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Investigating best practices for engaging chemistry students in online learning

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Introduction and background

In the Winter 2020 semester, teaching and learning changed for good. A pandemic struck the world causing everything to move to a remote setting, including education. This impacted students trying to further their education from the Winter 2020 semester and on. It is no secret that the world keeps getting hit with new variants and that waves of fear hit each educator and student with the thought of moving the classroom to a virtual setting every time a new variant is announced. This fear is present because online learning is new. While education has been studied for decades, leading to knowledge about the way students learn and different teaching pedagogies, online learning has only existed for approximately 25 years, and is less understood. As early as 2012, educators warned that moving to an online environment would not be a one-to-one substitute for classroom learning, but would require the development of new competencies for both educators and learners, and that the impact of online learning on the emotions of learners could negatively impact content acquisition[1].

Because most instructors had not previously engaged in online learning, most educators became confused as to the correct way of giving students the best virtual educational experience when forced to pivot with little warning in 2020. Instructors began learning in their community, in the form of anecdotal information and opinions from places such as Facebook groups to help them get different insights on how to lead their virtual classrooms. In an article written by Grand Valley's own Dr. Dekorver[2], we see a summary of the conversations taking place during the shift to remote learning in one such online community for chemistry instructors, including suggestions for what generally worked best for the instructors. For example, Dr. DeKorver notes that questions about technology and pedagogy were prevalent in many instructor concerns. While instructors provided arguments for how technology could best support student learning, there was little research to suggest that a particular modality or pedagogy was clearly superior.

Two forms of online learning that Grand Valley offers which we will be exploring are asynchronous and synchronous content delivery. Grand Valley defines asynchronous learning as a virtual classroom setting where there are no set meeting times and students complete the coursework on their own time; however, a synchronous setting is defined as a virtual classroom setting in which students meet on set days and times with their instructor, but instead of being in person, you are on a platform such as Zoom or Blackboard. Currently, when classes are online, the instructor is choosing whether they conduct the classroom in an asynchronous or synchronous manner based on their personal preference, or their view of student preference, rather than data.

Chemistry in particular is understudied in terms of moving to an online environment, in large part because the "hands on" nature of chemistry has led many instructors to believe content could not be reliably taught in an online setting[3]. Because of the abstract nature of chemistry, which uses symbolic language to explain macroscopic phenomena caused by interactions at an unseen particulate level, classroom instruction often relies on a combination of demonstrations, model kits and other manipulatives, group problem solving, and drawings or use of other representations such as animations. Many of these are seen as indispensable for student success, yet are difficult to recreate in an online environment. However, chemistry is a foundational course required by many majors and pre-professional programs at GVSU. In the winter of 2020 alone, approximately 2500 students were impacted by the shift to online learning in 100- and 200-level chemistry courses. Student success in courses such as these are pivotal to student success and retention, and teaching chemistry well in an online environment will likely be a factor that comes into play frequently in the post-COVID world.

Citations:

1. Cleveland-Innes, M., & Campbell, P. (2012). Emotional presence, learning, and the online learning environment. *The International Review of Research in Open and Distributed Learning*, *13*(4), 269-292.
2. DeKorver, B., Chaney, A., & Herrington, D. (2020). Strategies for teaching chemistry online: A content analysis of a chemistry instruction online learning community during the time of COVID-19. *Journal of Chemical Education*, *97*(9), 2825-2833.
3. Rupnow, R. L., LaDue, N. D., James, N. M., & Bergan-Roller, H. E. (2020). A perturbed system: how tenured faculty responded to the COVID-19 shift to remote instruction. *Journal of Chemical Education*, *97*(9), 2397-2407.

<u>Research Questions</u>

- What form of online teaching will best benefit the students, both in terms of improving their content knowledge and understanding, as well as supporting them socially and emotionally?
- What delivery method do students feel most supports their learning, and is easier to use and understand?
- Identify best practices for teaching chemistry in an online environment through the application of quantitative and qualitative research methods to simulated learning environments.
- Identify the most supportive learning environment for students: asynchronous or synchronous.

