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Medical Students' Understanding of the Nature of Science

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ABSTRACT

A questionnaire pertaining to the nature of science was distributed to 120 students matriculating into a midwestern medical school. Questions were so designed to understand student's ideas on the nature of science and research, their previous involvement in research, and how they see research playing a role in their lives as future physicians. This study was performed to gain a more accurate understanding of what medical students perceive the nature of science and research is along with possible benefits throughout their careers. There is a division in literature concerning the benefits of research in medical school and its ability to significantly show an increase in student success during and after medical school. We as a community should be actively seeking a deeper understanding as to how medical students perceive research and the nature of science as it may lend insight as to the success research is as a tool to equip students and future clinicians with pertinent cognitive, metacognitive, and critical thinking skills that are a necessity in the medical field. Students and physicians without a clear and complete understanding of the theories behind the nature of science and scientific knowledge may not only fail to be successful physicians but may engage in practices that are not helpful or even harmful toward patients.

INTRODUCTION

Physicians are responsible for taking their clinical knowledge, organizing it in a manner that best suits a patient's differential and diagnosis, providing the most appropriate care, and then repeating the process with a new patient and scenario. It is fundamental that a successful physician have the capacity to do this time and time again. Doctors can achieve this through development of cognitive strategies and critical thinking skills. Successful physicians are also aware of their own cognitive processes, known as metacognition, to better develop higher-order thinking skills^{1,2}. A physician who has honed their cognitive and metacognitive skills is better to adapt and cope with uncertainty and complex cases than one who has not³.

Medical and undergraduate schools understand that development of critical thinking, cognitive, and metacognitive skills are important to become excellent clinicians⁴. Development of these skills help prevent factual overload from inhibiting critical thinking³. Student research and independent studies are often used to help develop these skills in an educational setting as they have had been proven to be an eminent and successful tool^{3,5,6}. The medical community deems research so important as to even use it as a selection criterion by U.S. medical schools.

It is thought that the success of research as a tool to mature critical thinking skills stems from a greater scientific foundation and a deeper understanding of the nature of science (NOS)⁷. The nature of science is ever-changing, and it is common to see scientists disagree on specific issues regarding it but as a general definition, scientists agree that the nature of science refers to the theory of knowledge and is a critical corner stone to our basis on scientific knowledge⁷. It has been shown that when students have a greater understanding of the NOS they begin to improve their ability to ask more investigable questions, switch from asking descriptive questions to cause-and-effect or pattern-seeking questions, and display a greater degree of creativity and subjectivity⁷.

Although a great number of articles pronounce that research is important to help mature these skills to become a successful medical student and future clinician there is literature declaring that students who do conduct research do not statistically do better in the clinical phase of medical school and may have a small, negative association with internship performance⁸. With conflicting literature, it may not be so clear as to how research and maturing an understanding of the NOS benefits medical students during and after medical school. With conflicting literature, inspiration to gain a deeper understanding as to what medical students perceive to be the nature of science and the foundation of scientific knowledge arose.

Our objective of this study was to gain a deeper understanding as to what medical students' conceptions of the nature of science is to help accompany and enrich the vast array of literature that discusses research, scientific knowledge, and the nature of science in the setting of success as a medical student and future physician. Our research question is, "What are medical students understanding of the

nature of science and how do they believe this understanding will benefit their career as a future physician?”

FRAMEWORK

I will be basing my theoretical framework from work previously proposed by Leederman and colleagues and their characteristics of the NOS⁹. There are five characteristics outlined in their work that are detailed in Table 1. It is important for students to understand scientific processes as it plays a crucial role in the exploration of observations. This is not to be confused with the nature of science as it often is among individuals. Although the NOS is intertwined with scientific processes to a certain degree, it is unique as it is deeply rooted in the theory of knowledge, or epistemology. To gain a better understanding as to what medical students believe the NOS to be, we used these characteristics as the standard.

| Characteristics of the Nature of Science | Description |
|---|--|
| Tentative | Subject to change |
| Empirically based | Based on and/or derived from observations of the natural world |
| Subjective | Observations are theory-laden (affected by presuppositions) |
| Product of human inference, imagination, and creativity | Imagination and creativity are used to make sense of observations and provide explanations to interpretations and inferences |
| Socially and culturally embedded | Science shifts to reflect the needs and priorities of society |

Table 1 The five characteristics of the nature of science that is proposed by Leederman.

