Comparing Instructors' Motivational Support across Online and In-Person STEM Learning Environments

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Abstract

Instructors' motivationally supportive teaching plays an essential role in supporting students' motivation in both online and in-person learning environments. Due to the global pandemic, universities experienced an emergency switch from in-person teaching to remote online education, which likely prompted changes in instructors' motivationally supportive behaviors and statements. Grounded in expectancy-value theory (Eccles & Wigfield, 2020) and self-determination theory (Ryan & Deci, 2020), the present study investigated how instructors supported students' motivation through relevance statements, supporting autonomy, and showing their enthusiasm in the classroom settings in both pre-pandemic in-person and pandemic online STEM learning environments. Findings from 107 10-minute lecture recording segments in 2019 and 66 10-minute video segments in 2020 demonstrated instructors' in-class motivational support differed across the two learning conditions. Instructors provided more relevance statements and enthusiasm in pandemic online learning environments. Conversely, instructors appeared to offer more autonomy support in pre-pandemic in-person STEM classes. These findings expand our understanding of how instructors supported students' in-class motivation and whether instructors' motivational support might change across in-person and online STEM learning environments in university-level STEM courses.

Keywords: Motivational support, STEM education, in-person learning environments, online learning environments

Abrégé

L'enseignement motivant des instructeurs joue un rôle primordial pour la motivation des étudiants dans les milieux d'apprentissage en ligne et en présentiel. En raison de la pandémie mondiale, les universités ont dû passer d'urgence d'un enseignement en présentiel à un enseignement en ligne à distance, ce qui apporte éventuellement des changements aux comportements et aux énoncés motivants des instructeurs. Basée sur la théorie de l'espérance-valeur (Eccles & Wigfield, 2020) et la théorie de l'autodétermination (Ryan & Deci, 2020), la présente étude consiste à examiner comment les instructeurs motivent les étudiants en faisant des énoncés pertinents, en favorisant l'autonomie et en faisant preuve d'enthousiasme dans les milieux d'apprentissage STEM en présentiel avant la pandémie et en ligne pendant la pandémie. Selon les résultats tirés de 107 segments audio de cours de 10 minutes enregistrés en 2019 et de 66 segments vidéo de 10 minutes enregistrés en 2020, le soutien motivationnel en classe des instructeurs diffère dans les deux milieux d'apprentissage susmentionnés. Les instructeurs fournissent plus d'énoncés pertinents et font preuve de plus d'enthousiasme dans le milieu d'apprentissage en ligne pendant la pandémie. Au contraire, ils semblent favoriser davantage l'autonomie dans les cours STEM en présentiel avant la pandémie. Ces résultats nous permettent de mieux comprendre comment les instructeurs motivent les étudiants en classe et si le soutien motivationnel des instructeurs peut changer entre les milieux d'apprentissage STEM en présentiel et en ligne dans les cours universitaires STEM.

Mots-clés: Support motivationnel, enseignement STEM, milieu d'apprentissage en présentiel, milieu d'apprentissage en ligne

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As a developing motivation researcher, the first thing that I would like to mention here is that I feel highly and intrinsically motivated during the process of conducting the whole project. Writing a thesis is not always an easy thing, but it is much harder for a future scholar to accomplish a thesis with great pleasure, enjoyment, as well as stupendous yearning to continuously discover the mystery of motivational support. And I do feel so lucky that I did it during the discovery path.

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do happen sometimes, with all the power from love, I believe I can always be happy, optimistic, confident, and powerful enough to confront and to fight.

Contribution of Authors

The thesis contains six parts, including the introduction, literature review, present study, results, discussion, and conclusion. I independently wrote all six parts of this thesis. As my supervisor, Dr. Kristy Robinson offered me suggestions and guidance during the planning, writing, and revising process. In the introduction, literature review, and present study session, I individually conceived the thesis ideas, collected the relevant articles, summarized the previous findings, and developed the research questions and hypotheses. Dr. Kristy Robinson, who served as the principal investigator, gathered all the lecture video recordings from chemistry instructors with approval ethics. The coding scheme selection was based on two conference presentation projects, and I was the co-first author with my lab mate Sanheeta Potola in both projects. In the process of trial coding, I invited two graduate lab members, Sanheeta Potola and Ella Christiaans, to code six 10-minute video segments to ensure inter-rater reliabilities. I coded all the remaining lecture video recordings used in the analysis process, created my dataset, and conducted both quantitative and qualitative analyses.

