The Benefits of Enlightenment: A Strategic Pedagogy for Strengthening Sense of Belonging in Chemistry Classrooms

Shana V. Stoddard

Abstract: Science, technology, engineering, and mathematics (STEM) fields have remained stagnant in increasing diversity. An important factor in increasing diversity is building and supporting diverse cohorts of future STEM professionals in our classrooms. A strong sense of belonging in STEM has been demonstrated to increase persistence of women, underrepresented minorities, and first-generation college students in STEM or the college atmosphere. Therefore, it is important that STEM faculty develop inclusive teaching strategies to increase and support this sense of belonging in STEM for all students. This work evaluates a faculty-developed assignment implemented in Fall 2020 at a liberal arts college on a student’s sense of belonging in STEM. The results demonstrated that this semester-long project increased students’ sense of belonging in STEM. Current literature about any faculty-developed assignments focused on supporting a student’s sense of belonging and awareness of diversity in STEM implemented in chemistry courses is limited. This work represents a new approach grounded in inclusive pedagogy that can be utilized in addition to other institutional and departmental support structures to increase diversity and equity in STEM.

Keywords: sense of belonging in STEM; diversity; equity and inclusion in STEM

1. Introduction

Diversity in the field of STEM has lagged in many areas [1]. There are still higher attrition rates for women, underrepresented minorities (URM: African American/Black, Alaskan Native, American Indian, and individuals of Hispanic/Latinx ethnicity), women of color (WOC), and first-generation college (FGC) students. Students from these backgrounds can face unique challenges due to their race, gender, or educational status as a result of the structural inequities in the educational system. For example, women, URM, and WOC must contend with stereotype threat—“the fear of confirming a negative stereotype about a group you identify with,” microaggressions, stereotype lift—“the fear of not living up to a positive stereotype of a group you identify with,” and the lack of relatable representations [2–8]. FGC may have lower academic and social integration at the college level producing a number of challenges in adequately accessing the college environment [9].

One common theme in the literature studying students’ sense of belonging in STEM, or “the feeling of connectedness to the community and feeling valued, accepted, included, and encouraged by others to be a part” [10], is lower in these groups compared to individuals who are not underrepresented in STEM [11–15]. A growing body of literature has consistently pointed to a sense of belonging as an important factor which predicts interest, STEM success, and achievement [4,16] linking a sense of belonging to increased student success [17], and persistence of students from women and URM in STEM [4,11] This highlights the need to identify more ways to support and promote a sense of belonging to increase matriculation and success of women, URM, WOC, and FGC into STEM careers.

Principles have been elucidated to assist institutions and faculty to facilitate the development of a stronger sense of belonging in STEM for these populations [5,7] at the programmatic, classroom, and faculty level. At the programmatic level, establishment
of programs to mentor and support students from these groups such as the Engineering Retention Program developed at Sunny University [7], STEM-Dawgs at the University of Washington [18], Sundial Mentoring Program developed at Arizona State University [19], and Focusing on Cultivating Scientists and Carleton Summer Science Fellows programs at Carleton College [20] have been developed. At the classroom level, much emphasis has been placed on the establishment of tutorial support structures and peer role model programs to enhance academic achievement [18]. On the faculty side, a number of efforts have been made to foster more participation from marginalized groups in STEM [21–23]. Some of these successful efforts are providing faculty development, encouraging faculty to use culturally responsive pedagogies, challenge implicit biases, and understanding how privilege impacts faculty members’ interactions with their students. Another important intervention for faculty is participating in inclusive excellence in teaching [21–23].

Despite the importance of a faculty member’s role in fostering a sense of belonging in students in STEM courses, more work is needed to explore faculty-designed classroom interventions that promote a student’s sense of belonging. Curricula integrating social justice and environmental justice have been integrated into the chemistry classroom as a means to increase the relevance of chemistry to students and help them understand their role in being agents of change [24–27]. A new chemistry curriculum has been argued for, as a path to increasing representation of underrepresented groups in STEM [28]. However, none of the aforementioned reports or studies have specifically focused on or evaluated impacts on students’ sense of belonging. In regard to diversity, only one report could be found that explicitly taught about social diversity in a chemistry classroom. Nawarathne et al. developed and described an assignment introducing diversity in an organic chemistry course at a predominantly white liberal arts institution. In these assignments, students were charged to consider the ways carbon is so versatile and relate this molecular diversity to social diversity [29]. The students then drew representations that related the diversity in organic chemistry to social diversity. The assignment was demonstrated to reinforce the value of diversity, but did not evaluate the assignment’s impact on students’ sense of belonging in STEM.

There is a need for more resources for STEM faculty to mitigate the challenges that students from these backgrounds may be presented within our classrooms, on our campuses, and in the STEM workforce. Unfortunately, STEM faculty members can have difficulty with introducing curricula surrounding diversity, equity, and inclusion in their courses [30]. This article reports on a faculty-developed classroom activity that was demonstrated to increase a student’s sense of belonging. While these measures are known to be strongly correlated to enhancing academic performance of these populations [4,16,17], gains in academic performance are not the scope of this work. This pilot study aims to provide a practical assignment which can be implemented in chemistry and STEM classrooms at large, which will support students’ sense of belonging in STEM. The overall goal is to use the project-based assignment as a tool to dismantle the negative impact of psychosocial factors (such as stereotypes, lower self-efficacy, lack of available role models, and a decreased sense of belonging), in addition to structural barriers in the classroom (lack of diverse representations, no integration of topics of diversity, equity or inclusion, and lack of faculty resources to integrate these topics). These factors compete against and discourage students from marginalized backgrounds to pursue, persist, and prosper in STEM, thus work is needed to develop strategies to nullify their effects in our classrooms. This “enlightenment” discovery of awareness of diversity and equity challenges in STEM is explored in this paper. Thus, the hypothesis evaluated in this study was:

*Strategic exposure to diversity, equity, and inclusion themes in a chemistry course will have a positive effect on a student’s sense of belonging in STEM.*
2. Materials and Methods

2.1. IRB Approval

This article reports the evaluation of an instructor-developed project termed the “Chemtutorials” project, which was conducted during the Fall 2020 semester. This retrospective pilot study was conducted after the course ended. IRB approval was secured to survey students about their perspectives on the Chemtutorials project. Data were collected from students for the two-week period beginning after the final day of class. Of the 39 students enrolled, 29 students completed the post survey and consented to participation in the research study.

