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Development and Implementation of a Biochemistry Argumentation Task to Promote Scientific Literacy Among Undergraduate Students

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DEVELOPMENT AND IMPLEMENTATION OF A BIOCHEMISTRY ARGUMENTATION TASK TO PROMOTE SCIENTIFIC LITERACY AMONG UNDERGRADUATE STUDENTS

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ABSTRACT

Science education reform efforts at the postsecondary level have been lacking regardless of meaningful reform at the K-12 level. Of these reforms, the Next Generation Science Standards (NGSS) serve to reframe effective science teaching and learning as three-dimensional (3D). That is, 3D instruction integrates core disciplinary ideas, cross-cutting concepts, and science practices to support students' science learning. There have been calls to extend this 3D model to the postsecondary level. The purpose of this study was to design, implement, and evaluate a 3D task in a university-level biochemistry course. The task was implemented as a homework assignment to 107 students in an upper-level biochemistry course. Students' responses were analyzed using an altered form of Toulmin's Argument Pattern (TAP) to understand the effects of varying levels of scaffolding in questions. Results showed that students made roughly the same number of claims as they did evidence statements, but varied in the amount of reasoning they use to support their argument depending on the question type.

Key Words: Chemistry Education Research, Biochemistry Education, Argumentative Task, 3D Learning, Argumentation

INTRODUCTION

Revisions and reformatting of curriculum and instruction are necessary for the ever-changing field of science. As we learn more about how students learn and communicate scientific information, it is important to adapt our teaching styles to provide the highest quality support for the betterment of student's scientific knowledge. One goal of science education is to ensure students are scientifically literate so that they can properly engage with broader public science-relevant discourse (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996). Students' ability to properly understand and construct scientific arguments is key to improving this literacy. That is, students should be able to analyze data, make claims based on evidence, and form reasoning for why these two are connected.

Argumentation has been increasingly studied in scientific discourse with regards to understanding its role in enhancing understanding. Argumentation is often thought of as verbal debates between two or more individuals; however, argumentation can be represented in writing as well. From a theoretical perspective, the justification for executing research about argumentation discourse among science fields is the nature of the way science has been defended in the past. Scientific explanations are rarely created and accepted in general accord, rather, argumentation, debate, and contention are what serve to advance the field (Kuhn, 1962; Latour and Woolgar, 1986). In order to explain the phenomena around us, science has consisted of the development of theories that are able to be discussed, supported, and undermined through the use of experimentation and evidence (Popper, 1959). Hence, it is through the process of forming cohesive arguments that analyze reasoning, correctly interpret evidence, make knowledgeable claims, and accurately evaluate the experimental design process that play a crucial role in the discourse created among scientists (Erduran, 2004). The importance of argumentation in scientific discourse demands a need to teach, research, and improve the ways argumentation is taught to younger generations with the goal to enhance their scientific literacy and understanding of correct versus faulty assertions.

In this context, argumentation is a form of discourse that needs to be taught and elicited from students. Argumentation is a tool used by scientists to build an explanation of their position with respect to their claim, the evidence shown, and reasoning for the connection between the two (Erduran, 2004). Argumentation can be elicited from students in a variety of ways. In the most supported case, a student could be asked to provide a claim, evidence, and reasoning statement in a task. This amount of scaffolding will directly guide them to the correct answer, but not enough could leave the students without proper guidance to develop a full and well-supported argument. The primary purpose of this study was to answer the following research question.

How does the task structure relate to student argument construction?

To enhance and evaluate how we learn and teach argumentation in the classroom, we must analyze how students respond differently to variable argumentative task constructions and how this may impact the formulation of their argument. Further work will need to be done to evaluate the validity of the arguments created. Here, we focus primarily on the construction of the arguments created by Biochemistry students as the basis to see how task structure can impact their creation of complete arguments. By analyzing the differences among the structures of the questions and viewing the results of how the arguments are constructed we can learn more about which variables help to increase and enhance the ability of students to create full arguments, which in this study will be based off of a student's claims, evidence, and their reasoning.

METHODS

Task Development

This task was designed by aligning with two frames: 1) learning objectives for the course, and 2) NGSS.

The goals outlined for the biochemistry class for this study are shown in Table 1 below.