METHODS

Our surveyed population was a state-funded midwestern medical school in 2018. Our survey was distributed to and collected from first year medical school students in the month of August. The class size was 120 students with 120 students completing the survey. The survey was an assignment given to students from a longitudinal module called Scholarship in Medicine. Scholarship in Medicine is designed to educate medical students on the collection and/or use of data to address questions about biomedical phenomena and how it contributes to the body of scientific knowledge to improve the health of patients

and/or populations. The responses collected from the survey were so interesting that further investigation was conducted.

Our anonymous survey was entitled '*How will understanding of the nature of scientific knowledge and the scientific method impact your future practice as a physician/physician-researcher?*'

Our survey was distributed through Qualtrics. Questions consisted of both closed and open-ended styles.

All students who completed the survey were included in any data analysis conducted during this study.

Data analysis was not begun until all data was collected. Questions analyzed in this study from the questionnaire are listed below:

1. Which of the following best represents your experience with research?
 - a. I have never been involved in a research project
 - b. I have had a small level of involvement in a research project
 - c. I have been heavily involved in a research project
2. In how many scholarly publications are you listed as an author?
 - a. [Students entered a number into the answer box]
3. Think about your future in medicine and write a short paragraph (at least 3 sentences) to answer the question: How will understanding of the nature of scientific knowledge and the scientific method impact your future practice as a physician/physician-researcher?

DATA ANALYSIS

Responses to closed-ended questions were organized and catalogued while responses to open-ended questions were analyzed through development of a code book. The code book was developed with Leederman's framework on the nature of science in mind. Codes were written to help identify students understanding of the nature of science based on Leederman's characteristics of the nature of science. See Table 2 for the six codes used along with a brief description and examples.

Interrater agreement was established through the previously mentioned code book. Ten student responses were randomly chosen through a random number generator and analyzed by two researchers. Greater than 70% agreement among the two researchers was achieved.

| CODE | DESCRIPTION | EXAMPLES |
|----------------------------------|--|--|
| Tentative | Science is subject to change as new progress is made. | <p>“Science changes over time.”</p> <p>“Science progresses over time.”</p> <p>“I will do/read research to update my current knowledge to keep me up-to-date.”</p> <p>“Some areas of science are novel, leaving more to be investigated.”</p> |
| Empirically based | Based on and/or derived from observations of the natural world. | <p>“I am bound to formulate questions based on observations I make”</p> <p>“Science allows us to make inquiries regarding our observations.”</p> |
| Subjective | Observations are theory-laden (affected by presuppositions) | “One data set may be interpreted differently in research literature.” |
| Objective | Science is black and white. There is no human error. Scientists can separate their presuppositions from their work. | <p>“Science makes the world an objective place.”</p> <p>“Science removes opinion from conclusions.”</p> |
| Product of human interference | Imagination and creativity are used to make sense of observations and provide explanations to interpretations and inferences. It involves the invention of explanation and the ability to design and carry out an investigation and then state the findings from said investigation. | <p>“The nature of science is to question, investigate, and better the understanding of a topic.”</p> <p>“The scientific method will allow me to better research my own curiosities to get answers.”</p> |
| Socially and culturally embedded | Science shifts to reflect the needs and priorities of society. | <p>“Research is driven by the needs of medicine.”</p> <p>“We perform research to provide the best care for our patients.”</p> |

Table 2 Code book developed to accurately analyze qualitative data received from our survey developed to better understand medical students understanding of the nature of science.

