5-3-2024

Using Student Interests to Explore Inclusion in Undergraduate Chemistry

Sonja Hoversten
College of Saint Benedict/Saint John's University

Using Student Interests to Explore Inclusion in Undergraduate Chemistry

Sonja Hoversten

The College of Saint Benedict and Saint John's University

COLG 398: Distinguished Thesis

2022-2024

Approved By:

Dr. Lisa Gentile

Thesis Advisor

Professor of Chemistry

Dr. Alicia Peterson

Faculty Reader

Chemistry Department Chair

Dr. Diana Fenton

Faculty Reader

Professor of Education

Abstract

For students who are not chemistry majors, but who are on a career track requiring four chemistry courses, taking the final reactivity chemistry course (CHEM 251) for pre-health students can be daunting. For this reason, this research is focused on the CHEM 251 course at The College of Saint Benedict and St John's University (CSBSJU) which is one of the four required chemistry courses for pre-medicine and some pre-physician assistant students, and all chemistry and biochemistry majors. Student perception of inclusion in the course increased through the implementation of group assignments including prompts for individual application of the material. The updated group homework model created room for students to research wider connections of chosen topics and write about their relevance to the world around them and their own personal lives. For example, within the organometallic catalysis unit, students explored the MCM-RHA catalyst and its applications to ceramic art, local indigenous groups, and use as a green catalyst. Having students work together fosters connections with peers and allows for more personal stake in the outcome of group work. A personal response section to the group homework assignments was added to encourage personal participation. Students in the Fall 2023 section of the course acted as a control and students in the Spring 2024 section of the course completed the updated assignments including the personal prompts. Student perceptions of inclusion were measured using a Likert scale survey taken week 11 of the semester. Students in the Spring section of the course had a more confident and increased level of perceived inclusion compared to students in the Fall section. The individual application prompts were shown to increase student perceptions of inclusion while also providing tangible evidence that students were engaging with the material at a more personal level than before.

Introduction and Background

At the College of Saint Benedict and Saint John's University (CSBSJU), the chemistry course CHEM 251 is one of four required courses for pre-medicine, some pre-physician assistant students, and all chemistry and biochemistry students. The chemistry curriculum begins with an introductory structure and reactivity course, two reactivity courses, and one macroscopic course that can be taken at any point after the first introductory course. Every course in the sequence fully integrates inorganic/coordination chemistry, organic, and biochemistry topics. CHEM 251 is the last reactivity course and can be daunting for students who are not chemistry or biochemistry majors. Learning goals for each course are met through group-homework, practice problems, short daily quizzes, short problem-solving assessments, and longer literature based problem-solving assessments. The focus of this study is on group work, which has been shown to increase retention of chemistry and student attitudes surrounding the subject matter (1). Students who work with teams of their peers to practice concepts learned in class retain information better and form relationships with their peers. However, the social dynamics found within peer groups influence the efficacy of this learning style (2). Students who feel left out, or behind their peers tend to withdraw from the group learning. In this study we implemented a group work model that will explore topics of student interest with room for personal exploration of a topic. Topics being introduced to group work include applications in food toxicology, art and connections to local indigenous groups, and polymer chemistry. In addition to a group example problem for the unit, students completed an individual section relating to the topic and its relevance related to their own personal interests, identities, and pre-professional goals. Having students work together on the application section introduces a concept during group work, and having each student individually complete questions on their own interests and applications fosters student connections to their own individual interests or identities. In addition to creating a class community, the individual section increases student investment in the group work as well as allowing for unique exploration. We chose to add the personal section as a way to overcome the challenges that social dynamics can introduce to group learning.

Methods

In the fall of 2023, there were twenty-five students taking the section of CHEM 251 this research focused on. There were two other sections of CHEM 251 taught by a different instructor that were not observed. This selection of students from the CHEM 251 course were part of a control group and did not have a changed group work model. Of the students in this class 36% of them are not required by their major to take the course but may have a pre-professional program such as pre-med, pre-optometry, or pre-dental requiring them to take the course, and 16% of students are not required to take the course by either their major or pre-professional program. The 16% of students not required to take the course were biology students, pre-physician assistant students, exercise science students, and psychology students. Students were given a Likert scale survey (Fig. 1) week 11 of the semester to inventory their perceptions towards inclusion of their interests in the course with the unchanged group homework model.

Figure 1:

1. The coursework given throughout this course was inclusive of my desired career path and goals.
2. The coursework promoted more personal engagement with the topics covered.
3. The group homework assignments were helpful to creating community within the class.
4. I felt like my contributions were valued within my group work.
5. The material presented connected learning outcomes to relevant topics in the world around me.
    a. Strongly Agree
    b. Agree
    c. Somewhat Agree
    d. Somewhat Disagree
    e. Disagree
    f. Strongly Disagree

Figure 1.) Five question Likert Scale survey given to Fall 2023 students and Spring 2024 students.

In the spring of 2024, there were eighteen students taking CHEM 251 with the same instructor as the Fall 2023 control section. Of the students in the class, 34% of them were not required by their major to take the course, and 17% of them were not required to take the course by either their major or pre-professional program. For this section of the course, three of seven group homework assignments were changed to include personal sections asking students to choose something related to the topic and explore connections to their own interests and goals. These assignments happened at weeks 5, 10, and 15. A personal section was chosen as individual interest driven learning has been successful as a way to promote inclusion when implemented within other chemistry programs (3). Though other institutions have implemented this strategy in the form of a full course/lab section the same idea is being applied on a smaller scale within this research. Students were given the same Likert scale survey (Fig. 1) at the same point in the semester to measure the efficacy of changes made and the effect on student perceptions of inclusion. At this point in the semester students have completed two of the three total changed group assignments.

In order to assess student interests and engagement with the material in a personal way, in depth analysis of student responses to individual components were completed using qualitative observations of student writing. Student responses were assigned to three different categories: pre-professional goals, student identity, or student hobbies/interests. The three categories observed were used to assess the level of student engagement with a specific topic across participants in the course toward the beginning of the term and closer to the end. This qualitative analysis of student responses alongside the Likert scale survey were used to measure the efficacy of the changes made to the course.

Results and Discussion

Within the Fall 2023 section of CHEM 251, no changes were made to the course and students were given the survey in figure 1. This section of the course helped to establish a baseline level of student perceptions of inclusion. Student survey responses in the fall showed that students already had a somewhat positive outlook on inclusion within the course. (Fig. 2.).