Table 1. Goals for student development as outlined by instructor for BIOC431 from Syllabus

Main Goals	Supporting Goals		
Chemical structure determines biological function	Explain and describe the salient features of biological chemicals and macromolecules	Predict chemical function and enzyme mechanism based on structure	Interpret experimental data to support theories about biochemical structure &function
Biochemical reactions allow organisms to harness chemical energy to do work	Provide a thermodynamic explanation for the spontaneity of living processes	Connect the flow of electrons to work done in biochemical systems	Predict the input and output of biochemical pathways in terms of energy
Biochemical systems are regulated to maintain homeostasis	Identify regulatory points in biochemical pathways and predict responses to regulatory changes	Explain the mode of action of components in biochemical signaling cascades	

Our task targeted the first goal: understand how “Chemical structure determines biological function.” The context of our task was related to the antibiotic properties of flavanone molecules. The students were given background information regarding how these flavanone molecules were synthesized and tested for their ability to kill off bacteria. The students were provided the structures of thirteen different flavanone molecules and data including the minimum inhibitory concentrations (MIC) of each. The students were also given a table representing the differences in functional groups on the different carbon molecules of the flavanones, and asked to analyze how different functional groups impacted the ability of the flavanones to kill bacteria. The second question provided the students with two different models about how the flavanone molecules could have been killing the bacteria, one involving the cell membrane and one involving direct interaction with DNA molecules. Students were expected to use what they had learned about the impact of certain functional groups, and the types of chemical interactions normally associated with these groups. The task prompted students to analyze structures of different molecules, relate this to how the molecules functioned differently, and interpret data to provide an explanation of why the functions differ based on structure.

Although the NGSS focus on development of scientific knowledge in K-12 education, they can provide a useful outline for designing argumentative prompts for collegiate level classrooms. The NGSS created a model for learning and a vision for how students will continue to learn science known as three-dimensional learning. The three dimensions of this learning system are scientific practices, crosscutting concepts, and disciplinary core ideas. The first dimension is what students should be able to do with their knowledge. Eight scientific and engineering practices were acknowledged including Developing and Using Models, Constructing Explanations, and Engaging in Argument from Evidence just to name a few. The practices listed above were used and incorporated into our task development. Our task targeted these by having students analyze models, construct explanations for which model may better explain the data, and requests that the students use evidence to support their arguments. The second dimension refers to ideas that are common across scientific disciplines. Specifically, in this study, the cross-cutting concepts as outlined by the NGSS were used to develop the argumentative prompt. The NGSS outlined seven crosscutting concepts that they believe are applied across all disciplines of science. The seven cross cutting concepts are as follows: 1. Patterns, 2. Cause and Effect, 3. Scale, Proportion, and Quantity 4. Systems and System Models, 5. Energy and Matter, Structure and Function, 7. Stability and Change. By aligning argumentative prompt questions around these cross-cutting concepts, it allows students to develop their arguments around these important aspects, such as Cause and Effect, that can be used and applied across any scientific discipline (Laverty, 2016). The third dimension focuses on concepts that are essential to the study of a discipline. This refers to focusing the learning on core ideas related to that specific field of study. It was our goal to create a 3D argumentative prompt that incorporated all of these different aspects to hopefully maximize the amount of benefit students can gather from working through the task. The two questions in this task can be viewed below.

Question 1:
"Using the data provided above, what claim(s) can be made about the relationship between the different flavanone structures and anti-MRSA activity? Justify your claims with the data available. Be sure to include a discussion of the role of varying functional groups and consider both identity and position of the functional groups provided in Table 1."

Question 2:
"Two mechanisms have been produced as a hypothesis for the flavanone antibiotic properties. Based on the information and data presented, provide an argument for which mechanism you think is correct. Make sure to discuss what functional groups and types of interactions are occurring."

In this prompt the students were provided with a background of the scientific experiment, provided with structures, and a table breaking down these structures in an easier to view format. Question one was constructed to emphasize the cross-cutting concepts of Patterns, Cause and Effect. Students are able to extract patterns by analyzing the differences in functional groups among the different molecules. Cause and effect can be analyzed by looking at the differences in the patterns and deciding how one change in a functional group can have an effect on the data. Question two focuses on the Structure and Function concept and prompts students to analyze two different models while using the structure to evaluate which model better explained the data.

