence between science, technology, engineering, and mathematics (STEM disciplines, which are computable) and the arts (A, which is non-computable).

4. Remarks

In this letter, a method of interdisciplinarity mixing computable and non-computable concepts has been presented. In particular, over 300 projects involving close to 1,000 student participants in the last four years have shown that the method is easy to implement, yields convergence among diverse disciplines, and provides clear measurements of actual interconnections. Moreover, interdisciplinarity

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can be implemented while pursuing expertise in traditional disciplines.

It should be noted that interdisciplinarity, as proposed in this letter, bears resemblance to the study of big data (McAfee *et al.*, 2012), which attempts to analyze a large set of data. However, the present proposal differs from big data analytics in that it puts emphasis on simply interconnecting computable and non-computable concepts. Moreover, not much importance is placed on the size of the data set; instead, creative intuition is needed to come up with a clever numerical representation of an element that was previously considered abstract. It is also noted that although the present method describes transforming non-computable concepts into computable ideas, it may also work the other way around. That is, one may adopt various methods to transform computable elements into non-computable ideas.

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