Of the twenty-five students in the course in this section of the course, twenty students completed the survey. The students that took the survey tended to agree with the prompts asked of them. With only 16% of students in the class not required to take the course for their major, or desired pre-professional, it is not surprising that 70% of the students who took the survey either agreed or somewhat agreed with the statement in question one (Fig 2.A). Similarly, 45% of students agreed that the course promoted personal engagement with the topics covered. (Fig. 2.B). When students were asked about the efficacy of groupwork in creating relationships within the class, 40% of students agreed. More notably, 10% of students strongly disagreed and 10% somewhat disagreed (Fig. 2.C). Similarly, when asked if their contributions felt valued within their group work, most students agreed with the statement, but 5% of students strongly disagreed (Fig. 2.E). This small group of students disagreeing with statements regarding the social and learning aspects of group work is notable as student disagreements in peer groups has been shown to negatively affect the learning outcomes of the assignment (4). Similarly to the first two questions, 75% students responded positively to the statement that the material presented within the course was relevant to topics around them. There were still 25% of student disagreeing with the statement which confirmed the presence of room to grow in the realm of student perceptions of inclusion within the course (Fig. 2.E).

Figure 2:

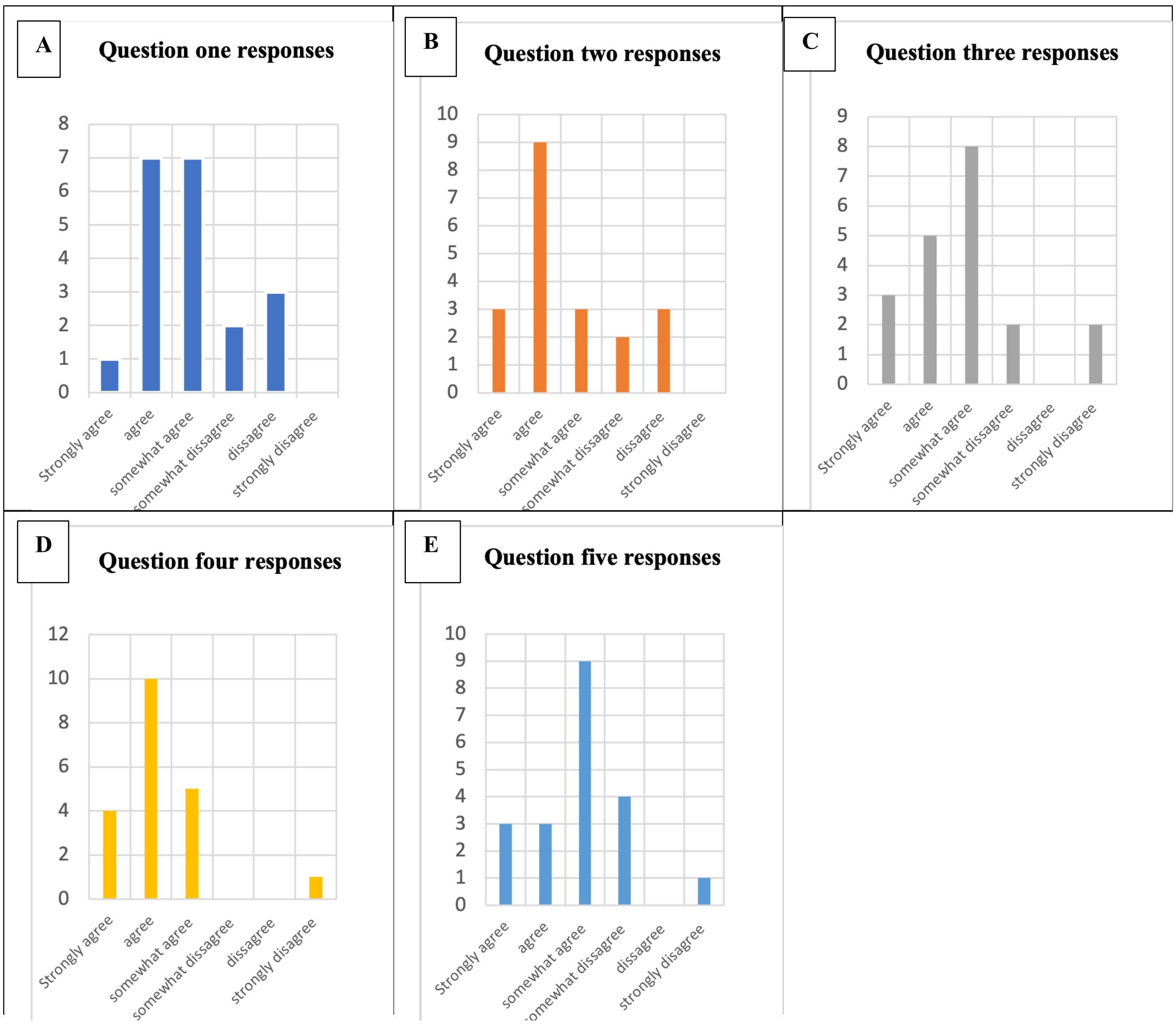


Figure 2.) Student responses to survey questions. 2.A.) Student responses to the question: The coursework given throughout this course was inclusive of my desired career path and goals. 2.B.) Student responses to the question: The coursework promoted more personal engagement with the topics covered. 2.C.) Student responses to the question: The group homework assignments were helpful to creating community within the class. 2.D.) Student responses to the question: I felt like my contributions were valued within my group work. 2.E.) Student responses to the question: The material presented connected learning outcomes to relevant topics in the world around me.

Using the results from Fall 2023 as a comparison tool, students were given the same survey at the same point in the semester to measure the change in student perceptions of inclusion in the Spring 2024 section of the course taught by the same instructor. Similarly to the group in the fall, the 17 students surveyed largely agreed with the statements asked within the survey (Fig. 3).

Figure 3:

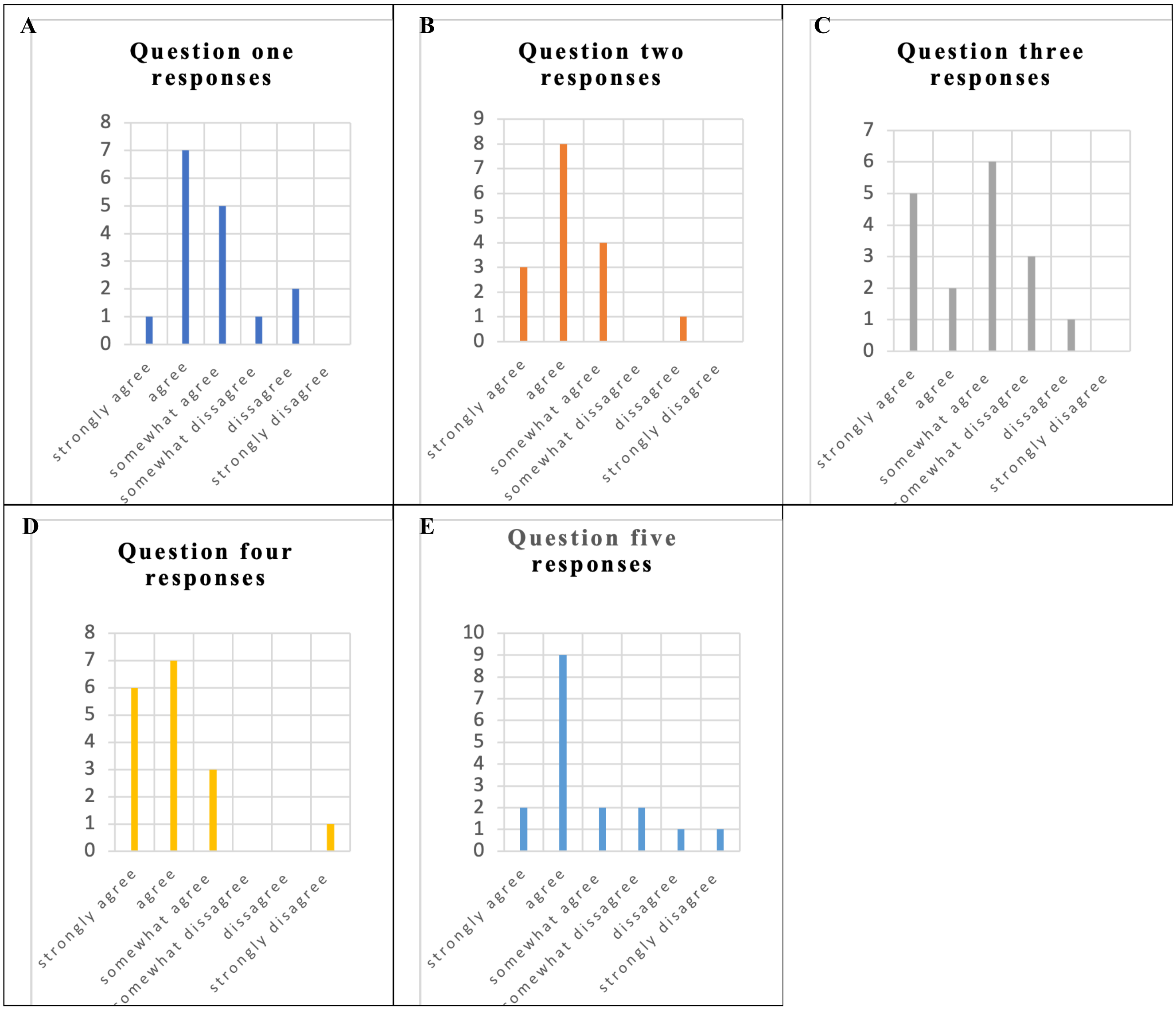


Figure 3.) Spring 2024 student responses to survey questions. 3.A.) Student responses to the question: The coursework given throughout this course was inclusive of my desired career path and goals. 3.B.) Student responses to the question: The coursework promoted more personal engagement with the topics covered. 3.C.) Student responses to the question: The group homework assignments were helpful to creating community within the class. 3.D.) Student responses to the question: I felt like my contributions were valued within my group work. 3.E.) Student responses to the question: The material presented connected learning outcomes to relevant topics in the world around me.

With 17% of students falling into the category of not being required to take the course for their major or a pre-professional program this similarity was expected. These survey results represent student perceptions of inclusion in the course at the 11 week point in the semester. Students completed two of the three altered group assignments prior to taking the survey.

Considering that the course makeup was similar between the Fall and Spring sections, the increase from 70% (Fig. 2A) of students who agreed with question one to 80% of students agreeing (Fig. 3A) would suggest that the material of the Spring course was more inclusive than that of the Fall section. For question two this same increase was observed from 75% of students agreeing in Fall 2023 (Fig. 2B) to 95% of students agreeing in the Spring 2023 course (Fig. 3B). This increase suggests that students reported engagement with materials present increased after the new assignments were implemented. Students in the Spring section of the course after completing two group assignments rated the efficacy of the group assignments as a community builder similarly. While 10% of students in the Fall section of the course strongly disagreed (Fig. 2C), no students in the Spring section expressed strong disagreement (Fig. 3C). When students were asked if their contributions to group work were valued, the Fall and Spring sections had similar results as well. Most notably, the number of students who strongly agreed increased from 20% (Fig. 2D) to 35% in the Spring (Fig. 3D). This increase suggests that while the number of agreeing students did not increase, students who agreed felt more strongly about it. When students were asked how relevant the material felt to the world around them, the Fall and Spring groups had similar results in terms of students disagreeing with the prompt. The obvious difference between the two groups is the increase in students who agreed vs. somewhat agreed with the prompt. The Fall group had 45% of students somewhat agree and 15% of students agree (Fig. 2E). The Spring group had 12% of students answer somewhat agree and 53% of students agree. While both sections of the course answered similarly across several questions, there was a notable difference in the confidence of the answer provided. Students in the Spring section of the course agreed with the questions more confidently than the students in the Fall did. This difference suggests that the change in group work model influenced how obviously students perceived the level of inclusion in the course.

In addition to evaluation of both fall and spring survey results, student responses to the individual components of two group assignments were evaluated. The third group assignment with an individual section on applications of cationic polymers was not evaluated due to time constraints. The first assignment given to students was a food toxicology application of substitution and elimination reactions. The second assignment given was an application of organometallic catalysis to the local indigenous communities and how green chemistry research can directly benefit them.

Figure 4:

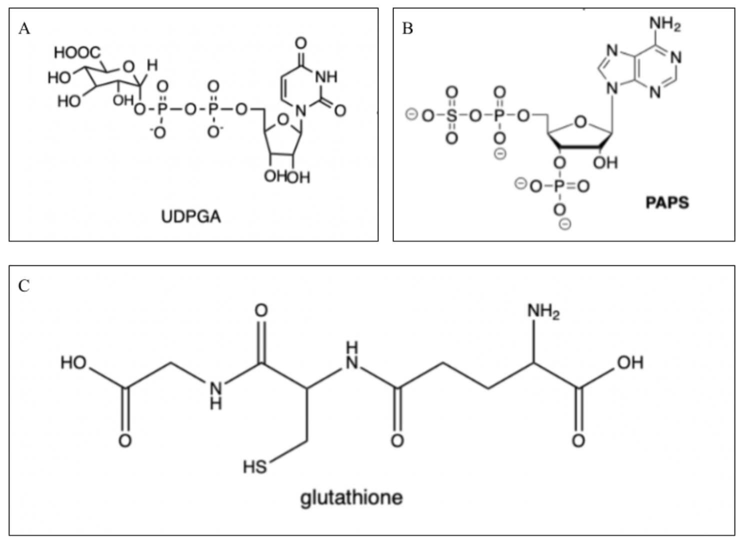


Figure 4.) Structures of UDPGA (A), PAPS (B), and GSH (C) given to students to draw a mechanism of reaction with student selected toxins and xenobiotics.