When choosing topic idea for this prompt is was very important that all of the data be extracted from primary literature. The data for this prompt was all taken from one paper titled "Comparative study on the antibacterial activity of phytochemical flavanones against methicillin-resistant *Staphylococcus aureus"* (Tsuchiya, 1996). This study was completed to discover the differences in antibacterial activity among a variety of flavanone molecules and analyze the structure-activity relationships shown. By discovering which flavanones had the best antibacterial properties this flavanone could be used as a phytotheuraputic way to fight off MRSA infections. MRSA is very common among hospitals and can cause many issues in procedures which prompts researchers to develop a way to best eliminate the bacteria. The nature of this study directly maps onto the course objectives listed for chemical structure determines biological function. The first objective is to *Explain and describe the salient features of biological chemicals and macromolecules,* and students are able to accomplish this by analyzing the differences between the flavanones. Another objective for this section listed in the syllabus was to *Predict chemical function and enzyme mechanism based on structure,* and this can be executed in the task because the paper provides different structures and students can determine which model correctly represents how the flavanones are working based on the structures of the molecules provided. The final objective of this section was to *Interpret experimental data to support theories about biochemical structure & function.* This paper provides data about the antibacterial properties of each flavanone molecule, and so students can interpret the data to determine which pieces of the structure are most valuable in achieving this. Then, after analyzing the best functional groups, students can use this understanding to determine which model may represent a more accurate mechanism of how these molecules are acting with the understanding that some specific functional groups allow the molecules to have higher antibacterial properties. This paper provides structural components for analysis and easily observable data that can be understood at a collegiate level. Antibiotic resistant is just one example of a current relevant scientific topic due to the over prescription of antibiotic drugs and the inability of the pharmaceutical industry to keep up with the newly resistant forms of bacteria. To ensure the students found this material relevant to their class work, this task was administered directly after they learned about the mechanisms of antibiotic resistance with regards to Methicillin and Penicillin in their textbook.

When developing these tasks there are some important considerations that were immediately known as necessary components via the previous discussions. Primary data was included that contained individual chemical structures to aid students in their ability to successfully investigate the Structure-Function cross-cutting concept. Both questions were designed as open-ended questions to allow for students to develop their arguments in any way they pleased. Open-ended questions allow students the ability to best develop an argument, as opposed to close-ended questions that limit the students thinking past a certain point.

Scaffolding refers to how much information is given to the students in order to guide them. It can be difficult to frame and scaffold questions in a way that allows proper guidance. This brings up an important difficulty in how to correctly scaffold these prompts. There is a difficult balance in scaffolding where the two extremes exist as giving the students no guidance in their answering of the question and giving them all of the answers to complete the task. This scaffolding dilemma is necessary to prompt students to guide them in their development of a proper argument. The first question is heavily scaffolded to help lead the students to create a claim, evidence, and reasoning based argument. The first question asks students what claims they can make, using the data, about the relationship between the flavanone structure and the antibiotic capabilities, directly prompting for them to make a claim. The second sentence tells the students to justify the claims with the data available, which prompts their evidence statement to include empirical data. The last sentence tells the students to include a discussion of the role of varying functional groups, and to consider the identity and position of the groups provided. This statement partially prompts for reasoning as it focuses on the identity and the position of the groups. The position part of the last statement would still only prompt an evidence statement as the positioning is something that can only be observed from this data set. However, if students think about the identity of a group, they would be prompted to think about the varying properties that each group contains such as hydrophobicity and hydrophilicity as one example which would represent a proper reasoning of why the evidence may show some groups as having higher antibiotic activity.

Question two is scaffolded in a slightly different way. The second question tells the students to provide an argument for one of the hypothesized mechanisms based on the information and the data present. This statement directly tells the students to make a claim about which mechanism they think is correct, and then use the data they are given to back this claim with evidence. After prompting for the first two pieces of argument, the question tells the students to discuss what functional groups and types of interactions are occurring. This more directly prompts the reasoning than the first question because it directly tells the students what pieces of outside information, they should be considering to think about how the interactions would support one mechanism or the other. There was no correct answer for this question, but rather, the question was supposed to allow the students to use the pieces of the structure that they analyzed in the first question to support their choice for the second question. Both mechanisms are proposed as possible scenarios for the true antibiotic resistance forms in the research literature. When students asked for help, they were not shifted toward either hypothesis, but prompted to pick the mechanism they believed to best fit the data that they had analyzed.

Participants and Setting

The task was implemented in the first-semester biochemistry course known as Structure and Metabolism, or BIOC431. There were 107 biochemistry students who completed the task, and majority of the class were third year college students. This course serves as the first semester of biochemistry that focuses on structure and metabolic processes that occur in the body.