2.2. Study Location and Participants

The project was conducted at Rhodes College, a selective, private, residential liberal arts institution. Rhodes is a predominately White institution, with the following demographics: 1.8% American Indian/Native Alaskan, 11.6% Black/African American, 11.5% Asian, 72.7% White, 5.2% multiracial, 32.6% persons of color (POC), 66.7% majority students, 58.1% women, 41.9% men. The instructor’s course, Chem 120: Foundations of Chemistry, is a first-year introductory chemistry course. The course was taught remotely via Zoom during the Fall 2020 semester and had 39 students enrolled. The course covered material from 14 chapters (Chapters 1–10, 13, 15, 16, and 20) of the Gilbert Chemistry 4th edition text. The demographics of the instructor’s course were as follows: 4.5% American Indian/Native Alaskan, 20.5% Black/African American, 20.5% Asian, 56.8%, White, 7.7% multiracial, 53.8% POC, 46.2% majority students 66.7% women, 33.3% men. The 29 students who consented to participate in the study were allowed to self-identify their biographical information. A total of 65.5% self-identified as women, 37.9% as URM, 31% as WOC, and 13.8% as FGC students. No students self-identified as non-binary.

The Chemtutorials post survey (Table S1 in Supplementary) was a 31-item survey data collection tool developed to measure the impact the project had on students’ STEM identity, feelings of belonging in STEM, and motivation to persist. Additionally, the survey was used to evaluate student attitudes toward the project, experiences in STEM, and impact the project had on student awareness of careers in chemistry. Out of the 31 questions, 29 were Likert scale/numerical scale questions using the response options (1 = Strongly disagree, 2 = Disagree, 3 = Neither disagree or agree, 4 = agree, or 5 = Strongly agree). Students were asked to rank their level of agreement with the statement presented. Eight of the 29 Likert scale/numerical scale questions also had associated follow-up open-form (essay response) questions to garner qualitative data. All qualitative data were acquired through the survey responses. The 30th item was an open answer fill in the blank response. The 31st item was a free response comment box for students to add any additional comments they wanted to have documented.

2.3. Chemtutorials Project Design and Implementation

The Chemtutorials project was a semester-long project worth a total of 100 points with the project itself and the classroom discussion worth 75 and 25 points, respectively. The total amount of points students could earn in the course was 900. The course instructor uses a cooperative learning teaching style and places all students in cooperative discussion learning groups, of two to three students, for the duration of the semester. Students were required to complete the Chemtutorials project within their instructor-assigned groups.

The goals of the project were three-fold; to explore the benefits and impact of diversity in chemistry, identify the accomplishments of chemists in the real world, and develop a presentation and placard for the cabinet display remodel to be included in the chemistry building on campus. As part of the project, students had to interview a living chemist of color from an underrepresented background in STEM and develop a summary of the discussion highlighting their career, their experiences, and their major innovations in chemistry. Students were required to research at least three chemists adhering to the following criteria:
- At least two chemists had to be from a racial background that is currently underrepresented in chemistry (American Indian, Alaskan Native, Black or African American, and Hispanic);
- At least one chemist had to be female;
- At least one chemist had to be living;
- At least one chemist must have been born before 1950;
- The selection of chemists had to represent at least two different fields of chemistry (e.g., medicinal chemistry, analytical chemistry, forensic chemistry, computational chemistry, biochemistry, etc.) and represent at least two sectors of work (e.g., industry, academia, government, entrepreneurship, non-profit sector, etc.)

To ensure that no chemist was selected twice, student groups were instructed to obtain approval from the instructor on their selections. The aim was to increase the number of chemists that students would be exposed to by the end of the project. Students choosing a chemist that had already been selected by another group were instructed to choose another chemist to research.

Students were required to develop an educational resource to highlight their selected chemists, which included the following information:
- An explanation of the chemical concepts that were discovered or used by their chemists;
- A copy of at least one publication, patent, or image of the invention that their selected chemists had developed:
  - Two to three nice images of their chemists. A headshot was required, and images of their chemist at work were recommended;
- Five practice problems that related to the chemistry the chemist used in their innovations;
- A summary of the interview with their living chemist of color;
- The references for their information;
- A placard for each of the chemists researched having the following information:
  - A brief summary of the chemist’s specific field of chemistry, innovations, career highlights, and challenges they have overcome; and
  - A label in the bottom right-hand corner to identify the students’ work using the following phrase: “This placard was created by, “Students names,” Class of “Graduation year”;

Students were also required to research statistical data and create a visual graph to display the answers to the following questions as part of the Chemtutorials project:
- How many B.S., M.S., PhD’s in chemistry are earned every year by women, men, all racial groups, and overall?;
- How many Nobel Laureates in Chemistry, Physics, Medicine and Physiology, Literature, and Peace are from Asian/South Asian, American Indian, Alaskan Native, Black or African American, Caucasian, and Hispanic backgrounds?;
- How many Nobel Laureates are women?

