"Areas of knowledge are most useful in combination with each other." Discuss this claim with reference to two areas of knowledge.

From education through the IB to research at universities, the combination of AOKs is commonplace. The title stipulates that the combination of AOKs renders them most useful. This essay makes a point to analyse "combination" as a study of multidisciplinarity, which draws knowledge from different AOKs, together with interdisciplinarity, which unifies knowledge and methods of inquiry from different AOKs (Jensenius). Their "usefulness" is measured in their effectiveness in acquisition of new knowledge by researchers in each of the relevant fields, as well as within the combined field. This essay investigates the interdisciplinary nature of mathematics and the natural sciences, while considering the benefits of multidisciplinarity within the human sciences.

Illustrations of strong interdisciplinary research lie within the natural sciences and mathematics, which paves the way for mathematical sciences. When learning about entropy in IB chemistry, which describes the probabilistic tendencies for a system, I realised that the topic did not follow a typical structure. Other topics utilised practical knowledge and chemical theory from natural sciences, while entropy utilised statistical mechanics and probability theory from mathematics. Entropy is a concept created for the natural sciences, but its development is mathematical (Kausik). It indicates that natural sciences follows the scientific method, but regularly borrows tools from mathematics to model scientific systems. The combination of knowledge from natural sciences and methodology from mathematics vastly increases the scope of the AOKs in research and development of scientific theories.

While research in natural sciences has benefited from interdisciplinary work with mathematics, the converse is also true. In conducting my EE, I examined the applications of mathematics in the development of quantum mechanics during the 1900s. Contrary to my initial belief, quantum mechanics made little use of existing mathematical theory, opting to create a new mathematical theory that was designed to support modern research. Eventually, this led to the creation of new fields of mathematics, specifically in linear algebra. Mathematics was initially used to support the construction of knowledge in the natural sciences, but was able to develop novel knowledge structures that could be used in independence. The new theories are now canon in multiple fields of mathematical research, owing to natural sciences. The identical observation can be made with regards to statistical mechanics, which was developed as a formalism for chemical theory, but is used extensively in computer science and probability theory (Kausik). The combination of AOKs precipitated independent mathematical research which would not occur otherwise.

This contrasts with mathematical nominalism which presses for the elimination of all abstract mathematical entities (Goodman and Quine 105). It would posit the premise that mathematics exists only as an extension of physical empirical entities (Horsten). This would imply that mathematical theory can only be developed with reference to physical observations of reality gained through sense perception, effectively reducing mathematics to the interdisciplinary study of mathematical sciences. However, evidence of independent mathematical research suggests that mathematical theory can exist and be developed in isolation, even if it stems from a physical formalism. It implicates that mathematics does not need to exist in combination with natural sciences in order to be useful, but may benefit from intersections of research.

Furthermore, methods of inquiry utilised in mathematics are not always applicable to natural sciences. String theory is an attempt at formulating a grand unified theory of the universe encapsulating classical and quantum mechanics (Ananthaswamy), which has been studied for over 40 years (Woit). In this time, it has lacked experimental confirmation, since the resources available to humanity cannot realistically validate it. The lack of usage of the scientific method with empirically testable conjectures and experimental confirmation has met with critique from philosophers of science and physicists ("A philosopher of science"). The theory ventures to gain merit through the mathematical elegance of its conclusions, detracting from the traditional structure of research in natural sciences. In doing so, it appeals to an aesthetic criteria rather than the scientific method. G.H. Hardy in his book, *A Mathematician's Apology*, describes the usage of an aesthetic criteria in mathematics as aestheticism. He describes mathematical research as the pursuit of elegance within abstract concepts; an art form. While many mathematical schools of thought exist, an element of aestheticism is common in most mathematical research, albeit to varying degrees. It permits for a broad construction of knowledge, as definitions of elegance are subject to interpretation, enabling mathematics to exist as an inherently open and subjective pursuit of knowledge. The intersection of aestheticism with natural sciences in string theory draws the question - can AOKs favour extrinsic methods of inquiry to acquire knowledge? Physicist Sabine Hossenfelder, in opposition of the development of string theory, disagrees: "Why should the laws of nature care about what I find beautiful?" (Lost in Math). This objection claims that truth in natural sciences is independent of a subjective interpretation of elegance and as such, results from testable predictions should guide the direction of research. In other words, the most useful way to conduct accurate scientific research is to restrictively follow the scientific method, which string theory brushes aside. Natural sciences is inhibited when scientific theory relies more heavily upon mathematical methods of inquiry as a result of interdisciplinarity.