Citation

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Introduction

Science, technology, engineering, and mathematics (STEM) education has been increasingly recognized as fundamental to national economic growth, innovation, and educational development (Freeman et al., 2019; Marginson et al., 2013). However, it is a persistent problem in Canada and North America that students tend to lose their interest in STEM fields (Rosenzweig & Wigfield, 2016; Wall, 2019; Wigfield et al., 2015). Given the findings that students' motivation declines throughout primary, secondary (Fredricks & Eccles, 2002; Watt, 2004), and postsecondary studies (Barr et al., 2008; Kosovich et al., 2017; Robinson et al., 2019), it is important to investigate how to prevent motivational declines in STEM courses.

Teachers play an important role in students' motivation. Studies find that teachers' practices can have a positive influence on students' motivation outcomes both in secondary (Kebritchi et al., 2010; Rosenzweig & Wigfield, 2016; Wentzel, 2009; Wentzel & Wigfield, 2007) and postsecondary (Canning et al., 2019; Hancock, 1996; Tanveer et al., 2012) school contexts. However, prior studies have largely not examined exactly how teachers can support students' motivation, particularly comparing face-to-face and online contexts in STEM courses. Therefore, little is known about how effective teachers' practices look within postsecondary STEM classroom settings.

More specifically, teachers might change their instructional strategies in different learning environments or over time (Brophy & Good, 1974; De Meyer et al., 2016; Rosenzweig & Wigfield, 2016). Considering that the effectiveness of certain instructional strategies can be differential when they are applied to different learning environments (Smith et al., 2000), it is important to know how teachers interact with students across diverse learning settings. Moreover, differences in instructional practices, such as different learning settings, various in-class activities, can lead to different levels and quality of students' motivation (Pintrich, 2003). But limited literature can be found to show any such detailed differences in how instructors support students' motivation across diverse learning environments, particularly in STEM education. Hence, it is imperative to detect how STEM instructors support students' motivation and what specific strategies they tend to choose in different environments so as to prevent students' motivation from consistently declining due to the changes in instructional practices.

With the development of technology-enhanced education, multiple types of learning environments such as online learning environments and blended learning environments have introduced new challenges for STEM education (Yang et al., 2015). Based on previous studies (Roseth et al., 2011; Stark, 2019), students reported lower motivation when learning online compared to face-to-face learning. Due to the global pandemic, the major delivery method in university-level STEM education has been changed from in-person to online in recent semesters. Teachers tended to have less experience in motivating their students in online education (Bolliger & Wasilik, 2009). The sudden shift of the learning environments, together with other influencing factors such as COVID stress (Arslan & Allen, 2021) and socio-political events (Cao et al., 2020), exacerbated the challenges for both students and instructors. Given that students' motivation and in-class engagement in university-level STEM majors declined in online learning during the COVID time (Wester et al., 2021), it might be more difficult for STEM course instructors to support students' motivation in an online learning setting. Accounting for the decreasing tendency of student-reported motivation in STEM education and online learning environment in the realm of higher education (Bolliger & Wasilik, 2009; Robinson et al., 2019; Rosenzweig et al., 2019;), more in-class motivational support provided by instructors is needed. Therefore, there is a need to explore whether instructors have offered adaptive motivationally supportive instruction in class to tackle the negative impacts brought by the sudden changes of learning environments and social circumstances. Or, compared to the face-to-face classroom environment, instructors' in-class motivational support may have also experienced a decline in postsecondary STEM disciplines.

To sum up, in order to build a foundation of knowledge about instructors' in-class motivational support in both online and in-person learning environments, this study focused on capturing evidence of instructors' motivational support in STEM courses from both in-person and online delivery modes. Specifically, instructors' in-class motivational support via lecture video coding was used to examine the quantitative and qualitative differences in motivational support between the two learning environments. By analyzing the coding results, this research compared instructors' in-class motivational support in university-level STEM courses, intending to provide evidence needed for improving teaching practices in online and offline learning settings.