Student groups were required to interview a chemist of color. The interviews were implemented as part of the project to expose students to living chemists who are from underrepresented backgrounds and doing great work. Students from all backgrounds were exposed to chemists from underrepresented backgrounds in an effort to dismantle the dominant representations that students are presented with in STEM. Interviews with chemists were set up and scheduled by the students with guidance from the professor. Students were provided with an email draft to send to request interviews from their selected chemists. Students were provided with seven questions to ask during the interview and were required to create three additional questions. All questions had to be approved by the professor. Questions similar or relating to “How do we fix all the problems with diversity in STEM?,” “Why is it difficult being a woman in STEM?,” “Do you feel that there is racism in STEM or have you faced racism/sexism in STEM while pursuing your career?,” or questions that would only elicit “Yes” or “No” answer were not approved.
The goal of the interviews was to genuinely get to know a chemist of color and have a
great conversation, as opposed to using the chemist of color to find out about the “isms”
present today and burden them with coming up with all the solutions. Emails sent to each
chemist from students included the drafted email from the professor, the full Chemtutorials
project guidelines and rubric, and the ten interview questions. The professor was CC’d in
all correspondence between the chemists and students.

Each student group interviewed at least one chemist of color. Three groups interviewed
a chemist of color who was not from a background underrepresented in STEM, but was
from an Asian background; this, however, was permitted because these particular groups
had students of color from the same background or were interviewing multiple chemists in
which one was from an underrepresented background. In total, 15 chemists of color were
interviewed through the project. One student group interviewed three chemists. Chemists
interviewed were located in the US (13), Canada (1), and Mexico (1).

Each group of students was required to develop a short video, approximately 10 min
long, to present all of the chemists they had researched, the summary of the statistics,
the overview of the interview and the questions they developed which demonstrated the
chemical principles that their chemist used in their work. Prior to the first class period of
the discussion, students were required to view at least five other groups’ videos. This was
also done to expose students to at least 15 different chemists. In this article, all interviews
refer to the student interviews with their chemist of color.

In summary, the key elements of the Chemtutorials project were that students were
required to:
- Research at least three chemists and develop an educational resource to highlight their
  selected chemists;
- Research statistical data about earned degrees in STEM fields at the bachelor, master,
  and doctoral level in addition to the Nobel laureate prize winners and create a visual
  graph to display the demographic differences;
- Interview, via zoom, a living chemist of color from an underrepresented background
  in STEM and develop a summary of the discussion highlighting their career, their
  experiences, and their major innovations in chemistry;
- Create practice chemistry questions which demonstrated the chemical principles that
  the chemist they interviewed used in their daily work; and
- Participate in a classroom discussion about diversity, equity, and inclusion in STEM.

2.4. Classroom Discussion

To prepare students for the classroom discussion, students were instructed to view
at least five student-groups’ videos and prepare a summary of the interview with their
chemist. The classroom discussion was then conducted in two parts. Students were placed
in three instructor-selected groups of approximately 12 to 13 students each. A total of
38 students participated in the group discussions. Students were required to have their
cameras on during the entire discussion to facilitate a more welcoming environment during
the discussion. The groups were divided so that students of color were grouped together
to be at least 75% of a group. It was important to the authors that students of color saw
a visible presence of each other in their student discussion group to help minimize the
impact of spokesperson or stereotype threat [31] by creating a critical mass of students of
color [32]. Furthermore, the group composition requirement was an appropriate means
to increase student interactions across groups and facilitate discussion for all participants
while raising awareness of diversity issues in STEM.

At the beginning of class on day one, the instructor emphasized several points to
foster an inclusive and open environment for discussion and establish ground rules for the
conversation. First, everyone is in a different place when it comes to diversity, we must
appreciate this. Second, we should use “I feel . . . ” and “I experienced . . . ” statements
to express our opinions. Third, there may be a wide range of perspectives offered during
discussion and we should try to understand each other. The instructor acknowledged that
diversity is not a topic which is typically discussed in a STEM class, that some individuals are uncomfortable discussing diversity, and while we must again appreciate this aspect during our conversation, we must also acknowledge that it is an important topic to discuss. On day one of the discussion, students completed a class Google Slides document (Table S3) working together in their groups and participated in a peer discussion in their groups. On day two, students were instructed to finalize any details from the class Google Slides presentation and then complete a newly added slide to the Google Slides document asking them to create a bumper sticker to summarize their thoughts. Following the completion of the bumper stickers, the larger instructor-facilitated class discussion was conducted.

During the instructor-facilitated discussion component, the instructor started by selecting a group and asking them to summarize a particular slide. To continue the discussion then, the other groups were asked if they found anything similar or different. The instructor facilitated discussion for approximately 30 min of the class session. During the discussion, the instructor also shared her own experiences as an African American woman in STEM. The discussion ended with the students overviewing their chosen bumper sticker and then the instructor presented instructor-developed bumper stickers to draw out the final take-home points of the conversations (Table S4).

2.5. Data Analysis

Data were analyzed for trends to determine the associations between completing the Chemtutorials project and students’ sense of belonging in STEM. Qualitative data from the written survey responses were analyzed by coding student’s responses under broad categories. The qualitative content analysis (QCA) was used to analyze the responses [33]. The qualitative data were evaluated by the course instructor. To address potential bias that could be present, the researcher used reflexivity to identify personal beliefs, experiences, and theoretical orientations that could skew the authors’ analysis of the data. Qualitative responses were analyzed to determine themes from students’ comments. Initially, responses were coded question by question. However, upon looking at responses across questions, it was made clear that themes were interwoven between multiple questions, thus, data were then evaluated as a whole instead of question by question. Themes that emerged were coded and paired with quantitative data to evaluate the data collected. Student responses which identified specific faculty members’ names were changed to protect the identity of the faculty member. Selected quotes which represent themes that emerged are provided in the article.

