Interdisciplinary Research

Amir Daneshgar

Department of Mathematical Sciences
Sharif University of Technology

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Outline

Disciplines (15th century onwards)

- Julie Thompson Klein (1990)[1]:
  The academic discipline was an invention of the late Middle Ages. The term was first applied to three academic areas for which universities had the responsibility of producing trained professionals: theology, law and medicine.

[1] Interdisciplinarity/History, Theory, and Practice, Detroit: Wayne State University Press.

Disciplines (15th century onwards)

- Joe Moran (2002)[2]:
  This early disciplining of knowledge was a response to external demands, while the specialization into disciplines that emerged in the 19th century was due to internal reasons. By that time science and the pursuit of scholarly and new knowledge had become an institutionalised and highly systematic endeavour. Disciplinarity helped recruiting and producing the specialists that were needed in the context of the industrialisation and the advance of technology.

[2] Interdisciplinarity: The New Critical Idiom, London: Routledge

Disciplines (15th century onwards)

- As society grew in complexity, the social sciences, which tried to emulate the natural sciences, were invented. The consequence was that a whole range of new disciplines were institutionally established in the late 19th and early 20th century, including the main social sciences sociology, anthropology, psychology, political science and economics[3].

[3] The first chair in sociology in Britain was established in 1907; the Royal Anthropological Institute was founded in 1871; the British Psychological Society was founded in 1901; the first chair in international politics in Britain was established at the University of Wales in 1912.

Disciplines (categories)

Joe Moran: Inside the university, the term discipline refers to a particular branch of learning or body of knowledge such as physics, psychology, or history.

There are four clusters or categories of traditional disciplines:

- The natural sciences (biology or life sciences, chemistry, Earth sciences, mathematics, and physics)
- The social sciences (anthropology, economics, political science, psychology, and sociology)
- The humanities (art and art history, literature, music, philosophy, and religious studies)
- The applied professions (business and its subfields, communications and its subfields, criminal justice, education, engineering and its various subfields, law, social work, nursing, and medicine)

Disciplines (characteristics)

A general list of characteristics would include:

- disciplines have a particular object and method of research though the object of research maybe shared with another discipline;
- disciplines have a body of accumulated specialist knowledge referring to their object of research, which is specific to them and not generally shared with another discipline;
- disciplines use specific terminologies or a specific technical language adjusted to their research object;
- disciplines must have some institutional manifestation in the form of subjects taught at universities or colleges, respective academic departments and professional associations connected to it.

Explosion of knowledge

- Please just listen!!

Two versions of interdisciplinarity

- Generalist interdisciplinarians (such as Joe Moran, Lisa Lattuca, Donald G. Richards) understand interdisciplinarity loosely to mean any form of dialog or interaction between two or more disciplines.
- Integrationists (such as Julie Thompson Klein, William H. Newell) stress the priority of integration and are concerned with developing a distinctively interdisciplinary theory-based research process and describing how it operates.

A definition based on integration

- Julie Thompson Klein and William H. Newell (1997):
  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 and drawing on disciplinary perspectives and integrating their insights by producing a more comprehensive understanding.
- Integrationists are especially concerned with the process and product of research, arguing that process determines product. The hallmark of the interdisciplinary research process, they insist, is integration, and the way to achieve integration is to create common ground among disciplinary insights.

Theory of Cognitive Interdisciplinarity

- Cognitive psychologist Herbert H. Clark traces the technical notion of common ground to Robert Stalnaker (1978) who based his notion on an older family of related notions that includes common knowledge (Lewis, 1969), mutual knowledge or belief (Schiffer, 1972). Clark (1996) defines common ground as the knowledge, beliefs, and suppositions that each person has to establish with another person in order to interact with that person.

Theory of Cognitive Interdisciplinarity

- Klein (1990): Drawing on the earlier work of Hursh, Haas, and Moore, advances a 12-step research model resolving disciplinary conflicts by working towards a common vocabulary (and focusing on reciprocal learning in teamwork). The importance of Kleins model is that it particularizes Newell and Greens call for a distinctly interdisciplinary research process that features integration and includes common ground.

Theory of Cognitive Interdisciplinarity

- Newell (2001)[4]: Complexity should be the primary justification for interdisciplinary work and the controversy it continues to stir have overshadowed a second and equally important assertion that has gone largely unnoticed: that creating common ground makes integration possible and that integration is the hallmark of the interdisciplinary research process.
  Newell adopts much of Kleins model of the interdisciplinary process but makes a significant departure from it by adding a new step, creating common ground.

[4] A Theory of Interdisciplinary Studies

Theory of Cognitive Interdisciplinarity

- Recently, the work of integrationists has begun intersecting with research by cognitive psychologist Rainer Bromme (2000) who is applying Clarks theory of common ground to interdisciplinary work. Building on the work of Clark, Bromme develops a theory of cognitive interdisciplinarity. A significant finding of Bromme is that in interdisciplinary communication, differences in common ground are frequently discovered only when the partners of cooperation find out that they use the same concepts with different meanings, or that they use different codings (terms, symbol systems) for approximately the same concepts.