Within the food toxicology assignment, students were asked to individually identify a specific food toxin or other xenobiotic and provide a mechanism of the reaction between their choice and UDPGA, PAPS, or GSH (Fig. 4). Out of a total of 18 students, all but one student chose a compound to complete this assignment with. Student responses were evaluated within three categories to measure levels of engagement with the topic of choice. Each student chose a molecule of interest and related it to either their identity, interests, or pre-professional goals. Some students related their choice to more than one category. Most notably, one student chose Red 40 and its reaction with UDPGA for their individual investigation. The student chose red 40 dyes as they are common in the candies that their community ingests regularly, the student also related their choice to their goal of becoming a doctor and that knowing more about this dye can help them to be a more culturally competent doctor, especially when in relation to their own community. Another student chose heterocyclic amines found in meats after grilling. This student wrote about their choice and how it related to their love of grilled and cured meats and that they hadn't considered that the chemistry they were currently learning could be so applicable to the food they eat. Overall, most of the students that completed the assignment answered in relation to one of the three categories (Fig. 5). With only 7% of students not choosing a molecule relevant to their career goals, identity, or interests, most students related to one or more category. The majority of students related the topic to a career goal. With only 17% of students in the course not required to take CHEM 251 for their major, or preprofessional program it is no surprise that students were expanding the topic of food toxicology to include their own interests or goals relating to non-medical applications of the topic in green chemistry research, agricultural chemistry, or sports. This assignment also led to students relating chemistry topics to their hobbies and identities outside of education. Several students related their molecule to the communities around them and potential implications of toxicity to their community. The previously mentioned student who chose heterocyclic amines expressed concern around repeat ingestion of grilled meats for their friends and family members. Another student chose BPA as their molecule of choice and related the topic to their on-campus summer research project on microplastics within local waterways.

Figure 5:

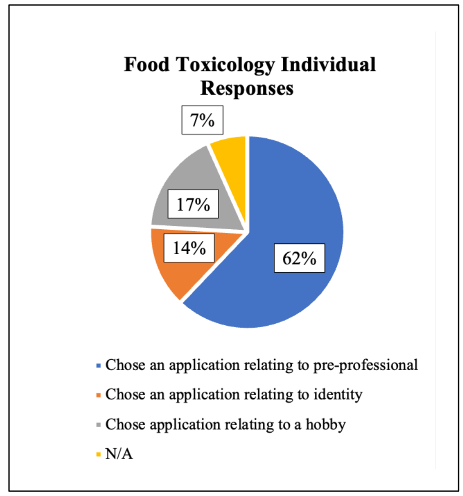


Figure 5.) Individual student responses to the food toxicology assignment sorted into categories representing student engagement.

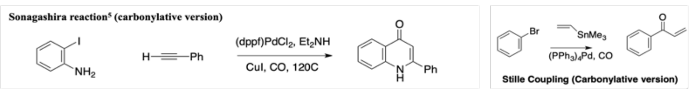
Within the organometallic catalysis group homework students were asked to provide the catalytic cycles for both Sonagashira (5) and Stille coupling carbonylative reactions. Individually, students were given a literature article outlining the Sonagashira reaction with the use of the mesoporous silica catalyst prepared using rice husk waste from agriculture (6). Students were also given a literature article detailing the process of silica extraction of white rice husks and preparation of the mesoporous silica catalyst (7). After the completion of background reading and catalytic cycle mechanism drawings (Fig. 6A), students moved on to the individual identity application of the topic.

Before students moved on from the problems presented in Figure 6A, students were individually given background on White Earth Nation and the history of boarding schools run by The Order of Saint Benedict monastery. Students were also given background directly from White Earth Nation and their important history of the cultivation of Manoomin, which is Ojibwe for wild rice. After reading the background on local indigenous communities, students were given an example application of green silica extraction and how it can be applied to ceramic pottery. Students were also asked to find, and cite, a literature publication of recycled rice hulls, give a summary of the paper, and an explanation about what connects them to the paper they chose (Fig. 6B)

Figure 6A:

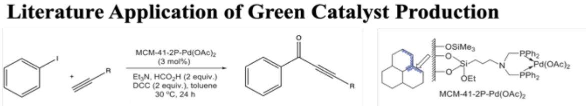
Sample Questions Taken From the Assignment:

The following group assignment falls ¾ of the way through the semester. Students will have had all the in-class instruction on the topic of organometallic catalytic cycles and will be preparing to take the cumulative problem-solving assessment for the unit. The goal of this assignment is to prepare students for the cumulative assessment by engaging them with literature and providing more practice to ensure student understanding of organometallic topics.. The updated version of the assessment will also touch on CSBSJU history and the topic of art as it relates to silica catalysts.



For the reactions above students in groups will be asked to propose a catalytic cycle following what they have learned in class. Students are typically given class time for this assignment.

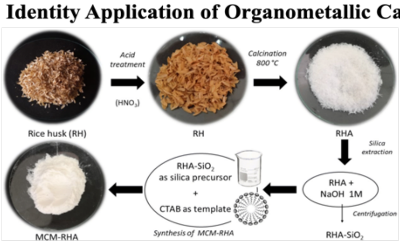
Literature Application of Green Catalyst Production



[6]Sonogashira reaction using MCM-41-2P-Pd(OAc)$_2$ [6]Structure of MCM-41-2P-Pd(Oac)$_2$

Using the literature applications provided students will be asked to compare the two methods of the Sonagashira process and explain why the use of a heterogeneous catalyst could be better than a homogeneous catalyst.

Identity Application of Organometallic Catalytic Cycles



Using the example for the preparation of MCM-RHA using white rice husks, students are introduced to the history of CSBSJU and White Earth Nation. Students will complete this aspect of the homework individually.

Eco-friendly synthesis of nanostructured mesoporous materials from natural source rice husk silica for environmental applications[7]

Figure 6A.) First half of the organometallic catalysis group homework including both group work problems and individual literature exploration.

Figure 6B:

Background on White Earth Nation[4] and Minnesota Wild Rice

White Earth Reservation is located in Becker, Clearwater, and Mahnomen counties in north-central Minnesota. Created in 1867 by a treaty between the United States and the Mississippi Band of Ojibwe Indians, it is one of seven Ojibwe reservations in Minnesota. Although the White Earth Ojibwe no longer live as their ancestors did, they have kept alive their tribal heritage. Almost every aspect of their present-day life has been strongly influenced by the past[7].