To evaluate the descriptive quantitative data, questionnaire items were collapsed to indicate either disagreement or neutrality (“Strongly disagree,” “Disagree,” “Neither disagree nor agree”), or agreement (“Agree,” “Strongly agree”) in response to the presented survey prompt. Demographic variables were used only as a means to assess whether differences based on demographics identities were present in response to the Chemtutorials project, and are not meant to represent identity of male, White, or CGC as the norm for comparison. Demographic variables were grouped as follows:

- Gender (n = 28, excludes n = 1 response not indicating any gender)—male, female;
- Race (n = 27, excludes n = 2 responses not indicating any race)- White (indicated race as “White/European descent” only; n = 15), non-White (indicated race as “Asian/South Asian/Asian Descent,” “American Indian or Alaska Native,” “Black/African/African-American/Caribbean American,” or selected multiple races; n = 12);
- Underrepresented minority (URM) in STEM (n = 27, excludes n = 2 responses not indicating any race)—URM in STEM (indicated “American Indian or Alaska Native,” “Black/African/African-American/Caribbean American,” selected multiple URM races, or “Hispanic/Latino” ethnicity; n = 8), Non-URM in STEM (indicated race as “White/European descent” only, “Asian/South Asian/Asian Descent,” or selected multiple non-URM races; n = 19);
- Hispanic ethnicity (n = 28, excludes n = 1 response not indicating any ethnicity)—Yes (indicated Hispanic ethnicity; n = 5), No (did not indicate Hispanic ethnicity; n = 23); and
• First-generation college student (n = 29)—Yes (indicated first-generation college student status; n = 4), No (did not indicate first-generation college student status; n = 25).

Percentages provided are of the number of respondents, labeled in parentheses, i.e., (n = x), responding with agree or strongly agree to the statement.

3. Results

3.1. Student Perceptions on Belonging in STEM

To evaluate students' perceptions on feelings of belonging in STEM, Survey items 9, 14, 15, and 23 were assessed. Only 17.8% of respondents agreed or strongly agreed with Item 9 “Before the Chemtutorials project if I pictured a chemist in my mind they would have looked like me.” Thus, for the majority of students in all demographics, they could not imagine a chemist who looked like them before the start of the project. Zero percent of WOC (n = 9) could imagine a chemist that looked like them. White female respondents (n = 9) had a greater proportion (33.3%) in agreement that they could imagine a chemist that looked like them before the start of the project, however, the percentage is still very low. While there can be a number of reasons that students may not envision themselves or someone from their background in a field, when comparing the qualitative statements reported by students, one major theme which emerged was that representation matters and encourages STEM identity. The interviews with professional chemists gave students an opportunity to see someone who looked like them and this was inspiring, encouraging, and confirming for their STEM identity.

“It made me feel like I could do it if someone like me did it.” (Male American Indian/Alaskan Native, Hispanic, FGC)

“The chemist that my group interviewed looked just like me and to hear her story was inspiring. It really let me see that there are places and positions for people like me.” (Female, Black/African American)

The students clearly indicated in many cases that seeing someone who looked like them helped to confirm for them that they could pursue a career in STEM and that they belonged in STEM. This is consistent with the current literature, and again demonstrates the need to have diverse representations that are relatable for students so they can see themselves in STEM [34–36]. Exposing students to relatable role models, even by way of just biographies, has been demonstrated to increase performance and reduce stereotype threat [2] and has a positive effect on a student’s sense of belonging [37]. The results of this project demonstrate that this is also true when students meet authentic successful professionals in chemistry. The responses indicate that the interviews with STEM professionals positively influenced the students’ sense of belonging and support the growing body of literature that relatable role-models have a valuable impact on sense of belonging.

3.2. Supporting Feelings of Belonging in STEM

Over 65% of all respondents selected agree or strongly agree on the Likert scale to Item 23 “I have experienced moments where I did not feel like I belonged in STEM.” More female than male respondents reported experiencing one or more moments where they did not feel they belonged in STEM (68.4 versus 55.6%, respectively). Larger proportions of FGC (n = 4), URM (n = 8), and POC (n = 12) students selected agree or strongly agree when asked about experiences with exclusionary moments (100.0, 87.5, 83.3%, respectively). In comparison, far fewer CGC (n = 25), non-URM (n = 19), and non-POC (n = 15) students reported experiencing moments of exclusion in STEM (60.0, 52.6, and 46.7%, respectively). More WOC (n = 9) than White women (n = 9) respondents agreed that they had experienced moments where they felt they did not belong in STEM (77.8% versus 55.6%, respectively).

For Item 14, “The Chemtutorials project strengthened my feelings of belonging in STEM,” 65.5% of all respondents selected agree or strongly agree on the Likert scale. More female (n = 19) than male (n = 9) respondents’ feelings of belonging in STEM were strengthened during the Chemtutorials project (68.4 versus 55.6%, respectively). Similarly,
more FGC students’ (n = 4) feelings of belonging in STEM were strengthened compared to CGC students (n = 25); (100.0 versus 60.0%, respectively). More students identifying as POC (n = 12) and URM (n = 8) agreed that feelings of belonging in STEM were strengthened as a result of the Chemtutorials project compared to students identifying as White (n = 15) or non-URM (n = 17); (91.7% for POC versus 40.0% for non-POC students; 87.5% for URM versus 52.6% for non-URM students). More WOC (n = 9) than White female (n = 9) respondents agreed that their feelings of belonging in STEM were strengthened after completing the Chemtutorials project (88.9% for WOC versus 44.4% for White female respondents). The responses from students demonstrated another critical theme, that while many students have hesitancy in pursuing a STEM field, their STEM identity and belonging can be supported when provided with opportunities to meet individuals from diverse backgrounds.