Methods

In order to address the research questions stated above, we recruited 29 different students from all different chemistry backgrounds to partake in our research. Once recruited, students filled out a survey on Qualtrics indicating how much chemistry experience they had, their major, and other general information so they could participate in the research. Based on the students' responses in the survey the students were placed into two different groups, either “group A”, or “group B”. Group A students were students who had chemistry experience. Chemistry experience is defined as students who had previously taken a college chemistry course such as CHM 109, 115, or 116 at Grand Valley. Group B students were students who did not have any previous chemistry experience. Not having chemistry experience is defined as students who had not previously taken a college chemistry course, and noted in the survey they either had high school chemistry, AP chemistry, or no chemistry at all. A few students signed up for this research project that had a substantial amount of chemistry experience. Substantial chemistry experience can be defined as students who noted in the survey they have completed more than once sequence of chemistry at Grand Valley such as, CHM 109 and CHM 230, or CHM 115, CHM 116, and CHM 241 and CHM 242. These students were randomly placed into either “group A” or “group B”, and used as controls. The expertise level was noted, and accounted for in data analysis.

After “group A” and “group B” were separated, the students in each subgroup were placed into yet another subgroup: asynchronous or synchronous. The process of placing students into asynchronous and synchronous was done randomly. Asynchronous students received a pre- and post-test in order to collect quantitative data on performance. Students took a pre-test, watched a video on a chemistry topic, and then took a post-test. This portion was done completely remotely, and on the students' own time to match with the Grand Valley's definition of asynchronous learning. For the synchronous content, students completed a pre-test, participated in a zoom lesson, and then completed a post-test once the zoom was completed. This portion was done remotely, with presentation of content given in a Zoom setting to match with Grand Valley's definition of synchronous learning. The pre/post test questions were the same whether the student was in the asynchronous group or synchronous group.

The chemistry topic chosen to be taught to group A was bond-line structures. In the lecture, whether asynchronous or synchronous, students were taught what an organic compound is, a hydrocarbon, and creating formulas for bond-line structures including twists of branched structures, and double bonds. This topic was chosen because it is an introductory organic chemistry topic. Students placed in group A had completed general chemistry; therefore, students were able to have enough chemistry knowledge to understand the complexity of bond-line structures. The chemistry topic chosen to be taught to group B was naming ionic compounds. In the lecture, whether asynchronous or synchronous, students were taught what an ionic compound is, the definition of a cation and anion, and how to create ionic compounds both by being given the formula and naming the formula or vice versa. Students were also taught what polyatomic ions were, and how to incorporate those in ionic compounds. This topic was chosen because this group primarily had no chemistry experience and because of this, students were able to be taught the basics of the periodic table, and learn how to create ionic compounds without any previous knowledge of chemistry.

Quantitative data was collected from the pre- and post- test scores to evaluate the students' chemistry performance. The quantitative data was analyzed through SPSS ANOVA. Qualitative data on affective topics were obtained by adding a few questions to the post test about their motivation, and concentration during the video/ Zoom lecture. The post-test also included an open-ended portion where students' could share their thoughts, feelings, and opinions about their assigned delivery method: asynchronous or synchronous. The open ended responses were annotated by looking at all student responses, and picking out key words, and phrases to get a general feel for what the majority of the students' feelings towards online learning in their assigned delivery method. The pre/post tests were all completed via GVSU Blackboard. The asynchronous content was presented via Panopto video, and synchronous content was presented via Zoom.

Results and Data

Quantitative-

Modality= Synchronous, Asynchronous
Expertise= No chem- 13, Gen chem-10, substantial amounts of chem-6
Topic= Organic vs. Naming
Time= Pre/Post test
Bold= statistical significance

Wilks' Lambda Test:

Tested Variable	F	Significance
Main effect for Time	$F_{1,21}$= 16.32	**.001**
Main effect for Topic	$F_{1,21}$= .12	.734
Main effect for Modality	$F_{1,21}$= .25	.623
Main effect for expertise	$F_{2,21}$= 10.52	**.001**
2-way Interaction effect for Time x Topic	$F_{1,21}$= 0.57	.459
2-way Interaction effect for Time x Modality	$F_{1,21}$= 3.65	.070
2-way Interaction effect for Time x Expertise	$F_{2,21}$= 8.64	**.002**

3-way Interaction effect for Time x Topic x Modality	$F_{1,21}$= 0.57	.459
3-way Interaction effect for Time x Modality x Expertise	$F_{2,21}$= 0.54	.591

When analyzing the quantitative data, the statistical test that was used was a repeated measures analysis of variance. In order for a variable to be statistically significant, the p-value needs to be less than 0.05. The test of significance used was $F_{X,X}$. F is the stat that is calculated, and the subscripts show the "degrees of freedom", which is how many levels of each variable there were. After running the pre/post test data on an ANOVA test, the data was ready to be analyzed for each variable tested.