Data Collection

Responses were gathered from 107 students and analyzed. The task was implemented and distributed as a homework assignment for the biochemistry class and the submissions were gathered electronically. Extra teaching assistant office hours were held so students could come in and ask questions about how to answer the questions. To ensure that all questions were answered in the same way without swaying students' responses, other teaching assistants from the class were restricted from helping the students answer these questions and were told to direct any questions to us during these office hours. In all questions, students were guided to look at the data they have been given in the prompt and asked to answer the questions based off of this data set.

Data Analysis

To analyze the effectiveness of this argumentative prompt for eliciting students' argument understanding and discourse skills, each question response was separately analyzed and categorized into three different statements types: claim, evidence, and reasoning. A statement was categorized as a claim if it served to directly answer the question at hand. A statement categorized as evidence was any statement that referred to the data in the figure or used information directly visible in the structural images to explain and support the claims made. A statement was categorized as reasoning if it used supporting information for the claim and, or, evidence with information that could not be extracted from the data given. Results were analyzed using the rubric as shown in Table 2 below to characterize the structure of students' arguments. Claim, evidence, and reasoning were color coded to emphasize pieces of argumentation that were used to support each other as shown in the example below.

Table 2. Rubric for argument categorization elements.

Piece of Argument	Definition
Claim	A conclusion that answers the original question
Evidence	Use of scientific data that was supplied in the question or outside of the question to supplement the claim made.
Reasoning	An explanation or justification that links the claim and evidence and provides an explanation of why the evidence may have occurred.

These three categories were chosen because they serve as the primary three components that make up an argument. Many similar argument analysis forms have been used and evaluated for their ability to properly analyze argument structure with one of the most famous and highly used being Toulmin's argumentation pattern, or TAP, which includes an increased number of pieces such as warrants and rebuttals. The form used here is a simplified version of this argument analysis. Analysis was carried out by reading each sentence and determining whether that sentence was primarily a claim, primarily a piece of evidence that could have been found from the data provided, or if the statement was reasoning about why the claim produced the results it did. There was some difficulty in categorizing the argument statements because many of the evidence statements sound as if they are making a reasoning for the claims made. However, if the statement was referring to the data that was supplied in the task then it had to be categorized as evidence. The only way a statement could be categorized as reasoning is if it brought in outside information that was not present in the task. This information was often related to the types of interactions that occur with certain functional groups. Multiple arguments were often made within one response. New arguments were started when separate claims were made with supporting evidence. Some claims had multiple evidence statements supporting that claim while other claims were left without any justification.

RESULTS and DISCUSSION

Examples of the separate categorizations can be shown below for question one and question two. The color coding in the Table 3 and Table 4, again, represent the formulation of separate arguments. For example, the reasoning statement in purple, serves to explain the evidence statement in purple which serves to justify the claim made in purple. To give a clearer understanding of this, the claims are often written in the order of the colors, so the reader would read all of the statements in black, then red, and finally purple. If you look at the left column you can see the entire argument in its entirety. Just by observing these examples, it is clear that the two questions elicited argumentative responses that have varying characteristics. The examples were used because they represent a common way that the arguments were structured for many of the responses, mainly, the responses to the first question had arguments with many claims and less reasoning compared to the second question responses that were more balanced with relatively equal amounts of each piece of the argument. Different arguments were also well represented in the examples as can be seen by the separate color-coding scheme. These examples are well representative of the other arguments made for each question because they directly support the data in terms of the relative number of claims evidence and reasoning respectively.

Many claims in question one have supporting evidence, but very few claims are supported with reasoning as shown in the graph and tables following.

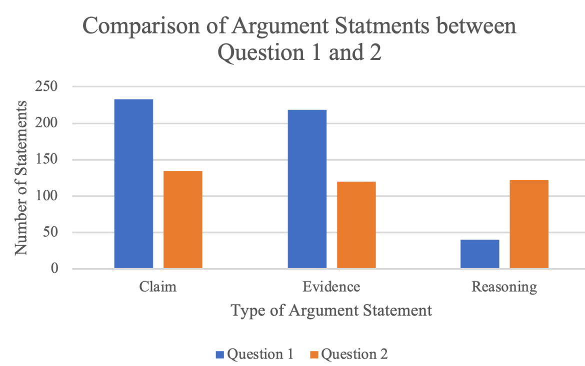


Figure 1. Breakdown of arguments between question one and two.