Literature Review

The purpose of this study is to compare instructors' in-class motivational support in different learning settings across online versus in-person learning environments. The literature review will cover the relevant theoretical frameworks, expectancy-value theory and self-determination theory, and their implications and related literature informing instructional designs for supporting students' academic motivation.

What is Instructor's Motivational Support: Theoretical Frameworks

Motivation research is the study of what energizes action and behaviors (Eccles & Wigfield, 2002). Associated with education, motivation refers to students' beliefs, values, goals, needs, desires, and willingness to succeed in the learning process (Bomia et al., 1997). Students' academic motivation consists of students' competence beliefs about themselves (can I do this) as well as values and goals (why do I want to do this) (Linnenbrink-Garcia et al., 2016). To be specific, "Can I do this?" means students' assessments of whether they are capable of success on learning tasks. “Why do I want to do this?” refers to the reasons that motivate students in the specific learning tasks, such as goals, values, the willingness to succeed, and their identities. Students' answers to these two questions indicate their current academic motivation level, quality, and sources of motivation. Therefore, these two questions provide a lens through which instructors can know how to better support students’ academic motivation through providing more competence-supportive and value-supportive instructions.

Classic motivation theories and prior studies have provided favorable evidence to indicate teaching strategies can be used to mitigate the decline of students’ motivation in the classroom settings (Cheon & Reeve, 2015; Rosenzweig & Wigfield, 2016; Su & Reeve, 2011). Classical motivation theories, including self-determination theory (Ryan & Deci, 2000) and situated expectancy-value theory (Eccles, 1983; Eccles & Wigfield, 2002; Eccles & Wigfield, 2020) have offered theoretical guidance for supporting students’ motivation from different but associated perspectives.

Expectancy-Value Theory

Expectancy-value theory focuses on students’ expectancy for success on a certain task and the perceived value obtained from the task. To be specific, expectancy refers to students’ beliefs about how well they will do on future learning tasks (Eccles & Wigfield, 1995; Linnenbrink-Garcia & Patall, 2016). Subjective task value is defined as students’ beliefs about the value of participating in learning tasks and the reasons that they are willing to join in those tasks. It can explain why students would like to engage or perform well in the learning activities (Brophy, 2008; Eccles & Wigfield, 2002). In terms of the model that Eccles et al. (1983, 2002, 2020) created, students’ expectancy and perceived task value are assumed to be the most important, proximal processes that shape their motivational beliefs and have a great impact on their task persistence, choices, performance, and levels of engagement (Eccles & Wigfield., 2020; Schunk et al., 2014). Different types of task value including utility, interest, and attainment value work effectively to predict students' persistence and performance in learning activities (Eccles & Wigfield, 2002; Eccles & Wigfield., 2020). Therefore, subjective task value and students' expectancy together influence students' achievement-related choices and performance.

Research has indicated instructional design principles based on expectancy-value theory, such as providing opportunities for students to reflect on the relevance or value of the material to their lives, can influence students' perceived value and expectancy in learning (Bergin, 1999; Brophy, 2004; Linnenbrink-Garcia et al., 2016). For example, supporting students' task value via implementing utility value intervention had a positive influence on enhancing students' interest and performance in the classroom settings (Hulleman et al., 2010; Lazowski & Hulleman, 2016; Rosenzweig & Wigfield, 2016; Schmidt., 2019). Many studies have indicated that value-supporting strategies such as personalized content or activities, attempting to link content to students' needs, authentic learning activities, and building learning on the students' existing learning skills can enhance their perceived value and appreciation (Frymier, 2002; Hoffmann, 2002; Hulleman & Harackiewicz, 2009; Pugh et al., 2018; Schmidt et al., 2019; Shaffer & Resnick, 1999).