The growth and collection of Manoomin, Ojibwe for wild rice, is a sacred practice of stewardship for the People of White Earth and other Midwest Indigenous communities[8].

CSB/SJU has ties to White Earth Nation in our institution's history running indigenous boarding schools.

Sample Identity Based Questions

Similar to the study done in the preparation of MCM-RHA, Minnesota wild rice also has a husk that is considered waste material.

- Suggest a difference between Minnesota wild rice and white rice that may affect silica yields in experimental studies.
- Suggest a way that collection of silica from wild rice hulls could benefit White Earth and other indigenous communities in the state of Minnesota

Another tie to White Earth and CSBSJU comes from the St. Johns pottery. Artist in Residence Richard Bresnahan recycles wild rice husk from White Earth for use in his artwork.

- Suggest a role in the creation of pottery for wild rice hulls and the silica that can be extracted from the husk

Using the study of Rice Hull recycling, and the St. Johns Pottery use of wild rice

- Propose a use for recycled rice hulls and the silica that can be harvested citing a recent publication relating to the topic

Figure 6B.) Second half of the organometallic catalysis assignment including background and history of White Earth Nation and ties to the community at CSB/SJU.

Within student responses to the individual components of the assignment students were asked to propose a way that use of wild rice hulls could directly benefit indigenous communities in Minnesota in addition to finding their own application of the rice husks. As students investigated the benefits of rice hull recycling to local indigenous communities, many of them found applications of mesoporous silica catalysts in water treatment and related it to the issue of a lack of clean water for indigenous populations due to outside pollutants. One student proposed that indigenous communities could recycle the rice hulls themselves to create profit for the community as they could sell the silica. Another student described the cultural benefits of indigenous communities recycling wild rice hulls as it would open the door for indigenous chemists to have a direct hand in silica containing chemistry across all fields of chemistry. The applications chosen by students were also evaluated using the three categories used in the food toxicology example to examine student interaction with the material (Fig. 7). Similarly to the food toxicology assignment, the majority of students applied the topic to a future career goal. One student with the goal of entering medicine provided an example of mesoporous silica catalysts and their application to pharmaceutical drug delivery in cancer patients. 19% of students related the topic to an aspect of their identity, several students continued their applications from the benefits to local indigenous communities to include their own concerns regarding access to clean water for consumption. Only 5% of students applied the topic to a hobby, but one student passionate about the effects of natural disaster on low income communities and ways to mitigate inequality also expanded on how use of silica nanoparticles can be used as bioenergy and also in waste management.

Figure 7:

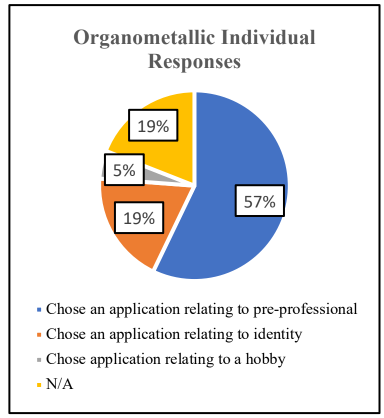


Figure 7.) Individual student responses to the organometallic catalysis assignment sorted into categories representing student engagement.

Comparing the levels of student engagement with the individual assignment with the results of the survey questions concerning group homework it is shown that the 6% of students who strongly disagreed with questions three and four (Fig. 3C-D) can be compared to the number of students who did not complete the individual engagement of each assignment (Fig. 5) (Fig. 7). After individual assignment submissions were reviewed, it was clear that some students engaged with the material more personally than others. The two data sets compared together suggest that the updated model including individual prompts successfully increased student perceptions of inclusion of their interests as well as increasing student engagement with the material on a personal level.

Conclusions

After analyzing survey results collected in both the unchanged Fall 2023 section of CHEM 251 and the Spring 2024 section after changes were implemented, there were notable changes to student responses. While students in the Spring section agreed and disagreed at similar rates, the number of students who chose “agree” and “strongly agree” increased compared to the fall section of the course. After analyzing student submissions, it is clear that the changes made to the group work had a positive effect on student engagement and a more confident perception of inclusion within the course.

Next steps would be to expand the updated group work model to include future sections of CHEM 251 taught by the same instructor to increase the sample size and draw more clear connections to the updated assignments and student survey results. The group work model proposed in this thesis could also be to include sections of CHEM 251 taught by other instructors to compare results between instructors. It is clear that increasing student engagement with topics has an effect of perceived inclusion in the course and a similar model can be implemented in the other chemistry courses offered at The College of Saint Benedict and Saint John’s University.

References

(1) Wilson, S. B.; Varma-Nelson, P. Small Groups, Significant Impact: A Review of Peer-Led Team Learning Research with Implications for STEM Education Researchers and Faculty. *Journal of Chemical Education* **2016**, *93* (10), 1686–1702. https://doi.org/10.1021/acs.jchemed.5b00862.

(2) Micari, M.; Drane, D. Intimidation in Small Learning Groups: The Roles of Social-Comparison Concern, Comfort, and Individual Characteristics in Student Academic Outcomes. *Active Learning in Higher Education* **2011**, *12* (3), 175–187. https://doi.org/10.1177/1469787411415078.

(3) ARNAUD, C. H. STUDENTS GET a SAY. *Chemical & Engineering News* **2008**, *86* (5), 31. https://doi.org/10.1021/cen-v086n005.p031.

(4) Lindow, J. A.; Wilkinson, L. C.; Peterson, P. L. Antecedents and Consequences of Verbal Disagreements during Small-Group Learning. *Journal of Educational Psychology* **1985**, *77* (6), 658–667. https://doi.org/10.1037/0022-0663.77.6.658.

(5) Kalinin, *Tet. Lett.*, **1992**, *33*, 373

(6) Carraro, P.M. *Environ Sci Pollut Res* **28,** 23707–23719 (2021).