“It really helped me feel like I’m not alone and that I’m not the only one who sometimes feels like giving up or like I’m not good enough. It helped me understand that it’s hard being a STEM student and it’s even harder being a STEM student of color, but that despite the hardships, I belong.” (Female, Asian)

“. . . I was not expecting the chemist to be so encouraging and positive throughout this process. I was pleasantly surprised and it made me truly feel as if I belong in STEM.” (Female, Asian)

“This project allowed me to see and understand that everyone belongs in the room. It helped me with doubts of not fitting in.” (Female, Black/African American)

“I already had a slight feeling of belonging in the STEM fields; however, this project has opened my eye that the field is open to everyone.” (Female, White)

“I personally am not interested in chemistry as my path but it (the Chemtutorials project) cemented that I belong in STEM.” (Male, White)

It is also encouraging that many White students had similar positive responses to interacting with a chemist of color. This is extremely important because inclusive pedagogy should be inclusive for everyone. Thus, there is a need to ensure that all students feel like part of the classroom and are encouraged by the curricular experiences. One powerful theme which emerged from the qualitative data was that it can be just as inspiring for some majority students to interact with a STEM professional from a background other than theirs also leading to confirmation that they belong in STEM. These responses from students indicate that the interview process was impactful in supporting their feelings of belonging in STEM for students from multiple backgrounds and especially for students identifying as women, FGC, URM, or POC.

3.3. Exposure to Diverse Role Models Should Happen Earlier

Many students already had a sense of belonging in STEM prior to the project, which suggests why some groups reported the Chemtutorials project having a smaller effect on their sense of belonging in STEM. These students typically were majority students or students who had prior exposure to relatable role models in STEM.

“I have always been worried about being a minority in STEM however everyone I have met has always encouraged me and I have an aunt who is a chemical engineer so I knew that if she could do it so could I.” (Female, White, Hispanic)

“I have never felt like I don’t belong in STEM.” (Male, White)

“I am white so I never really felt like I didn’t belong in STEM.” (Female, White)

Thus, this again continues to confirm the positive effects of having role models that are relatable, as these student’s sense of belonging in STEM had already been supported prior to the Chemtutorials project via the presence of a visible scientist in their life. It also suggests that we should consider how we present STEM to students early in their K-12 career and ensure that they have access to a diverse selection of role models to support their
sense of belonging prior to college. Students from marginalized backgrounds typically have more negative experiences and a larger feeling of exclusion in STEM. Students identifying as POC, URM, FGC, WOC, and female in this work reported the largest percentages of experiencing moments where they felt like they did not belong in STEM or felt excluded in the STEM classroom. It is important to note that there is some intersectionality between WOC, URM, and women represented. This intersectionality may also play a role in the responses presented, as some respondents identify as both female and as an URM. The response below from this female of color, from a racial background underrepresented in STEM, demonstrated how the STEM environment can foster these feelings of exclusion. More importantly, it demonstrated how the Chemtutorials project helped her to realize that this feeling is common, and she does not have to feel like she is alone.

“I think as a woman of color most times I have seen this field (STEM) giving light to white men more than anyone else. Sometimes, if not necessarily this particular field (STEM), you will be completely alone with a group of guys wondering why you are there but this project let me see that feeling is more common than I thought. And that I’m really not alone even if I don’t see anyone actually with me.” (Female, Black/African American)

Ways to negate negative experiences are seminal in increasing the persistence of marginalized groups in STEM. The project allowed these groups to feel acknowledged and present in the classroom. Giving light to diversity, equity, and inclusion in STEM increased the presence of visible role models the students were exposed to, thus, it made them feel like a larger part of the STEM community. Thus, this project served as a tangible way to combat these prior experiences and strengthen their sense of belonging.

3.4. Combating Exclusion in STEM

For Item 15, “The Chemtutorials project changed my feelings of who belongs in STEM,” only 24.1% of respondents agreed or strongly agreed with this statement on the Likert scale. Respondents identifying as FGC (n = 4), WOC (n = 9), and URM (n = 8) had higher proportions in agreement compared to CGC (n = 25), non-WOC (n = 9), and non-URM (n = 19) respondents (75.0, 55.6, and 50.0%, compared to 16.0, 22.2, 10.5%, respectively). Zero percent of respondents identifying as male or White male selected agree or strongly agree in response to Item 15. One theme that emerged from students not agreeing or strongly agreeing with the statement highlighted two problematic ideologies: the STEM ability stereotype and color-blindness.