Nevertheless, it is notable that interdisciplinarity is not an impediment to mathematical research in this context. Mathematical formalisms and structures are logical truths with an axiomatic structure, without reference to the external world and independent of empirical confirmation or sensory observation. Hence, any mathematical theory developed as a consequence of string theory does not hold value based on the condition that string theory is true. Even if string theory were falsified, the versatility of the mathematical theory involved allows for various future applications and developments as long as an axiomatic system and logical deduction is followed. This implies that an AOK based on irrefutable logical deduction may never be negatively impacted by failures in interdisciplinarity, since any developments from interdisciplinarity will always hold logical truth.

Considering multidisciplinarity between human sciences and natural sciences highlights different types of incompatibilities, with regards to research approach and subject specialisation. Sociologists conducted a study of a multidisciplinary project over several years (Dai and Boos 42), which they concluded was a failure (Dai, "What are fake"). They assigned a project investigating social networks to physicists and sociologists. Immediately, there were clashes in approach. The physicists formulated a hypothesis based on empirical results, having a data-oriented approach (52), whereas the sociologists created experiments designed to test a hypothesis based on existing theory, having a theory-oriented approach (53). The physicists attempted to create a mathematical model of social networks to test with, but the sociologist could not understand the purpose of empirical testing without considering existing theory and formulating a knowledgeable hypothesis (51). Both groups of researchers have an existing understanding of valid approaches towards the acquisition of knowledge within their AOKs, but the approaches are incompatible and the researchers lacked understanding of their peers' perspectives. But what component of AOKs is responsible for a hindrance in multidisciplinary research? This question can be answered by considering the conceptual differences in the theories being applied. The physicists developed a mathematical understanding of the social network as nodes on a graph. The sociologists developed a holistic understanding of the interpersonal relationships in the social network. Each group of researchers made the best use of their prior knowledge and experience to develop an appropriate understanding of the task. This ability can be characterised as the researcher's intuition in their field of work, honed by specialisation. The multidisciplinary approach will fail to effectively acquire knowledge if the intuitions of the researchers are fundamentally different. Be that as it may, it is worth considering that repeated collaboration can help develop a researcher's intuition in the combined field. This is the case with the mathematical sciences, which rarely suffers from the problem of differing intuition and misunderstandings amongst collaborators; combinations have been made easier with time. Through frequent collaboration, researchers in AOKs may develop a shared intuition to improve valuable research output.

Additionally, human sciences holds a unique position of being able to productively inform multiple other AOKs by providing socially aware perspectives. In IB economics, I learnt about the World Trade Organisation (WTO), which uses economy theory and mathematical models to make informed decisions regarding fairness in international trade. I noticed that it treated economics as a mathematical pursuit of optimising economic performance, but it lacked consideration of the social impacts of any decisions. It perpetuates poverty, inequality, and poor working conditions in favour of economic progress. In this situation, it would be beneficial to consider the perspective of human sciences in addition to mathematics, which would increase the efficacy of the WTO's researched decisions. This consideration is broadly categorised as social epistemology, which contextualises the pursuit of knowledge within society (Goldman and O'Connor). It places greater value on knowledge acquired through consideration of social factors (Rimkute 8). Hence, relevant AOKs can be considered in combination with human sciences to extend their scope of inquiry to ethical considerations.

The usefulness of a combination of AOKs is entirely dependent upon the nature of the knowledge structures and methods of inquiry within the combination. Natural science may not always benefit from an interdisciplinary approach due to incompatibilities with the scientific method. On the other hand, mathematics benefits from combinations of AOKs and its irrefutable logical knowledge claims are never disadvantaged either. This places mathematics at a unique position as a beneficiary and occasional contributor to the pursuit of knowledge. Human sciences provided social perspectives which allow it to act as an eternal benefactor to multiple AOKs. Discussion of the title also revealed that intuition is crucial to research within AOKs and collaborative intuition must be developed for effective combinations of AOKs, providing a template for future interdisciplinary research. With proper assessment of the relevant factors in research, AOKs are most useful in combination, but must be monitored for effectiveness.

Word Count: 1594 (excluding in-text parenthetical citations)

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