Table 5. Exact values of the arguments produced by students into Claim, Evidence, and Reasoning for questions one and two.

Question #	Claim	Evidence	Reasoning
1	233	218	40
2	134	120	122

When analyzing these scientific prompts, students showed little difficulty in developing a claim they believed to be true. Many students were able to support their claim with some sort of evidence that they were given as shown in the table above. It is important that students correctly analyze and select the correct data that supports their claim. The exact values of properly supporting evidence statements were not analyzed, but could be done in future analysis. This was not completed in this study as the main focus was on the construction of the argument and not the validity. However, previous studies have shown that students struggle dramatically with the ability to use evidence to support their claims (Sadler 2004).

Table 3. Categorization example for claim, evidence, and reasoning based argument, Question 1.

Example argument for question 1	Claim	Evidence	Reasoning
In general, any compound that had a functional group that contained 2 branched carbons connected to an sp2 carbon (Prenyl, Lavandulyl, or Geranyl structures) seemed to ultimately be useful in inhibiting the bacterial growth. Every drug had this structure somewhere on the molecule except for Naringenin, which also happened to be the least effective at inhibiting the bacteria. More specifically, it seems that having a polar group at B:4' is important in blocking the enzyme. For example, this was the only difference between Sophoraflavanone G (MIC=3.13-6.25) and 5,7,2-Trihydroxy-8-lavandulylflavanone (MIC>25), as well as, Exiguaflavanone A (MIC=6.25). Another important area is the B:2'. All of the compounds had an OH at this position other than Naringenin, which had the highest MIC value. Having polar groups in these areas could be important for proper compound alignment. If the drug is not properly aligned, it will not inhibit the bacteria as effectively. Changing the location of the prenyl, lavandulyl, or geranyl groups or the location of the hydrophilic groups could slightly change the alignment of these molecules. This would explain the slight differences in the effectiveness of the drugs. The molecules that offer the best alignment will have the lowest values of MIC.	In general, any compound that had a functional group that contained 2 branched carbons connected to an sp2 carbon (Prenyl, Lavandulyl, or Geranyl structures) seemed to ultimately be useful in inhibiting the bacterial growth. More specifically, it seems that having a polar group at B:4' is important in blocking the enzyme. Another important area is the B:2'. Changing the location of the prenyl, lavandulyl, or geranyl groups or the location of the hydrophilic groups could slightly change the alignment of these molecules. This would explain the slight differences in the effectiveness of the drugs. This would explain the slight differences in the effectiveness of the drugs. The molecules that offer the best alignment will have the lowest values of MIC.	Every drug had this structure somewhere on the molecule except for Naringenin, which also happened to be the least effective at inhibiting the bacteria. For example, this was the only difference between Sophoraflavanone G (MIC=3.13-6.25) and 5,7,2-Trihydroxy-8-lavandulylflavanone (MIC>25), as well as, Exiguaflavanone A (MIC=6.25). All of the compounds had an OH at this position other than Naringenin, which had the highest MIC value.	Having polar groups in these areas could be important for proper compound alignment. If the drug is not properly aligned, it will not inhibit the bacteria as effectively.

Table 4. Categorization example for claim, evidence, and reasoning based argument, Question 2