“I feel that anyone belongs in STEM as long as they have the abilities to be successful and perform well. I feel as if it depends on the individual so anyone can belong if they want to” (Male, White)

“I have always been a believer that anyone can do whatever they want. I never looked at people by their skin color.” (Male, White)

“I believe anyone who is intellectually capable and are willing to put in work belongs in STEM.” (Male, White)

The stereotype that you should already be equipped with the ability to perform well competes against the growth mentality “the concept that intelligence is not fixed but is malleable.” This unfortunately contributes to the idea that people are either born for STEM or not. This is an ideology that deters hard-working students who may not see themselves as smart enough from pursuing STEM. It also is problematic in light of those who might enter the field. It has been demonstrated that fields which have a higher percentage of individuals who hold the belief that innate ability is required are less welcoming of women and minorities [38]. It is probable that those who believe this might unknowingly not invest in students who are not “capable” or are seen as not having the “ability to perform,” thus signaling the importance of us teaching students who might one day enter the field that this philosophy is flawed. Research has shown that URMs are often discouraged by faculty members and advisors to not pursue STEM fields at PWI [39]. Thus, the question should
be raised of when do these assumptions and ideologies develop about who is capable and who is not and what interventions can be put in place to prevent their internalization. In doing so, we can begin to teach and equip a new generation of faculty members who are more responsive to the needs of the new student body which will be more diverse. The color-blind philosophy has been demonstrated to be threatening to African Americans and to decrease their overall trust in the workplace [32]. This philosophy would also have a similar effect in the classroom. Since the color-blind philosophy does not accurately identify race as a contributing factor for the success of students of color [40], it fails to acknowledge the systemic and structural inequities and biases that stand in the way of diversification efforts. Additionally, it does not address that inequitable distribution of resources also plays a role in what opportunities individuals are able to access. When we fail to acknowledge that race plays a role in how we are perceived, then we can also fail to accept that there are “isms” based on this construct. Additionally, for the POC, it suggests to them that they are invisible, because we are failing to acknowledge a seminal part of their identity. It can be very hurtful to POC when these racialized experiences are not acknowledged. The Chemtutorials project was, however, successful in helping some students understand the challenges that individuals from marginalized backgrounds in STEM face. One student commented:

“I already felt like anybody regardless of race or ethnicity belongs in STEM if they are willing to put in the work. My feelings about who belongs in STEM hasn’t changed, but I’ve gained an appreciation for minorities that have succeeded in STEM." (Female, White)

Gains in appreciation of the challenges that marginalized individuals face in pursuing their careers is an important step in understanding that there are in fact inequities that are prevalent as a result of individual differences such as race, gender, and ethnicity. This shift in viewpoint, acknowledging that some individuals must work extraordinarily hard to achieve the same level of success in STEM as their peers, at least gives light to the fact that these systems of racism do exist. Work by Stephens et al. demonstrated that a difference-education intervention aimed at educating students about how the differences in background can impact academic performance, was shown to improve academic performance on both FGC and CGC [41]. The work from the pilot study conducted in this paper may also suggest a similar theme that teaching about differences can be a positive intervention for students by helping students be able to better empathize and potentially be able to create a more inclusive environment.

3.5. Comparison for Prior Experiences in STEM

Survey items 24 and 25 are classified as experiences in STEM. For Item 24, “I have had experiences where someone told me by their actions or directly that I should not consider a career in STEM,” and Item 25, “I have experienced situations where I felt excluded in the STEM classroom,” 31.0% and 41.4%, respectively, of respondents agreed or strongly agreed with these statements. More female (n = 19) than male (n = 9) respondents had been told directly or through the actions of another that they should not consider a career in STEM (36.8% versus 11.1%, respectively). More female than male respondents also agreed that they had felt excluded in the STEM classroom (52.6% versus 33.3%, respectively). When comparing WOC (n = 9) and White female (n = 9) respondents, more WOC had been told either directly or through the actions of another not to consider a STEM career (55.6% versus 11.1%, respectively). In addition, more WOC than White female respondents reported experiences of exclusion in STEM classrooms (66.7 versus 33.3%, respectively). Interestingly, the proportion of White female respondents in agreement with Item 24 was closer to that of White male respondents (16.7%).

More POC (n = 12) and URM (n = 11) respondents reported having been told directly or through the actions of another that they should not consider a career in STEM (50.0% for POC versus 13.3% for non-POC; 37.5% for URM versus 26.3% for non-URM). Similarly, respondents identifying as POC and URM had higher proportions in agreement to having felt excluded in the STEM classroom relative to non-POC and non-URM students (66.7%
for POC versus 20.0% for non-POC; 75.0% for URM versus 26.3% for non-URM). For educational status, FGC (n = 4) also had higher proportions reporting that they have been told directly or through actions of another that they should not consider a career in STEM compared to that of CGC students (n = 25) (50.0 versus 28.0%, respectively). More FGC than CGC students reported having felt excluded in the STEM classroom (100.0 versus 32.0%, respectively). Notably, 0.0 and 16.7% of White male respondents agreed that they have felt excluded in STEM classrooms or have felt directly or indirectly discouraged from pursuing a STEM career.

3.6. Statistics Belonging and Experiences

Chi-squared analysis can be useful to determine if an association between two variables is present. This analysis was used to determine if differences were present in responses based on identifying with a group. A full description of methods used for Chi-squared analysis is detailed in the Supplementary information File S1. This analysis is not intended to present either group as the norm, but only to determine if any differences existed in how students responded to the project were observed based on identity. Due to lower sample sizes in this pilot study, only test of association was performed to determine if any statistically significant relationship was observed with any survey responses (Tables S5 and S6). After performing Bonferroni corrections, the statistical tests were not shown to produce p-values that demonstrate differences in outcomes for different groups based on this project. Thus, no significant differences were observed between the groups based on the intervention. This finding may be due to low sample sizes. While a larger follow-up study is needed to confirm this result, the qualitative data presented do support that the Chemtutorials project provides an additional avenue to counter negative prior experiences that underrepresented groups in STEM experience. Future work will be performed as this study is repeated to expand the data set for a more detailed and robust statistical analysis.