(7) Zebiao Zhou Synthetic Communications, 50:13, 2015-2025

(8) History. https://whiteearth.com/history

Appendix

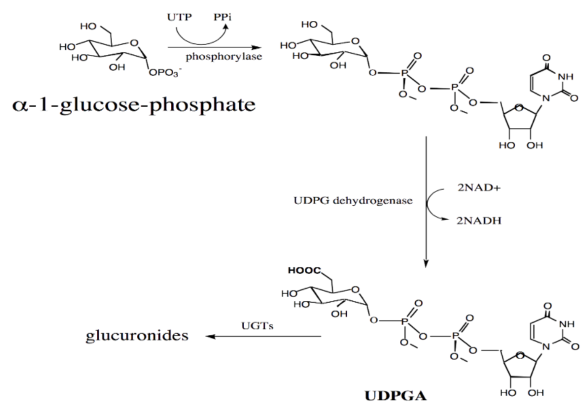
1. Group Homework Assignment: Food Toxicology Applications to Substitution and Elimination Reactions

Substitution and Elimination Group Homework: **Topic:** Food Toxicology

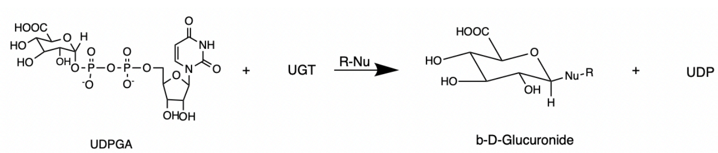
Background: The body needs to be able to convert lipophilic foreign substances (xenobiotics) to hydrophilic molecules that can be excreted in urine or bile. This happens by phase 1, phase 2, and phase 3 metabolic reactions. Phase 3 reactions describe a system of efflux pumps that exclude water soluble products of metabolism from the cell to the interstitial fluid, blood, and finally the kidneys. We will focus here on phase 2 reactions. (Parts of this are borrowed, with permission, from Dr. McIntee's Xenobiotic Metabolism class)

Phase 2 reactions: The most important phase 2 reactions are addition of glucuronic acid, sulfate, or glutathione to increase the hydrophilicity of a molecule so that it can be excreted by the kidneys (urine) or intestines (bile).

Glucuronic acid derivative: Glucuronidation is where a glucuronic acid is attached to a nucleophile. First the glucuronic acid must be made into a good electrophile (i.e. needs a good leaving group). Uridine 5'-diphospho-glucuronic acid (UDPGA) is the electrophile of choice (also known as a cofactor). The enzyme responsible for transferring the glucuronic acid onto a nucleophile is known as UDP-glucuronosyltransferases (or UGT).

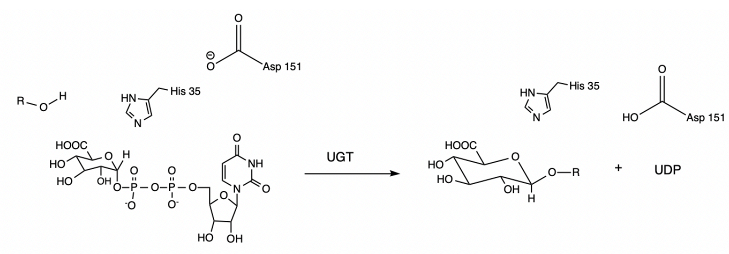


- Provide arrows for the following mechanism:



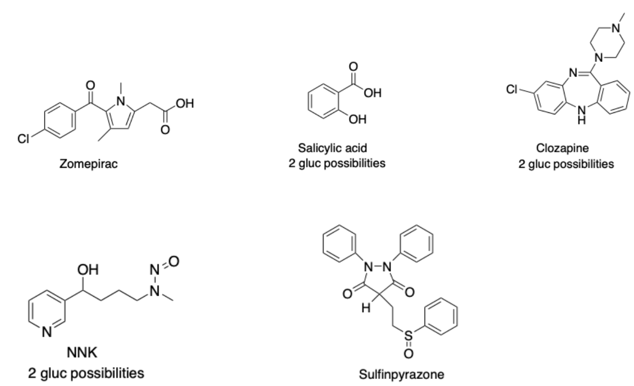
- What type of mechanism is this and why?

- In the active site are a histidine and aspartic acid. Suggest a role for these key amino acids and draw arrows for the mechanism.

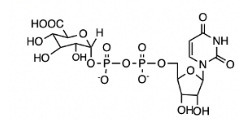


- For the mechanism above, is R-OH or R-O⁻ a better nucleophile?

- In each of the following molecules, circle the atom that will do the nucleophilic attack on UDPGA to form a glucuronide. (Hint: identify the most nucleophilic and least crowded sites):



Choose one of the above nucleophiles and propose a mechanism and product for a reaction with UDPGA. Remember to show reactants, products, and electron pushes for **each step** of the mechanism.

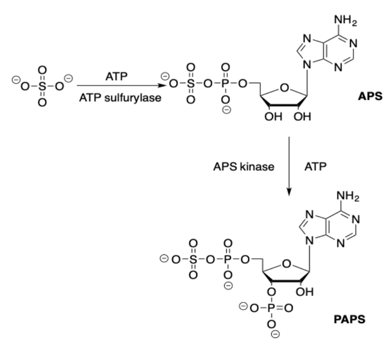


UDGPA

- ***Sulfate derivative***: Sulfonation is less extensive than glucuronidation. It has a similar preference for functional groups – a subset of acceptor types that glucuronidation has e.g., phenols, alcohols, arylamines. Sulfonation does not happen on thiols, carbanions, or carboxylates. It has many endogenous substrates – steroids, bile acids and phenols, neurotransmitters, proteins, carbohydrates, etc. Sulfonation is a low capacity, high affinity system whereas glucuronidation is high capacity, low affinity

The co-factor needed for sulfonation is 3'-phospho-adenosine-5'phosphosulfate (PAPS). PAPS is made from sulfate and ATP.

- Draw the mechanism for the first step (sulfate+ ATP).
- Draw the mechanism for the second step (APS+ATP).
- For each of the mechanisms you just drew, circle the nucleophile, draw a square around the electrophile, and highlight the leaving group.

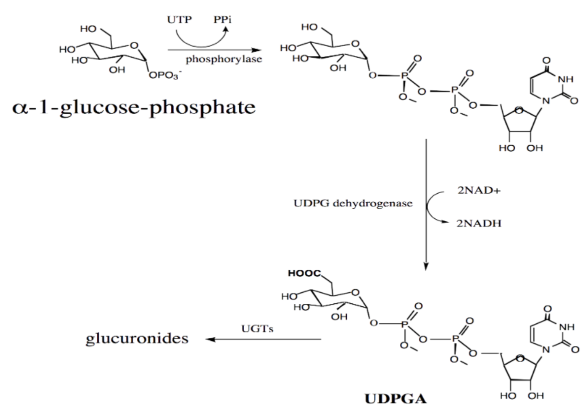


Substitution and Elimination Group Homework: **Topic:** Food Toxicology

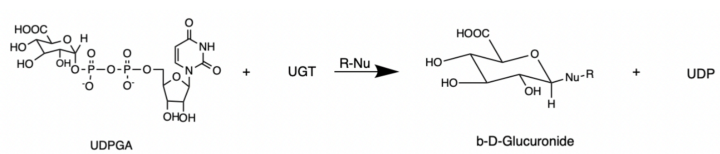
Background: The body needs to be able to convert lipophilic foreign substances (xenobiotics) to hydrophilic molecules that can be excreted in urine or bile. This happens by phase 1, phase 2, and phase 3 metabolic reactions. Phase 3 reactions describe a system of efflux pumps that exclude water soluble products of metabolism from the cell to the interstitial fluid, blood, and finally the kidneys. We will focus here on phase 2 reactions. (Parts of this are borrowed, with permission, from Dr. McIntee's Xenobiotic Metabolism class)

Phase 2 reactions: The most important phase 2 reactions are addition of glucuronic acid, sulfate, or glutathione to increase the hydrophilicity of a molecule so that it can be excreted by the kidneys (urine) or intestines (bile).