RESULTS

Data analyzed from student responses to open-ended questions were organized into which characteristic of the nature of science was mentioned and the number of characteristics mentioned. Seven students failed to mention a characteristic of the nature of science. 25 students mentioned one characteristic. 55 students mentioned two characteristics. 25 students mentioned three characteristics. Six students mentioned four characteristics and zero students were able to mention all five. See Figure 1 for a visual representation.

Based on the open-ended responses, the most frequent NOS characteristic mentioned was tentativeness with 99 medical students mentioning how science was ever-changing. 74 students mentioned how science was socially and culturally embedded. 52 students mentioned how science was a product of human interference. 12 students mentioned how science was empirically based. Two students recorded responses stating that science was objective while one student mentioned that science was subjective.

The number of characteristics of the NOS listed per student response were compared to both, the amount of research that students previously performed, and the number of previous research publications. There was no discernable difference between the number of characteristics mentioned and the amount of research performed, or number of publications acquired. See Figures 2 and 3.

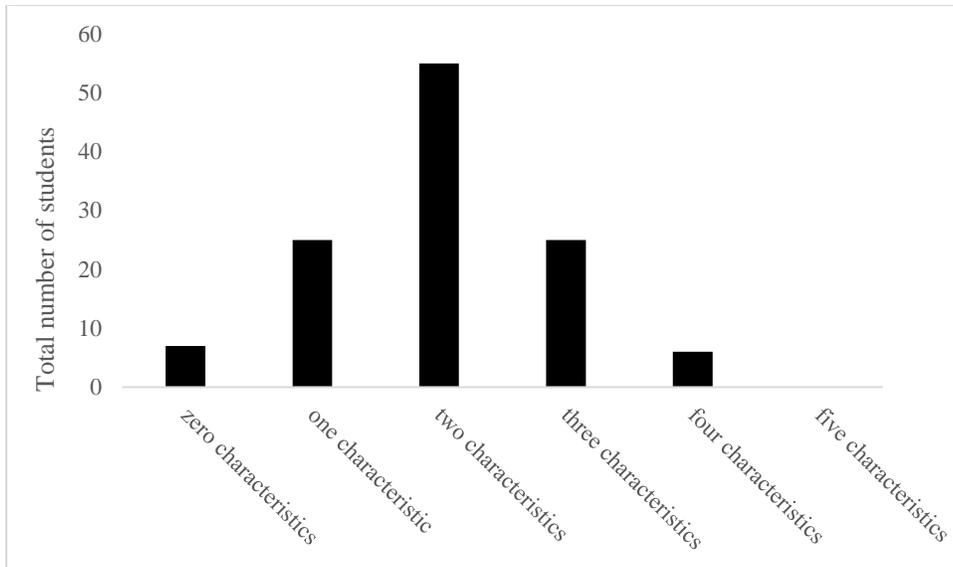


Figure 1 Number of characteristics of the nature of science recorded per medical student response. 120 student responses were analyzed and recorded.