Example argument for question 1	Claim	Evidence	Reasoning
Based on my observations above, I would hypothesize that mechanism 2 is the correct mechanism. I would hypothesize that the presence of lavadulyl, prenyl, or geranyl is an important part of the flavanone binding to the DNA. But, like I mentioned above, as the hydrocarbon backbone of the functional groups gets longer, the MIC is increased. This could be attributed to the fact that as the hydrocarbon backbone gets longer, the flavanone molecule gets bigger, leading to a decrease in the insertion into the DNA. The position of each of the functional groups would be extremely important in mechanism 2, which can be seen through out the table. As the functional groups are moved to different locations on the molecule, the MIC changes with it. Having a lavadulyl at position 8 on the molecule leads to the best MIC range, meaning this location leads to more favorable interactions with the bacteria's DNA. The presence of oxygen molecules around the ring could lead to favorable hydrogen bonding interactions. The presence of hydroxyl or methoxy groups at 4' and 6' seem to have a large impact on the MIC, leading me to believe that the locations stabilizing the binding of the flavanone with the DNA are on the opposite side of the lavadulyl, prenyl, or geranyl functional groups.	Based on my observations above, I would hypothesize that mechanism 2 is the correct mechanism. I would hypothesize that the presence of lavadulyl, prenyl, or geranyl is an important part of the flavanone binding to the DNA. The position of each of the functional groups would be extremely important in mechanism 2, which can be seen through out the table. The presence of oxygen molecules around the ring could lead to favorable hydrogen bonding interactions.	But, like I mentioned above, as the hydrocarbon backbone of the functional groups gets longer, the MIC is increased. As the functional groups are moved to different locations on the molecule, the MIC changes with it. Having a lavadulyl at position 8 on the molecule leads to the best MIC range, The presence of hydroxyl or methoxy groups at 4' and 6' seem to have a large impact on the MIC	This could be attributed to the fact that as the hydrocarbon backbone gets longer, the flavanone molecule gets bigger, leading to a decrease in the insertion into the DNA. meaning this location leads to more favorable interactions with the bacteria's DNA. leading me to believe that the locations stabilizing the binding of the flavanone with the DNA are on the opposite side of the lavadulyl, prenyl, or geranyl functional groups.

For question one, 233 claims were made and 218 evidence statements were made, and for question two there were 132 claims made supported with 120 pieces of evidence. This means that students, on average, constructed two arguments in response to questions one and on average, one argument for question two. These differences can be attributed to the nature of the questions. Question one asked an open-ended question which allowed the students to make as many claims as they pleased where question two asked the students to pick between two different theoretical models resulting in most of the answers being formatted as "I think mechanism one is correct". The open-ended nature of the question resulted in almost twice as many claims being made compared to question two. It should be noted that these evidence statements were not analyzed for their trueness in support of the student's claims. Because this research was gathered to primarily view the differences in question construction, there is no warrant to say

whether the evidence statements logically support the claims that were made.
Having an open-ended question seemed to elicit both more claims and more evidence statements, there is an underlying connection that exists between the number of claims and the number of evidence statements. In this study, students rarely made a claim about something without supporting the statement with some piece of evidence that was given in the data. This means that having an open-ended question may not directly increase the number of evidence statements, rather, this correlation is indirectly created by the increased number of claims made. In other words, by having an increased number of claims due to the form of the question this will cause an increase in the number of evidence statements.

There is a clear difference in the amount of reasoning statements that are created between the two questions. Question two provided nearly as many reasoning statements as evidence and claim statements. Questions two had three times more reasoning statements than question one and almost half of the number of claims. This argument often looked more complete, referring to having a claim, evidence, and reasoning statement per argument. As can be seen in Table 3, many of the arguments from question one were constructed in a way that had many claims, a similar amount of evidence statements, and few reasoning statements. Students were often able to make claims about the functional groups present and support their claims using the evidence from the table given, but students did not give reasoning of why these types of functional groups may have elicited better antibacterial properties. In question one, the students were told to include a discussion of the role of varying functional groups and consider both identity and position of the functional groups provided in Table 1. The students may have interpreted, "A discussion of the role of varying functional groups," as being fulfilled by saying which functional groups led to a better ability to kill bacteria. When asked to consider the identity, this was intended to prompt students to think about the nature of the functional group having an impact, such as if the group is hydrophilic or hydrophobic, and then to discuss how this may be a factor in changing whether or not a certain molecule is better or worse at killing bacteria. The word identity may have been too vague for students to gather an understanding of what was expected of them. In question two, the students were asked to discuss what functional groups and types of interactions are occurring. By asking the students about the types of interactions present, this directly asked them to discuss something that was not directly discussed or talked about in the data. By asking them to discuss the interactions between the molecules this also gave them a way to tie into how these interactions would act in the two different models, and helped them to decide which was more plausible. Another factor affecting the quality of the argument may have been the fact that in the second question, the images provided gave the students a visual representation of potential mechanisms that showed how the molecules interacted within different environments.