Glucuronic acid derivative: Glucuronidation is where a glucuronic acid is attached to a nucleophile. First the glucuronic acid must be made into a good electrophile (i.e. needs a good leaving group). Uridine 5'-diphospho-glucuronic acid (UDPGA) is the electrophile of choice (also known as a cofactor). The enzyme responsible for transferring the glucuronic acid onto a nucleophile is known as UDP-glucuronosyltransferases (or UGT).



- Provide arrows for the following mechanism:

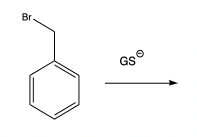


- What type of mechanism is this and why?

The enzyme responsible for transferring a GSH molecule is glutathione S-transferase.
GSH reactions: Sulfur on GSH is one of the best nucleophiles in your body.

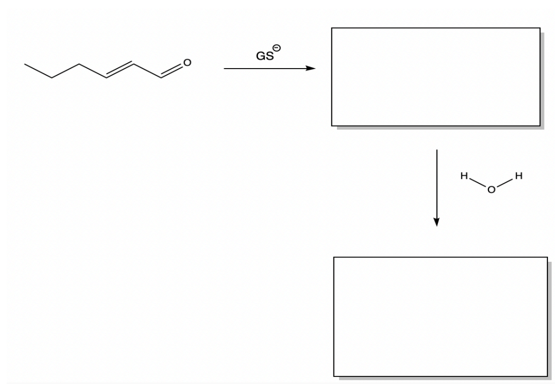
I. Nucleophilic substitutions.

- Predict the product of the following reaction and draw the mechanism:



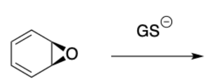
II. Nucleophilic additions to ketones, aldehydes, esters, α–β unsaturated Michael acceptors.

- Predict the product of the following reaction and draw the mechanism:



III. Nucleophilic addition to epoxides.

- Predict the product of the following reaction and draw the mechanism:
- What type of reaction is this?
- Make sure to draw stereochemistry of your product.

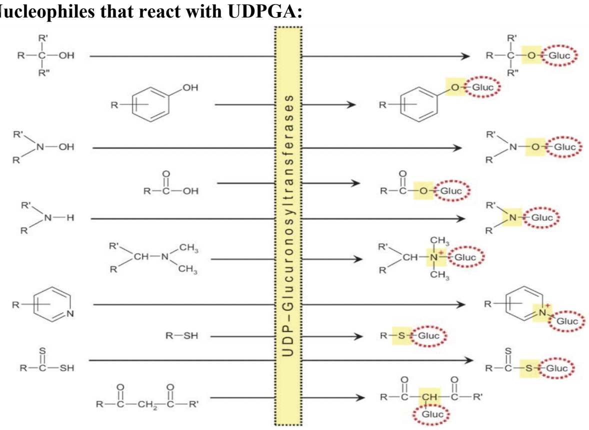


Each Group Member must complete (and upload to Canvas) this section individually

The processes described within this group homework relates to the ability of your body to expel lipophilic foreign substances through the bile or urine. This topic has ties to both nutrition and pharmacology as the kidneys filter foreign substances out.

1. Choose a molecule that is a food related toxin, drug, or other substance foreign to the human body and propose an interaction with UDPGA, PAPS, or GSH. Make sure to include structures of reactants and products. Note UDPGA can react with a wide range of nucleophiles (see figure below); PAPS reacts with alcohols, phenols, or arylamines; GSH reacts with a number of electrophiles (see page 5).

Nucleophiles that react with UDPGA:



2. Write three sentences about why you selected the molecule you did in question 1- does it relate to your future interests, plans, or goals; does it relate to something in your background; was it something you found interesting in the news?

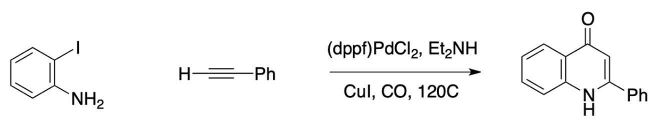
2. Group Homework Assignment: Organometallic Catalysis Applications to Local Indigenous Groups, Art, and Green Chemistry

Organometallic Catalysts Group Homework: Ties to our community

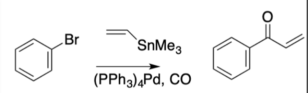
Sonogashira Application

Sonogashira reaction also has a carbonylation variation. The following example shows the synthesis of a pyridone in which the carbonylation and cyclization occur in tandem (Kalinin, *Tet. Lett.*, **1992**, *33*, 373).

- Propose a cycle for this process



Stille Coupling (Carbonylative Variation)



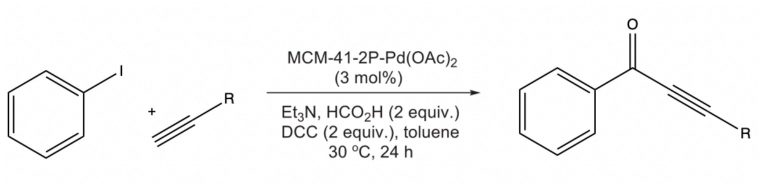
Stille Coupling (Carbonylative version)

Like many of these reactions, there is a carbonylative version of the Stille Coupling.