An integrated definition for common ground

- Allen Repko (2008) offers this definition of common ground that attempts to integrate Newells definition with the formulations of Clark and Bromme. Integration is not the end of the interdisciplinary enterprise but the means to achieve it.
- The end or purpose is to produce an interdisciplinary product or understanding of the problem and propose a more comprehensive solution to it. The term interdisciplinary understanding is a construct that integrates the notions of cognitive advancement advanced by Boix Mansilla (2005), a more comprehensive perspective advanced by Klein and Newell (1997), a more comprehensive understanding advanced by Newell (2007).

An integrated definition for common ground

- Common ground is something that must be created, except between the natural sciences where it can often be discovered.
- Creating or discovering common ground involves modifying or reinterpreting disciplinary components (i.e., its defining elements including perspectives, insights, theories, concepts, and assumptions).
- Modifying these components involves using various integrative techniques.

A DEFINITION!

- Allen Repko (2008): Interdisciplinary studies is 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 and draws on disciplinary perspectives and integrates their insights to produce a more comprehensive understanding or cognitive advancement.

Interdisciplinary studies vs. team-work

- Based on the definition, interdisciplinary studies is definitely different from team-work.

Interdisciplinary studies vs. multidisciplinary studies

- This is fruit salad vs. smoothie. Multidisciplinarity refers to the placing side by side of insights from two or more disciplines as, for example, one might find in a course that invites instructors from different departments to explain their disciplines perspective on the course topic in serial fashion but makes no attempt to integrate the insights produced by these perspectives into an interdisciplinary understanding of the topic.
- Joe Moran (2002): Here the relationship between the disciplines is merely one of proximity. There is no real integration between them.

Interdisciplinary studies vs. transdisciplinary studies

- Lattuca (2001): Transdisciplinarity is the application of theories, concepts, or methods across disciplines with the intent of developing an overarching synthesis .
- The contrast between interdisciplinary studies and transdisciplinary studies lies in their differing approaches to the disciplines. Interdisciplinary studies relies primarily on the disciplines for their perspectives, insights, data, concepts, theories, and methods in the process of developing an interdisciplinary understanding of a particular problem, not a class of similar problems.

Interdisciplinary research vs. Interdisciplinary researchers

- Please just listen!!

complexity Science

- Please just listen!!

Measuring researcher interdisciplinarity

- A. L. PORTER, *et.al.*, *Measuring researcher interdisciplinarity*, Scientometrics, **72** (2007), 117-147.

Mathematics & Applications

- Albert Einstein: How can it be that mathematics, being after all a product of human thought independent of experience, is so admirably adapted to the objects of reality?

Mathematics!

- In the 18th and 19th century mathematical language was vague and did not allow much interaction among mathematicians of different fields. In the period 1950's to 1970's mathematicians concentrated around problems of algebraic topology, algebraic geometry and complex analysis and they developed new concepts and new methods. New powerful mathematical tools were developed and the language of mathematics became highly developed and very powerful. This new approach to mathematics resulted in greater abstraction. Mathematicians spent years of apprenticeship in a full set of abstraction before doing their own thinking. Mathematics of the 20th century has started the path for harmonizing and unifying diverse fields. The unification of mathematics started with a common language that has greatly simplified the interaction between mathematicians.

Mathematics!

- In the period l930's to 1970's mathematics became more inward looking, and the distinction between pure and applied mathematics became much more pronounced. In the 1970s, there was a return to more classical topics but on a new level and this resulted in a new convergence between mathematics and physics. The 20th century approach to mathematics resulted in a more developed mathematical language, new powerful mathematical tools, and inspired new application areas that have resulted in tremendous discoveries in other applied sciences. Towards the end of the 20th Century, mathematicians were making a re-think on the need to bridge the division lines within mathematics, to open up more for other disciplines and to foster the line of inter-discipline research. The current cry is that this interaction will be further strengthened in the 21st Century.

Mathematics!

- As a consequence of the new approach to mathematics, pure mathematicians drifted away from applications and saw no need to collaborate with other scientists, even their traditional neighbors, and the physicists. On the other hand, application of the highly abstract modern mathematics could not be easily visualized by the traditional users of mathematics. The period l930's to 1970's saw a divergence within mathematics itself and between mathematics and other applied sciences. Mathematics became more inward looking, and the distinction between pure and applied mathematics became much more pronounced. The diversification of mathematics was first of all connected with external social phenomenon, the rapid growth of the scientific community and the breaking discoveries in physics.

Mathematics!

- In the 1930's the connection of mathematics and other sciences, especially physics was broken. Physicists got interested in solving more concrete problems that could be solved without the application of sophisticated and abstract modern mathematics. The developments of pure mathematics in the post World War II period became weakly connected with applied sciences especially physics. Mathematicians' could not view how physics could assist modern mathematics while physicist could not imagine the application of new abstract mathematical concepts such as sheaf, cohomology, etc. in their fields.