CONCLUSIONS

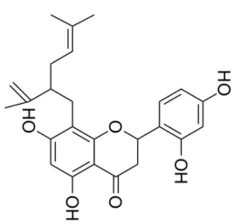
Overall, it was shown above that, with the proper prompting, scaffolding, guidance, students have the ability to create well rounded arguments, referring to their ability to create an argument based off of a claim, evidence, and reasoning statement, while analyzing primary science literature. Although the second question more efficiently prompted this type of argument, the first question could still hold great value within the argumentative task. Some may find value in having a question that allows students to get all of their thoughts on one page, even if this question does not directly elicit the formation of a complete argument. The first question gave students the opportunity to view structures of molecules and observe differences in their structures. The nature of this question being so open-ended, and allowing the students to make a large number of claims for the data helped to further prompt their thinking procedure when they arrived at the second question. In fact, many of the students based their answers for the second questions directly based off of the interactions created by the functional groups in the first question that they made claims about. If students observed more long chain structures, they would often choose the mechanism that was more dependent on the hydrophobic nature of the molecule. It would be interesting to see the connection between the claims made in the first question and how these effected or correlated with the students answers to the second question. Further analysis of the number of evidence statements that correctly support the claims and evaluation of the reasoning for the connection of the two could be useful information for the next step of this research in order to further understand which questions can properly guide students to developing robust argumentation skills. In future studies, it would also be useful to further analyze the claims, evidence, and reasoning for their validity. This could show how altering the way questions are scaffolded and prompted could affect the ability of students to create logical arguments with full claim, evidence, and reasoning statements.

APPENDIX

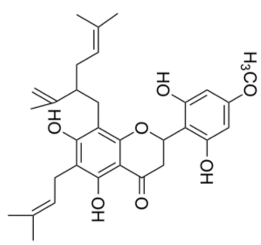
Biochemistry Argument Prompt:

Biochemistry Writing Assignment

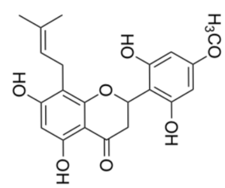
Staphylococcal infections, often referred to as staph infections, are a serious issue with regard to medical practices. Many strains of *Staphylococcus aureus* are now resistant to penicillin due to the production of the B-Lactamase enzyme in some of the bacteria that caused inhibition of the enzyme, transpeptidase. The synthetic compound, methicillin, was created to resolve the issue of penicillin resistance. Methicillin-resistant strains of bacteria have developed due to aggressive use of methicillin in hospitals. A variety of antibiotics have been developed to treat MRSA infections. The one that we will focus on in this task is a class of molecules called flavanones, which are a secondary metabolite derived from plants and fungus. A group of scientists set out to understand the relationship between flavanones with varying functional groups and anti-MRSA activity. The goal was to identify which structures had the best anti-MRSA activity; that is, they inhibited bacterial growth of methicillin-resistant strains of staph best. Helpful information regarding Methicillin can be found in section 13.2 of your Biochemistry textbook.