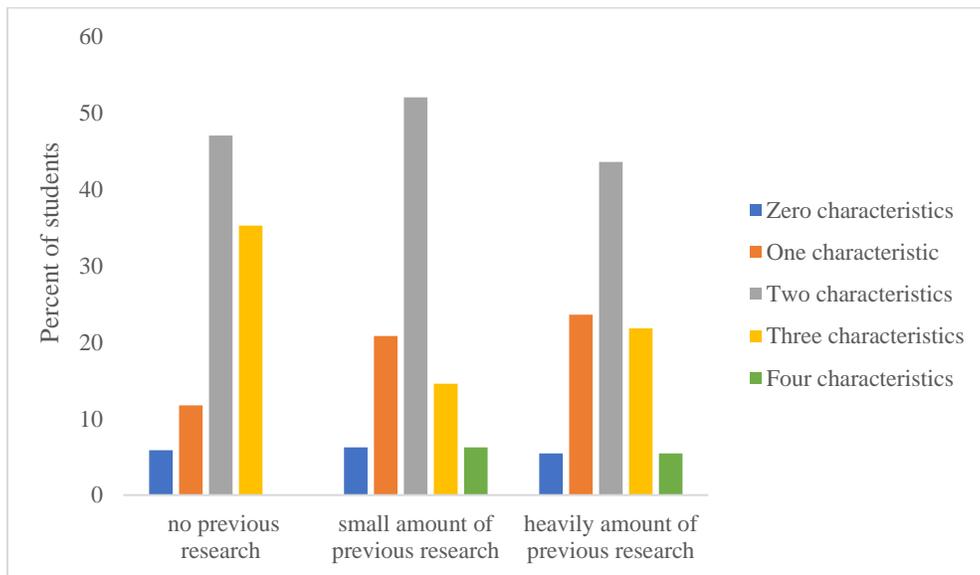


Figure 2 Number of characteristics of the nature of science mentioned per student response compared to amount of previous research performed.

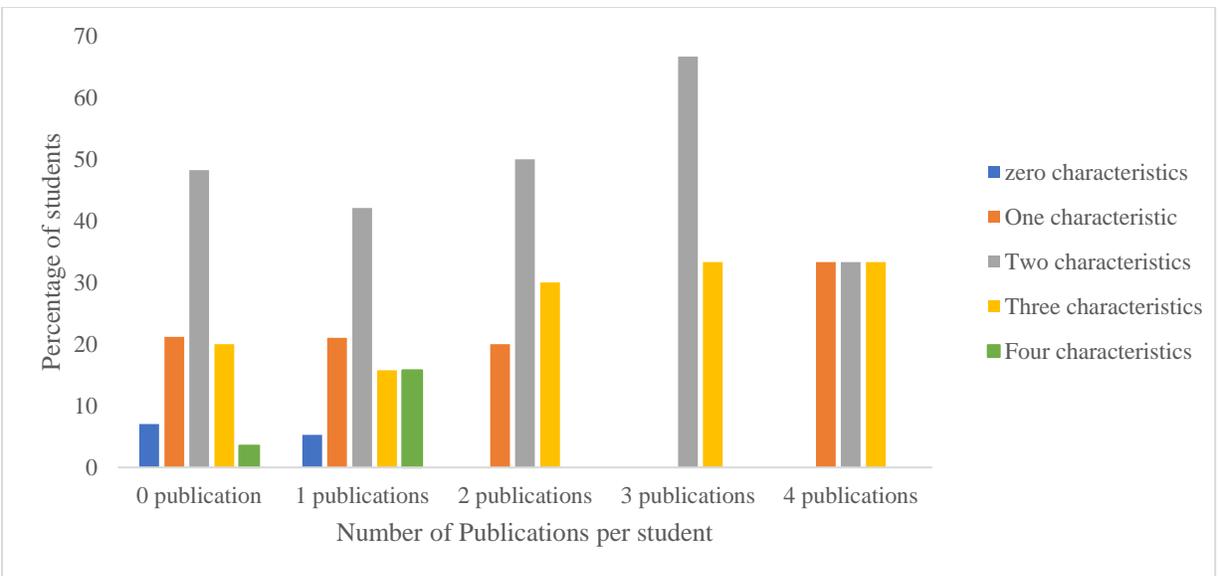


Figure 3 Number of characteristics of the nature of science mentioned per student response compared to number of previous student research publications recorded.

DISCUSSION

We separated the discussion into two sections. The first section will address student's ability to address characteristics of the NOS without having previously performed research or an independent study. The second section will address specific characteristics of the nature of science and students' statements and inquiries about them.