Mathematical physics

- From the beginning of 1970s, there was a return to more classical topics but on a new level. These developments resulted in the new convergence between mathematics and physics. Some modern mathematicians quickly saw new opportunities and challenges hidden in the new physics. Examples of mathematical results that got inspired by physical ideas include (for instance) gauge theory and resulted in the revisit of the Yang-Mills equations of elementary particles, which had been developed by physicists C. N. Yang and R. Mills almost twenty years earlier in 1954. In the 1970's information flow between mathematicians and physicists resumed and led to new and deeper connections between modern mathematicians and physicists.

Computer science (narrow sense!)

- The new approach to mathematics resulted in a more developed mathematical language, new powerful mathematical tools, and inspired new application areas that have resulted in tremendous discoveries in other applied sciences including computer science and computer technology. The new mathematical tools and the developments in computer technology, the development of algorithms, mathematical modeling and scientific computing have led to remarkable new discoveries is physics, technology, economics and other sciences in the last half of the 20th century. This has also enabled mathematicians to use modern mathematical tools to solve deep classical problems left by the previous generation of mathematicians.

Discrete Mathematics

- L. Lovasz (1998): Most of the advances in pure mathematics were propelled by problems in physics. In the last part of the 20th century mathematical analysis and differential geometry were no longer adequate. For example a biologist trying to understand the genetic code will need tools of graph theory than differential equations because the genetic code is discrete. Issues of information content, redundancy or stability of the code are more likely to find tools of theoretical computer science useful than those of classical mathematics are. Even in physics discrete systems such as elementary particles need use of combinatorial tools and statistical mechanics need tools of graph theory and probability theory. Now economics utilizes sophisticated mathematics in operations research such as linear programming, integer programming and other combinatorial optimization models.

Complex systems

- Theory of complex systems is an example of inter-discipline and is the new focus on research in mathematics. At the end of the 19th century, the first source of a general idea of complex systems was research in dynamical systems, in the context of classical mechanics. It is an interdisciplinary approach fueled by sophisticated mathematics, mathematical modeling and computer simulation, inspired by observations made on complex systems in the most diverse fields including meteorology, climate research, ecology, economics, physics, embryology, computer networks and many more. Examples are systems that adapt to changes in their environment in an extremely surprising way. They include Economics (economy of a country), Biodiversity (ecosystem of a pond), Biology (the immune system of an organism) and Artificial Intelligence (Computer Networks).

Probability theory

- Probability theory seems to bridge most of the division lines within mathematics. The importance of probabilistic methods in almost all areas of mathematics is exploding. Probability theory is one illustration of the unity of mathematics that goes deeper than just using tools from other branches of mathematics. With probability theory, many basic questions can be modeled as discrete or as continuous problems.

A QUOTE!

- Michael Atiyah: "Increasingly the complex problems that scientists now face require more sophisticated mathematical understanding. The advent of more powerful computers has in no way decreased the fundamental relevance of mathematics. I can illustrate the scope of mathematical interaction with other fields by listing just a few of the inter-disciplinary programmes that we have run at the Newton Institute in the past few years: computer vision, epidemics, geometry and physics, cryptology, financial mathematics, and meteorology".

Game theory

- Game theory, with roots in mathematics, statistics, and economics, is routinely applied today to understanding and predicting human behavior. Game theory recently played a pivotal role in the design of auctions for third-generation mobile telephone licences in the United Kingdom.

Mathematical finance

- The application of stochastic analysis to the financial industry has resulted in the creation of multi-trillion dollar security markets that have facilitated the international flow of capital and contributed to commerce and productivity. The development of reliable pricing methods for derivative securities that are used for risk management would have been impossible without the application of probabilistic models and stochastic analysis that have been developed over the past thirty years. This is only one example of the many contributions made by probability theory to predicting outcomes in stochastic environments.

Soft computing and data mining

- Data mining, the determination of patterns and anomalies in data, combines statistics with pure and applied mathematics as well as computer science. Analyzing and learning from data will be of increasing importance because the sheer volume of data associated with numerous applicationsastronomy, biology, medicine, geoscience, and atmospheric sciencesis growing at astonishing rates. Predictions abound that rapid, perhaps real-time, analysis will soon be needed for huge data sets.

A QUOTE!

- Finally, there is no field in the foreseeable future where mathematics will have a greater impact than in the life sciences. Four of the eight recommendations of the US report BIO2010, commissioned by the National Research Council, call for closer collaboration on the basis that the connections between the biological sciences, and the physical sciences, mathematics and computer science are rapidly becoming deeper and more extensive.

Some facts!

- The evolution of disciplines and interdisciplinaries is within a dynamical framework of a very complex system.
- New sophisticated interdisciplinary branches of mathematics evolving through this process provide academic chances of mastering and conducting new areas of research.
- This evolution can be controlled and is affected by researchers contributions and the behavior of our scientific community (society).
- It is our responsibility to conduct this process to where we want it to go!

Research assessment

- Research assessment is a very important and critical part of this control that must be conducted through a sophisticated community of leaders.
- The standards of this community naturally controls and and defines the standards of the rest of the society.
- In order to lead the society sophisticated mechanisms of control and conduct must be designed.
- Periodical public research assessments of the society is a mandatory part of this control process.

The End.

Thank You!