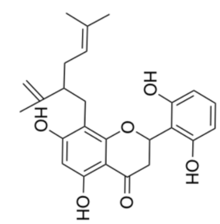
Sophoraflavanone G



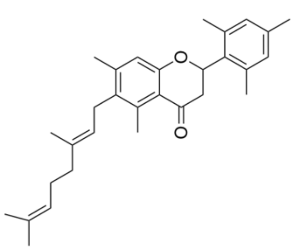
Exiguaflavanone D



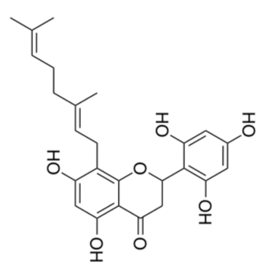
Kenusanone D



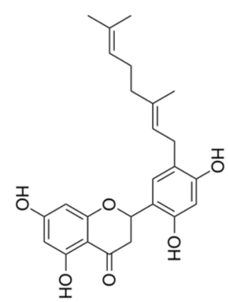
Exiguaflavanone A



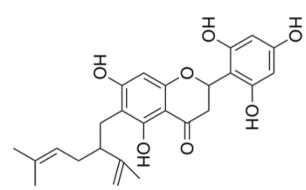
Sophoraflavanone D



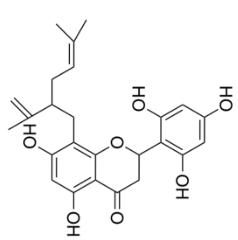
Sophoraflavanone E



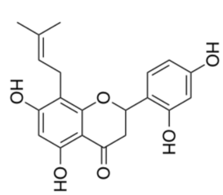
Kenusanone A



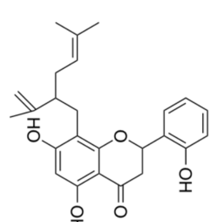
Exiguaflavanone C



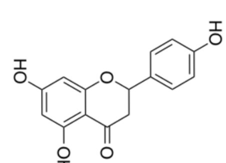
Exiguaflavanone G



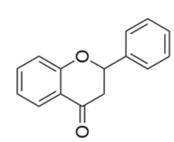
Leachianone G



5,7,2-Trihydroxy-8-lavandulylflavanone



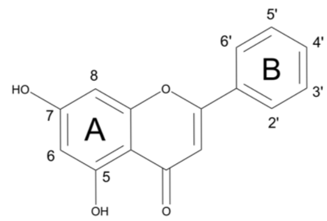
Naringenin



Flavanone

Figure 1. Chemical Structures of Flavanones

Table 1.
Anti-MRSA activity and chemical structures of flavanones



Flavanone	MIC Range (μg/ml)	A: 6	8	B: 2'	4'	5'	6'
Sophoraflavanone G	3.13-6.25	H	Lavandulyl	OH	OH	H	H
Exiguaflavanone D	3.13-6.25	Prenyl	Lavandulyl	OH	CH_3O	H	OH
Kenusanone D	3.13-12.5	H	Prenyl	OH	CH_3O	H	OH
Exiguaflavanone A	6.25	H	Lavandulyl	OH	H	H	OH
Sophoraflavanone D	3.13-12.5	Geranyl	H	OH	OH	H	OH
Sophoraflavanone E	6.25-12.5	H	Geranyl	OH	OH	H	OH
Kenusanone A	6.25-12.5	H	H	OH	OH	Geranyl	H
Exiguaflavanone C	12.5	Lavandulyl	H	OH	OH	H	OH
Exiguaflavanone G	12.5	H	Lavandulyl	OH	OH	H	OH
Leachianone G	12.5	H	Prenyl	OH	OH	H	H
5,7,2-Trihydroxy-8-lavandulyl-flavanone	>25	H	Lavandulyl	OH	H	H	H
Naringenin	200-400	H	H	H	OH	H	H

*The minimum inhibitory concentrations were defined as the lowest concentration of tested compounds which completely inhibited bacterial growth.

QUESTION 1: Using the data provided above, what claim(s) can be made about the relationship between the different flavanone structures and anti-MRSA activity? Justify your claims with the data available. Be sure to include a discussion of the role of varying functional groups and consider both identity and position of the functional groups provided in Table 1.

QUESTION 2: Two mechanisms have been produced as a hypothesis for the flavanone antibiotic properties. Based on the information and data presented, provide an argument for which mechanism you think is correct. Make sure to discuss what functional groups and types of interactions are occurring.

Mechanism 1: Inhibition of Energy Metabolism

The flavanone molecule interacts and binds to a porin protein on the cell membrane. This porin normally serves to transport small hydrophilic molecules into the cell such as glucose. The binding of the flavanone to this porin prevents this entry and thus limits the energy available to the cell causing death.

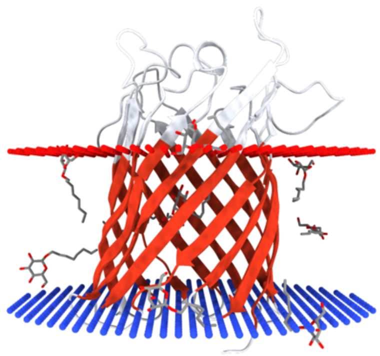


Figure 1. Image of OmpG Porin Protein that is used for Glucose Uptake

Mechanism 2: Inhibition of Nucleic Acid Synthesis

The flavanone structure acts as an intercalating agent and inserts itself into, and binds to the DNA. This damaged and disoriented DNA strand can no longer interact with DNA gyrase which is used as a preliminary step before DNA replication to unwind supercoils, and thus, nucleic acid synthesis is halted leading to the death of the bacteria.

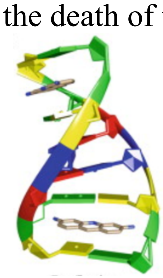


Figure 2. Image of flavanone acting as an intercalating agent in DNA

Cross-Cutting Concepts outlined by NGSS:

1. Patterns
Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

2. Cause and Effect
Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

3. Scale, Proportion, and Quantity
In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.

4. Systems and System Models
A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

5. Energy and Matter
Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.

6. Structure and Function
The way an object is shaped or structured determines many of its properties and functions.

7. Stability and Change
For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

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