As one particularly useful and scalable strategy, making relevance statements can help students personally value what they have learned and make connections to their future learning or career choices (Assor et al., 2002; Clegg & Kolodner, 2014; Schmidt et al., 2019). Making relevance statements is an instructional strategy in which the instructor highlights the meaning, applicability, or usefulness of course content beyond the instructional context (Schmidt et al., 2019). Schmidt and her colleagues detected that the more teachers made relevance statements during the natural course in science subjects, middle school students were more likely to regard the learning content as applicable outside the school (Schmidt et al., 2019). The same results were also revealed by "life-relevant science-learning programs" conducted by Clegg and colleagues in helping middle-school learners to pursue their individually meaningful goals (Clegg et al., 2014; Clegg & Kolodner, 2014). These studies provided rather rare evidence from direct observational data to demonstrate the nature and effectiveness of relevance statements in university-level STEM courses.

Therefore, motivationally supportive strategies based on expectancy-value theory, especially support for task value, are expected to be effective. Instructors can make a difference in enhancing students' perceived task value in class when they use relevance statements in their teaching. Despite expectancy-value theory's insights into how to support students' motivation in class, most evidence of motivationally supportive strategies from an expectancy-value perspective is based on intervention work (Canning et al., 2018; Hulleman & Harackiewicz, 2009). For instance, the implementation of a utility-value intervention was found to be associated with higher academic performance and better persistence in both secondary and undergraduate schools' contexts (Canning et al., 2018; Hulleman & Harackiewicz, 2009; Hulleman et al., 2017; Rosenzweig et al., 2019; Soicher, 2020). Utility-value interventions typically involve asking students to write about the personal relevance and usefulness of the course material (Canning et al., 2018). At the end of the semester, students who previously perceived lower academic motivation and had poorer academic performance would have higher perceived motivation and learning outcomes by making connections of their personal relevance and the learning materials (Canning et al., 2018).

However, most of the studies that contained utility-value or relevance supportive strategies used an intervention design, rarely involving the teacher's in-class behaviors and speech (Canning et al., 2018; Hulleman & Harackiewicz, 2009). In other words, previous studies have largely not focused on instructors as important socializers in enhancing students' perceived value and learning outcomes, and observational studies which focused on how instructors support students' utility value are limited. Because observational data involving teacher's behaviors and speech obtained directly from classroom observations provides detailed and practical evidence about how instructors taught within their classes, a literature gap needs to be filled in demonstrating how support for relevance works in real-world education settings.

Self-Determination Theory

In self-determination theory, Deci and Ryan (2000) have proposed three basic psychological needs: relatedness, autonomy, and competence. The need for autonomy refers to the need to self-regulate and self-organize, which means that you can control your own behaviors and goals to make them cohere without heteronomous control. For example, the autonomy-supportive situation means that you are free of options and have the opportunities to choose. And the need for relatedness means that you feel connected with others and experience caring and concerns for others. This kind of meaningful and connected relationship with others can make you feel supported (Lin, 2016). Competence beliefs refer to your confidence and feelings of effectiveness in doing certain tasks, which are relevant to the self-concepts of your abilities (Ryan & Deci, 2000). Similar to students' expectancies of success, students' competence beliefs also come from students' judgment of their abilities, perception of task demand, ideal self, and goals (Ryan & Deci, 2000; Wigfield & Eccles, 2002). Among those three, the needs for autonomy and competence are the most important in maintaining and enhancing students' motivation (Ryan & Deci, 2000, 2020). The need for belongingness is a critical supplement to autonomy and competence support (Ryan & Deci, 2009). According to this theory, students' motivation can be supported by the satisfaction of these psychological needs (Linnenbrink-Garcia & Patall., 2015; Ryan & Deci, 2000; Wallace & Sung., 2016; Williams et al., 2016).

Self-determination theory states that any social context that positively impacts an individual's sense of autonomy, competence, and interpersonal relatedness can facilitate students' motivation (Deci & Ryan, 1991; Wallace & Sung., 2016; Williams et al., 2016). Empirical findings suggested that students who received higher autonomy support from their instructors were more engaged (Reeve, 2006; Reeve et al., 2004; Turner et al., 2014) and more motivated in class (Patall et al., 2008; Tsai et al., 2008). For example, in STEM courses, results shown that students increased their interest with the help of autonomy-supportive lab supervisors and performed better than students under the instruction of controlling instructors (Black & Deci, 2000). Similar results appeared in several prior studies in students' courses, including chemistry, physics, medical biology, and so forth (Cheon & Reeve, 2015; Hagger et al., 2005; Jang et al., 2010; Reeve et al., 2008; Turner et al., 2014; Wiliam et al., 1997).