3.7. In One Word

Students were asked to describe the Chemtutorials project in one word. A word cloud (Figure 1) was generated to visualize the most dominant words selected. The five most frequent words were eye-opening, informative, inspiring, insightful, and interesting. Other strong positive words used once to describe the project were amazing, helpful, courageous, great, and powerful. Three students used neutral words for describing the project, such as unique, complex, and research. Only two students responded with words that were considered to be negative, describing the project as excessive and confusing. One theme that emerged in the qualitative data was that the instructions were confusing for some students and there was a lack of clarity in the rubric in some areas. This may be why some students described the project in this fashion. Taken together, these words demonstrate the strong positive perception the students have of the Chemtutorials project.

Figure 1. Word cloud produced from student responses to Item 30: “If you could describe the Chemtutorials project in one word, what would it be”.

4. Discussion

4.1. A Framework to Apply This Work to More STEM Classrooms

Faculty play an important role in cultivating a more inclusive environment in STEM. Supporting students’ sense of belonging can be achieved intentionally in curricula in STEM classrooms. As sense of belonging has been demonstrated to strengthen academic engagement [42], success [17], persistence [4,11], and matriculation of students into STEM careers, sense of belonging should be a top priority in our classrooms. The Chemtutorials project supports a student’s sense of belonging in STEM in several ways. Firstly, it challenged the representations they have been taught which compete against stereotype threat. Stereotype theory reveals that students can internalize negative stereotypes, which is damaging to their persistence. To explicitly break down inaccurate representations that students have been exposed to, which may have already been internalized prior to reaching our classrooms, it is necessary and imperative to openly bring these conversations and topics to the forefront so a new narrative can be created. In this work, the Chemtutorials project presented a counter-representation to the students via the interviews and researching visible chemists of color and emphasizing the value of their scientific contributions. These counter-representations of chemists challenged the dominant representations in STEM education. It can be posited that these aspects of the Chemtutorials project produced a greater sense of belonging as students became acquainted with the reality that women and POC were in fact very present and very successful in STEM.

A seminal question is “How do we allow for more time to teach these topics in our classrooms, when we have so much material to cover in our introductory courses?” In this work, to allow for the two-day discussion, the instructor streamlined course material by removing the topic balancing redox reactions in acidic and basic solution conditions and only teaching the basic form of balancing redox reaction. This more in-depth material of balancing redox reactions with regard to solution conditions is taught in analytical chemistry. Therefore, students who continue in the chemistry major will be exposed to this material later in the curriculum. The instructor also eliminated the discussion portion around one set of graphs in the gases section. The graphs which the instructor uses as one of the many opportunities in the course to develop students’ skills to interpret graphical analysis led to the simple conclusion that if gases are smaller, they move faster; and if the temperature is hotter, they move faster. However, as the instructor has multiple instances in the course where this objective of understanding graphical analysis is present and this skill is regularly taught in the laboratory curriculum and other upper-level courses, the instructor removed the discussion portion around the graphs relating to this topic in the gases section. These curricular changes allowed for more classroom time to facilitate the important discussion about the Chemtutorials project. The authors suggest that by looking at the broader curriculum wholistically, we can find concepts and skills that are covered in multiple classes in our curriculum long-term. By allowing some of these topics to be taught later and removing only one of the exposures for the curriculum, the students will still be taught the concepts and have opportunities to develop these skills through the full curriculum. Since a sense of belonging is important for students persisting in the STEM curriculum altogether, we argue that promoting a sense of belonging first outweighs introducing some of the more in-depth concepts which can be covered later. Additionally, skills which students are provided multiple opportunities to be exposed to and develop can also be streamlined in the curriculum to create enough exposure for mastery while opening opportunities to integrate new material into courses.

Using the Chemtutorials as a model assignment, a three-part framework was developed to provide a scaffold that can be used to expand this approach to other STEM classrooms. The framework contains three elements: 1. Make it count; 2. Create an experience; and 3. Prepare effectively. The first element, “Make it count”, means to give emphasis to the project in a way that makes it matter to students. To do this, the author assigned a project grade that totaled 100 points. Thus, the Chemtutorials project was worth a full test grade. Many students reported that they were not interested in completing the project,
thus, if the project was extra credit, or had a low point value, they would have been less likely to complete the work. However, students in this study actively participated and completed high-quality work. The second piece of the framework, “Create an experience”, is important because experiential learning allows for students to discover, engage, relate, and reflect on the difficult material. By having students discover the statistics themselves, engage with a chemist of color via an interview, relate the chemical principles their chemist used to what they were learning in class, and participate in a classroom discussion that allowed for reflection of all the components, an experience was created that promoted a deep dive into the topic of diversity and equity in STEM. Students were able to have reflections about the work that led to a positive impact on their personal sense of belonging in STEM. The third piece of the framework is preparing effectively. The topic of diversity can draw out intense emotions and feelings and discussions can quickly become challenging and tense. The instructor prepared for this discussion by first studying to develop professional skills to facilitate a discussion. The instructor reached out to professors in English, psychology, and biology, at her institution, who had significant experience with facilitating classroom discussion about various topics. By both attending their courses while they held discussions and by having them attend the instructor’s course during a practice discussion in a different upper-level class the instructor taught, the same semester, the instructor developed a discussion skillset. The instructor also spent time reflecting on her own identity and what that meant for how she is perceived and perceives the world. The instructor then used the tools and strategies learned from the professors she observed and had observe her. Lastly, the instructor fully participated in the instructor-led discussion component by sharing her own journey in STEM to be able to allow the students to explore her experiences. These elements of study, self-reflection, support, and a willingness to share created effective preparation for the discussion.