As seen in Figure 3, of the 85 students in this study who had never been published, at least 79 students (93%) were able to list one characteristic of the nature of science while 61 students (72%) were able to list at least two characteristics of the NOS. Of the 17 students who had claimed to never perform research or an independent study in the past, 16 of them were able to list at least one characteristic of the nature of science. We interpreted from this data that whether medical students had performed research in the past or not, most medical students were able to describe characteristics of the nature of science, meaning that somewhere along their journey to medical school they have learned major characteristics to the foundation of the sciences. This analysis stems questions addressed in the future direction section.

The second section addresses which characteristics were most frequently acknowledged in students' responses and in what context these characteristics were mentioned. As previously stated, the most popular characteristic mentioned was tentativeness. Science is the foundation of medicine in that it is durable and reliable. Although it is dependable, it is neither constant nor concrete. Science is ever-changing and evolving as new discoveries are made. We build on existing discoveries and derive new interpretations in hopes of solidifying and enriching our understanding in the sciences. 99 of the 120 students mentioned in one manner or another the tentativeness of science in their responses. It was addressed in several overarching themes. Some students simply stated that science was constantly changing. That it was a fluid being that is constantly updated with new discoveries:

Although many people see science as concrete and well-defined, this is very often not the case; science is constantly evolving as pieces of knowledge are added or refined.

Science and medicine are never ending human endeavors: there is always more to be investigated.

The practice of medicine inherently has many unanswered questions and so, having the ability to navigate the scientific method, will enable myself and others to learn and continuously expand the knowledge of the medical field.

Other students stated that due to science being constantly updated, there was a need to stay up-to-date on current affairs and research in the sciences to provide the most effective and safest care possible to their future patients:

Understanding the nature of scientific knowledge and the scientific method will have a large impact on my ability to practice medicine in the future. First, knowing that scientific

knowledge is always changing and evolving is beneficial because I understand that I should always stay up to date on the latest scientific research to provide the most innovative treatment methods to my future patients. This will allow me to provide the best quality of care, leading to the best potential health outcomes for my future patients.

I will combine prior, current, and future research to get the best possible diagnosis and treatment for my patients. I will constantly use new evidence from peer-reviewed sources to gain a better understanding of my patient's disease pathology and the new techniques available for treatment.

The evidence being gathered through research is constantly updating our knowledge of diseases, illnesses and injuries. Understanding the process that went into developing the current knowledge will help me to better understand the cause, but also form a better treatment plan for the disease. It will also motivate me to keep up with the research currently being done, since it is constantly evolving and updating the healthcare field.

The scientific method is the means that we utilize to be able to make new discoveries in medicine. It allows us to make observations in the natural world, and make inquiries regarding our observations, and from there find answers to some of those inquiries that we pose. As a physician it is important for me to understand not only how the scientific method works, but to understand current research so I can best treat my patients. As a physician-researcher I need to understand the scientific method so that I can properly carry out experiments that are valid and valuable to the scientific community.

Students understand that the science they are learning in medical school may not be the science they are using years after graduation to treat their patients. They understand that science is not static but ever-

changing. This is an ideology that medical students have strongly associated with their ability to successfully and safely treat and care for their future patients. Students expressed a responsibility to stay current with research. To understand that one of the characteristics of the nature of science is its tentativeness is one of importance for medical students and physicians alike. Without an understanding to commit to be a life-long learner in the medical field, one may not only provide less than adequate care to their patients but unintentionally be the vector for patient harm.

The second most mentioned characteristic of the nature of science addressed was how science is socially and culturally embedded. Simply stated, the direction and product of science is determined by the societies and cultures in which the science is being conducted. As the needs of societies change and develop, so do the areas of research. 74 of 120 students recognized that medicine was embedded in research and the direction of the medical research was driven by the need of patient care for specific pathologies:

As a physician, it is important to understand that the goal of the science is to benefit the community and come up with answers to questions that help to solve problems (like public health issues), contribute to overall knowledge (which will help with preventative care) and develop medical advances in technology that will allow for better patient treatment options

I value the ability to positively affect thousands of lives by understanding basic medical science, correlating this data to clinical cases, and applying clinical knowledge to affect the lives of patients. My previous research specifically help push the fields of trauma and diabetes forward, ultimately affecting the health of diabetic patients and how medicine is practiced. I hope to continue my research on how sleep fragmentation affects skin wound healing in a diabetic mouse model. This research serves as an example of how applying the scientific method helps my future patients

My goal for future research as a physician is to build knowledge, address societal issues, and inform policy. By having a good working knowledge of science and the scientific method, I will be able to contribute to these bodies of knowledge and more fully help patients (not just ones I personally see, but a greater patient population of those who use the research).