- Propose a catalytic cycle for carbonylative version shown above

Literature Applications

Recyclable heterogeneous palladium-catalyzed carbonylative Sonogashira coupling under CO gas-free conditions *(Zhou et al., 2020, 50, 13)*

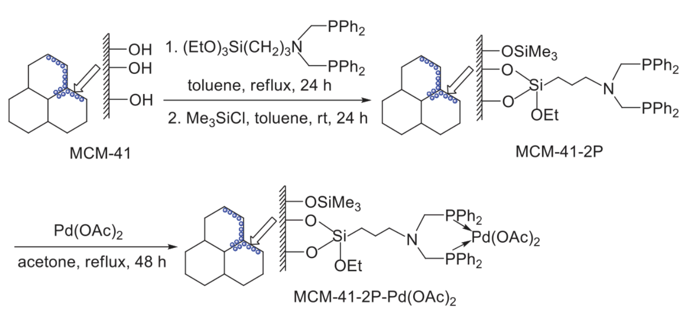


Through the heterogeneous palladium-catalyzed carbonylative Sonogashira coupling reactions of aryl iodides with terminal alkynes, with formic acid as the CO source, a wide range of alkynyl ketones could be produced in moderate to high yields. Importantly, this heterogeneous palladium catalyst can be easily recovered via a simple filtration process and recycled at least eight times without apparent loss of activity. This system not only avoids the usage of gaseous CO, but also solves the basic problems of palladium catalyst recovery and reuse. Thus, the present method represents the first example of both using formic acid as a liquid CO source and an MCM-41-supported palladium complex as a recyclable catalyst for the carbonylative Sonogashira coupling reaction. *(Zhou et al., 2020, 50, 13)*

MCM-41-2P-Pd(OAc)$_2$ acts as a heterogeneous catalyst, in other carbonylative Sonagashira couplings the catalyst is homogeneous.

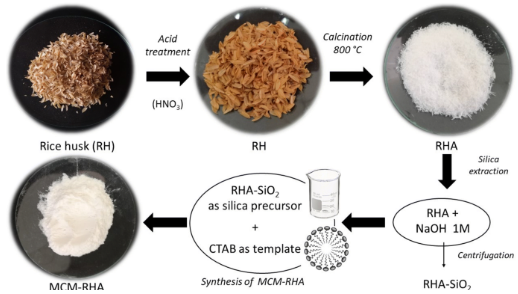
- Propose a reason for the benefit of a heterogeneous catalyst over a homogeneous catalyst.

Preparation of MCM-41-2P-Pd(OAc)$_2$



Let's make this greener!

Eco-friendly synthesis of nanostructured mesoporous materials from natural source rice husk silica for environmental applications *Environ Sci Pollut Res* **28,** 23707–23719 (2021)



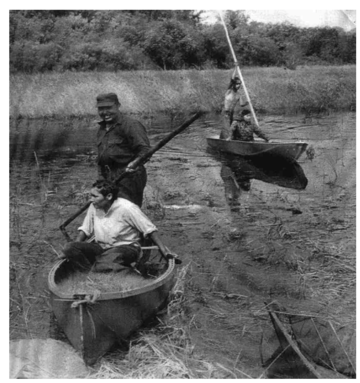
Using the process above, MCM-41 catalyst is produced using the MCM-RHA.

Community Application (Complete Individually): CSB/SJU has ties to White Earth Nation in our history running boarding schools.

From the White Earth Websites (https://whiteearth.com/history): White Earth Reservation is located in Becker, Clearwater, and Mahnomen counties in north-central Minnesota. Created in 1867 by a treaty between the United States and the Mississippi Band of Chippewa Indians, it is one of seven Chippewa reservations in Minnesota. Although the White Earth Chippewa no longer live as their ancestors did, they have kept alive their tribal heritage. Almost every aspect of their present-day life has been strongly influenced by the past.

The wild rice of the White Earth Reservation is an all natural grain that grows untamed in the cool clear waters of northern Minnesota. The rice kernel itself is actually a cereal grain produced from an annual water grass plant that rises to a height of three to eight feet with the seed pods emerging above the water's surface. Wild rice is one of only two cereal grains that are native to North America, and is the state grain of Minnesota.

Manoomin, the Ojibwa word for wild rice, translates to "good berry." The rice was not only a staple in the diets of the native people for generations; it is also a spiritual food, considered to be a gift from the Great Spirit or Creator. To this day we continue to only hand harvest the rice with non motorized canoes to help preserve the all natural product that we have. By hand harvesting, only the mature ripe kernels are taken ensuring the quality and taste and leaving the remaining immature kernels to ripen and fall back into the water to ensure the next year's crop.



Our product has an earthy nutty flavor that is high in protein, dietary fiber, amino acids and is low in fat. It is not to be mistaken with genetically altered cultivated or paddy wild rice that is now widely produced primarily in Minnesota and California with the use of pesticides, insecticides, and other chemicals. We take pride in the fact that that we have a naturally organic product that has remained the same for generations.

Growing wild in our natural lakes and rivers, our wild rice is traditionally hand harvested and finished, and is naturally organic- just the way mother nature intended it to be.

https://realwildrice.com/history/

Similar to the study done in the preparation of MCM-RHA, Minnesota wild rice also has a husk (also called a hull) that is considered waste material. The purpose of the husk (formed from hard materials, including silica) is to form a coating on the seed to protect it during the growing season.

- Suggest a difference between Minnesota wild rice and white rice that may affect silica yields in experimental studies. (Hint: search for difference in wild rice and white rice)

- Suggest a way that collection of silica from wild rice hulls could benefit White Earth and other indigenous communities in the state of Minnesota (i.e., how could it be productively used?).
    - (Hint: search some issues facing Minnesota's indigenous community health and applications of silica in environmental applications)

Another tie to White Earth and CSB/SJU comes from the St. Johns pottery. Artist in Residence Richard Bresnahan recycles wild rice husk from White Earth for use in his artwork.

- Suggest a role in the creation of pottery for wild rice hulls and the silica that can be extracted from the husk (Hint: search for how silica is used in pottery)

Recycled rice hulls, silica, and you/your interests:

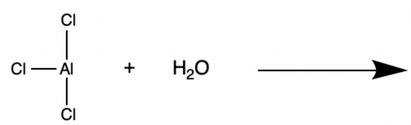
- Propose a use for recycled rice hulls and the silica that can be harvested that is of interest to you.
    - (Hint: in SciFinder search "Rice Husk" or "Silica" and find a topic that interests you)
- Include the ACS citation for the paper you found.
- Write a summary of the findings within the paper.
- Write a paragraph about how/why the topic interests you/relates to your own future interest and/or goals.

3. Group Homework Assignment: Cationic Polymers, Application of Choice

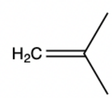
<u>Cationic Polymer Synthesis Group Homework</u>

<u>Synthesis of Polyisobutylene</u>

Provide arrows and draw the product of the following reaction:



Using the product above draw the initiation reaction of isobutylene



Using the initiation product above, provide the propagation reaction mechanism to add 2 monomer units and product.

Applications of cationic polymerization from literature. (Complete alone)

1. Provide an example of cationic polymerization other than polyisobutylene from the literature, including ACS citation (SciFinder is a good way to do this).
2. Draw the mechanism.
3. Explain the uses of the polymer.