Main effect for time: This variable answers the question, is there a difference in scores from pre to post test. The main effect for time was statistically significant ($F_{1,21}$=16.32, p=0.001). This means that everyone improved, and everyone, no matter what group students were placed in, did better on their post-test. This shows that students did in fact learn!

Main effect for Topic: This variable answers the question, If we average the pre and post for everyone, do the scores of group A and group B differ? The main effect for the topic was not statistically significant ($F_{1,21}$=0.12, p=0.734). This means that the students in group A and group B started in the same place. The groups were not biased, and they were selected fairly.

Main effect for Modality: This variable answers the question, if we average pre and post for everyone, do the scores of the synchronous & asynchronous groups differ? The main effect for modality was not statistically significant ($F_{1,21}$=0.25, p=0.623). This means that the students in synchronous and asynchronous groups started in the same place. The groups were not biased, and they were selected fairly.

Main effect for Expertise: This variable answers the question, if we average pre and post for everyone, do the scores of the expertise groups differ? The main effect for expertise was statistically significant ($F_{2,21}$=10.52, p=0.001). This is to be expected because the “experts” do better overall than those with less experience. This shows that the tests used in this experiment were fair. Our “control” group scored as expected, and the tests used were an accurate measure of how the students' chemistry knowledge differed before and after the asynchronous or synchronous lectures.

***2-way Interaction effect for Time x Topic**:* This variable answers the question, Is the pre-post gain seen different based on the topic they saw? The 2-way interaction effect for Time x Topic was not statistically significant ($F_{1,21}$=0.57, p=0.459). This shows that the topic given does not matter, and everyone does better on the post test. Results are not skewed one way or another.

***2-way Interaction effect for Time x Modality**:* This variable answers the question, Is the pre-post gain we see different for synchronous or asynchronous? The 2-way interaction effect for Time x Modality was not statistically significant ($F_{1,21}$=3.65, p=0.070). This means that both asynchronous and synchronous students did better on their pre and post test.

2-way Interaction effect for Time x Expertise: This variable answers the question, Is the pre-post gain we see different based on their expertise? The 2- way interaction effect for time x expertise was statistically significant ($F_{2,21}$=8.64, p=0.002). This means that the “experts” do better overall, but have less to gain on their pre/post test. This is to be expected.

3-way Interaction effect for Time x Topic x Modality: This variable answers the question, is the pre-post gain we see different for the 2 different topics across if we consider synchronous/asynchronous? There was no significant interaction effect for time x topic x modality ($F_{1,21}$=0.57, p=0.459). This means that everyone does better pre- post regardless of topic or modality. The previous points all held true regardless.

3-way Interaction effect for Time x Modality x Expertise: This variable answers the question, is the pre-post gain we see different for synchronous/asynchronous if we consider expertise? There was no significant interaction effect for time x modality x expertise. This means that all of the students performed the same pre/post regardless of expertise, or if they were in the synchronous/ asynchronous group.

Quantitative analysis conclusions: The results of the quantitative data show that there is no statistically significant data to show that the synchronous group did better than the asynchronous group and vice versa. The students did equally as well whether they were placed in the asynchronous or synchronous groups. The quantitative data does confirm that the testing instruments used were valid, and not biased. The experts did well, as to be expected. The groups were placed fairly, and everyone showed growth from their pre- to post-test.

Qualitative-

The qualitative data was analyzed using the students' open-ended responses. Themes were found, and trends in the responses were noted. A few examples of student responses can be found below:

> -“ The information was taught very well and I liked having multiple example problems to review during the lecture and how Megan kept looping back to connect older slides with the newer slides to tie all of the information together. I would suggest adding some sort of interactive piece since it is easy to get distracted and lose focus in an online class. I've found when classes enforce some sort of interaction that I pay attention more.” (Group a Synchronous student).
>
> -“I feel like you did very well in explaining all of the information in a way that someone with no chemistry experience could understand. The most difficult part I have found with

online learning is distractions around my house which cause me to lose focus. Lengthy classes have also had some cause to that as well. Some classes I have been able to. be successful in online learning, however others I have struggled. With those more difficult classes I feel like it is important for professors to make sure to break things down in an easy to understand way while still trying to keep things short to avoid losing the attention of the students, whether that be lecture videos for asynchronous classes or zoom calls." (Group B synchronous student).