Students commonly addressed the influence that the medical field has on research. That the need in medicine to best provide care for patients is a large driving force in the direction and speed in which research is conducted. That those disease pathologies that most affect society tend to be on the forefront of research. Similarly, to why medical students addressed the tentativeness of science, the social and cultural influence on research stems back to the idea of providing the best patient care in the safest manner.

Medical students did not commonly mention that science is subjective. Only one student's response specifically mentioned the subjectivity of science. That scientists can interpret same data sets differently and even though we do try to be objective while analyzing data, we cannot fully eliminate previous biases from influencing our works. That is not to say that students were amiss from acknowledging the importance of skepticism. 44 of 120 students mentioned that it was important to critique new advancements and understand that not all new advancements are always the best means of care for patients. Medical students found value in skepticism and they framed it in a manner of protection of their patients.

Perhaps this is why the objectivity of science was mentioned less. This characteristic has more to deal with the formation of research and from which it originates than the results. Medical students deeply correlate medical research with patient care and safety. They less frequently mention the derivation from which research stems, observations of the natural world. Of the students that had mentioned research stems from observations, 100% of them were previously involved in a previous research project.

Perhaps first year medical students have an innate understanding of the effects of research in medicine regardless of previous publications and research but do not actively think about the derivation of research. This is not to say that students who did not write about observations of the natural world do not understand its importance. Simply, students who have not previously conducted research may not actively be associating observations with research. Students and physicians observations of everyday occurrences are what drives medical research forward. Not actively associating observations with research opportunities may lead to missed opportunities to better the medical field and help the patient population. Medical students have a clear understanding that medical research positively furthers patient safety and care but should be reminded that it is their observations in school, hospitals, and clinics that help achieve the advancements of modern medicine. With participation in research and independent studies, students may be reminded of this simple characteristic of the nature of science and be more successful in their future endeavors as a physician.

LIMITATIONS AND FUTURE DIRECTION

Only one class of medical students have completed our survey therefore we have only one data set to analyze and draw conclusions from. We hope to have future medical classes complete the survey designed to gain a more accurate understanding of what medical students believe to be the nature of science and how this understanding will benefit their careers as future physicians. We also would like to send the survey to students throughout their years in medical school to track development and understanding of the characteristics of the NOS to gain a deeper understanding as to how and when students develop a greater understanding of the NOS if they previously do not already express an understanding throughout medical school.

We would also like to develop a code to analyze the depth medical students understand the NOS. With a scale, we can gauge the level of students understanding of the NOS before, during, and after medical school.

CONCLUSION

Regardless of previous publications and research, most medical students have some level of understanding of the nature of science at the beginning of their first year in medical school. Students also display an innate understanding that science is tentative, or ever-changing, and with that, they must stay current and up-to-date in their field of medicine to provide the best and safest care to their patients possible. Students also expressed that the needs of their patients, or the demand of society, is what drives the direction and product of research. Both ideologies stem from the direction, product, and outcomes of medical research but fail to address where research stems. Only 12 of 120 students addressed that research stems from observations of the natural world and all 12 of the students had previously performed some form of research prior to medical school. Perhaps most students enter medical school with the knowledge of why we do research regardless of partaking in research themselves but may fail to mention that one's own observations is from which research derives. If students were to be involved in research and independent studies, they may actively link their observations with possible research opportunities, furthering and advancing the medical field.

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