Thus, this work suggests a three-prong framework that can be used to get students to engage with the topic of diversity. To encourage a deeper level of engagement, instructors should: (1) Make it count; (2) Create an experience to allow students to discover, engage, relate, and reflect; and (3) Prepare effectively by seeking professional development, self-reflection, support, and having a readiness to share. Other activities and innovative curricula could be developed using this framework to adapt this activity or develop new projects in more STEM fields and classrooms.

4.2. Strategies to Deal with Preparation Time

The preparation to developing a course-based project using this framework was essential to its successful implementation. As STEM faculty, our time is limited, however, when considering the important role faculty play in our students’ career pursuits, finding strategies to incorporate this valuable aspect into our courses should be prioritized. Suggestions for managing the preparation needed are to consider developing an implementation timeline via a three-phase process for introducing the activity. In the first phase, develop the activity. In the second phase, complete the professional development. Then finally, in the third phase, implement the activity in the course. For example, developing the activity over the summer or the semester before you intend to implement the activity can be completed prior to completing the professional development. Spending the semester prior to implementing the activity developing professional skills for holding discussions in a course and reflecting on your own identity can allow for the time needed to develop the skill and to think deeply about your identity. Lastly, implement the activity after completing the first two phases in a subsequent semester. By strategically planning to implement the activity through a phased approach, it can allow for the preparation time that is not cumbersome compared to attempting to complete all of the work in one semester.
5. Future Work, Limitations, and Conclusions

5.1. Limitations and Future Work

The work presented is a retrospective pilot study conducted at a small liberal arts college. As classes are smaller at this institution, this study does not have a large number of participants. While descriptive data are presented, it should be noted that due to small group sizes, these data are not meant to be used to generalize differences between groups broadly. In the follow-up study, the descriptive data will be used to develop hypotheses that can be further evaluated with a larger data set. The qualitative data do suggest that there are common themes and that the Chemtutorials assignment was able to impact students’ sense of belonging. While the qualitative data do suggest positive effects on students’ sense of belonging, it is again important to note that this study cannot yet be generalized broadly. This work does, however, point to a successful implementation of an instructor-developed intervention to support students’ sense of belonging, but further work is needed to determine and explore the Chemtutorials project as a broader intervention.

Additionally, this study did not include a pre- and post-test to measure differences before and after the intervention. While the questionnaire specifically asked respondents to answer the questions as a result of their experiences with the Chemtutorials project, the results may not fully capture gains as a result of the Chemtutorials project alone. Due to this semester being taught remotely, there could also have been a sense of disconnection between students and the Chemtutorials project may inadvertently also measure some of this effect. While the project was completed in a chemistry course and with a chemistry focus, some of the questionnaire questions asked about STEM in general. Depending on how students interpreted STEM, they may not have identified with this category. In a future study, the use of a validated instrument for measuring STEM identity is being planned. The use of this instrument through both a pre- and post-test would mitigate the retrospective nature of the study and also better capture the change over time.

Future work is planned to expand this pilot study to a both a multi-semester and multi-institution study. A multi-semester and/or multi-site study would address the limitations to the small sample size of this pilot study. The pilot study is, however, still noteworthy in that the qualitative data do suggests that there was a beneficial impact of completing the Chemtutorials project. We encourage other STEM educators to implement this work in their classrooms to expand the opportunities for analysis of the Chemtutorials project and the frameworks developed in this work to explore this strategic pedagogy of “The Benefits of Enlightenment.”

5.2. Final Thoughts

Supporting women, underrepresented minorities, and FGC students in STEM must be intentional and integrated into how we adapt our curriculum as a way to demonstrate that everyone belongs in the room. The representations which students have been exposed to prior to reaching the college STEM classroom have been primarily White and male with regards to STEM for many of our students. The climate and culture may have been one of turbulence and strikingly different from the native culture of many of these students. As professors are one of the most prominent and frequent figures students interact with on the college campus, faculty in STEM can be an active proponent and advocate of embracing diversity in the classrooms through an explicit and engaging curriculum. Intentionality matters and is needed to advance diversity in STEM. This study demonstrates a course-based assignment that demonstrated promise as an engaging, eye-opening, and inspiring activity that supported students’ sense of belonging in the instructor’s classroom. Key elements of this are establishing a welcoming environment in the classroom and making students aware that you value diversity and want to highlight the benefits of diversity in STEM. Explicitly teaching about diversity, equity, and inclusion in STEM could pave the way for establishing and supporting the diversification we seek in STEM. Engaging curricula, such as the Chemtutorials project, which is demonstrated here to support and strengthen students’ sense of belonging, could expand diversity in STEM. Through analysis
of the qualitative data, the three key components which were most important were the interviews with the STEM professionals, researching the statistics, and the classroom conversation. This pilot project, which demonstrated a beneficial impact on students' sense of belonging, merits further exploration to expand this work to more STEM classrooms. Similar assignments, which could serve as potentially interventions, can be developed and implemented in more STEM classrooms and more STEM fields using the three-prong framework below:

1. Make it count;
2. Create an experience involving discovery, engagement, relating, and reflection;
3. Prepare effectively by study, self-reflection, support, and sharing.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/educsci12070498/s1, Table S1: Chemtutorials Post Survey and Coding System; Table S2: Interview Questions; Table S3: Google Slides Questions; Table S4: Instructor developed bumper stickers presented to students; Table S5: Sample Demographics; Table S6. Responses to Select Survey Questionnaire Items (n = 29); File S1: Methods for Chi-Square analysis.

Ref. [43] are cited for Supplementary Materials.

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