- "I enjoyed the warmth in the video and the helpful examples/ time allowed for practice problems and exploration on your own! It felt student-focused which I appreciate." (asynchronous student Group B)

- "I thought Megan was very engaging and passionate about her teaching. The enthusiasm made it very easy to concentrate and follow along. I do not have many suggestions as a whole as I think it was very easy to follow along for someone who needed a refresher in general chemistry or someone who has never taken a course in chemistry." (asynchronous group B).

The big takeaway from these responses is that students commented more about the teaching style rather than the actual delivery method. Students commented about the enthusiasm and engagement aspect in both asynchronous and synchronous. All future suggestions from students were about teaching style.

Throughout all of the responses received, students used the word "engaging" over a total of six times. Students mentioned that the examples were helpful over seven times. There was an overall theme of students really enjoying how much passion there was in the video, and how they enjoyed how material was brought together at the end. Students enjoyed the teaching strategies used in the video rather than the way the content was presented: asynchronous vs synchronous.

Qualitative analysis conclusion: The results of the qualitative portion of this research project support the quantitative results. Quantitative analysis showed that students did equally as well whether they were in an asynchronous or synchronous environment. The qualitative analysis showed that students care more about what teaching methods are used rather than getting the information from a Panopto video, or a Zoom lecture. Students commented on how engaging both the lecture and zoom was along with positive feedback about the use of examples.

Discussion and Recommendation for Future Work

After the analysis of both quantitative and qualitative data, the results are clear that asynchronous and synchronous delivery methods do not dictate how well a student learns. It doesn't matter if a chemistry student is put in a full asynchronous, or full synchronous course. What does matter, is how the student is taught. If the student is taught by a professor who shows enthusiasm, uses examples and shows passion in his or her lecture or Zoom, students will have better concentration. Although the efficiency of different teaching methods in a virtual environment were not measured in this study, it could be a potential future study.

All in all, instructors cannot be the same teacher they are in an in-person environment as you are in a virtual environment. This is why teachers were struggling to teach, and students were struggling to learn. For decades, teachers have gained all of their teaching skills from being in an in-person environment. Teachers and professors took the skills that were successful in their in person classrooms and expected them to work in an online environment. This is why there was so much struggle. An online environment presents different obstacles that students have to overcome such as: background noise, outside distractions etc. In an in-person classroom, students have a carved out time where they are expected to be in class. This is not always true for an online environment. Being a teacher in-person versus being a teacher online is not the same.

Recommendations for future teaching

Being a successful teacher in an online environment is very possible. You may just have to change the way you teach. According to the qualitative responses given by students in this study, students can tell your enthusiasm over the video. They can feel how much passion and preparation you put into your teaching- you do not have to be right in front of them. In one of the responses given by a student in the asynchronous group, the student says “I felt the warmth in the video”. The biggest complaint about online learning is how impersonal it is. People complain that the videos are monotone, or that the content is boring. This quote, along with many others in the qualitative analysis, shows how the students can feel the passion/ lack of passion in the videos. It is not about whether it is a synchronous lecture or a recorded video, students can tell how much the teacher or professor cares regardless of the delivery method.

Some teaching strategies that were mentioned by students in the qualitative portion of the study that could make the online learning process more successful and engaging is making the lectures short, and having more videos. Many students mentioned how they liked when professors made multiple short videos instead of doing one long lecture video. This could help students feel as if they were completing more. Separating topics into shorter videos also helps with the concentration aspect, which is a common complaint of online learning, especially in chemistry because of the complexity of the topic, and how much they build.

Conclusion

Whether you are teaching synchronously or asynchronously, the teaching strategies you use in those environments will probably change from the strategies that you use in person. Students can feel your enthusiasm, even behind a screen and through a pair of headphones. Overall, you cannot be the same teacher you are in an in person classroom as you are in an online environment.