Further, empirical studies have demonstrated that autonomous motivation is associated with desirable outcomes, including better academic achievement, and also ample research has illustrated the benefits brought from supporting students' autonomy (Deci et al., 1989; Deci et al., 2001; Reeve et al., 2004; Roth et al., 2007). For instance, prior research in a large university-level introductory journalism course have indicated that autonomy-supportive social contexts can predict positive learning outcomes via enhancing students' academic motivation and psychological need satisfaction (Filak & Sheldon, 2008). Reducing controlling teaching and adding autonomy support in the teaching process and instruction design, including providing more choices, accepting multiple interpretations, and caring about students' perspectives, it is an effective way to improve students' academic motivation (Ciani et al., 2010; Filak & Sheldon, 2008; Jang et al., 2010; Linnenbrink-Garcia et al., 2016).

Instructors' Enthusiasm in Motivational Support

Instructors' enthusiasm can be conceptualized as the enjoyment, excitement, and pleasure that instructors display during teaching (Frenzel et al., 2018). This kind of pleasure can be captured and felt by students and has supportive associations with students' engagement in class (Gaspard & Lauermann, 2021; Kunter et al., 2008, 2011).

Previous studies have highlighted that instructors' enthusiasm positively influences students' learning motivation, interest, and belongingness in classroom settings (Hotaman & Yüksel-Sahin, 2010; König, 2021; Kunter et al., 2013). Also, instructors' enthusiasm and personable characteristics would affect students' interest and engagement in class (Godin et al., 2015). In STEM courses, teachers' enthusiasm effectively supports both secondary and post-secondary students' achievement goals and academic motivation and improves students' learning achievement (Hotaman & Yüksel-Sahin, 2010; Jungert et al., 2020; Wood, 1998). However, prior studies mentioned above used survey methods, relying on student reports, and were conducted only in face-to-face classroom settings in K-12 education. To better understand how this strategy can be implemented, it is worth investigating how STEM instructors display their enthusiasm in the online university learning environment.

To conclude, within the classroom settings, a high level of instructor's enthusiasm can predict students' learning and motivation for further learning in STEM education. In particular, instructors' enthusiasm is more vital during the global pandemic because the sudden change of the learning environment is likely to cause more dramatic declines in students' motivation (Wahab & Iskandar, 2020). Therefore, how instructors behave and show enthusiasm is also essential in online education.

Unfortunately, the literature capturing evidence of instructors' in-class enthusiasm in online educational settings is very limited, highlighting a need to fill the gap in knowledge about how instructors' enthusiasm is enacted and differs between the two kinds of classroom settings to better improve instructors' in-class motivational support in the online learning environment.

Academic Motivation in Online and In-person Classroom Setting

In traditional in-person learning environments, authentic interactions or contact between students and instructors, as well as among students themselves, are relatively easy to apply (Howard, 2015). In contrast, online learning, which can also be called computer-based learning and distance learning, refers to the type of learning happening in the Internet-based learning environments where students learn fully virtually (Adnan & Anwar, 2020; Fryer & Bovee, 2018; Yang et al., 2015). It is a prevalent learning mode at the university level, especially during the COVID-19 pandemic (Daniels et al., 2021; Hyslop, 2020). Many STEM courses designed for undergraduate students have to be conducted in online learning conditions under the COVID-19 crisis (Dhawan, 2020; Sarnita et al., 2021; Wester et al., 2021).

As previous studies mentioned, although there were several similarities in students' motivation between different modalities, current evidence suggested there were still some differences in students' motivation and how students perceived motivationally supportive instruction across online and in-person learning environments and course formats (Jones, 2010; Yang et al., 2015). For instance, students tended to perceive lower cost and fewer negative feelings when teachers utilized relevance statements during the middle of the semester in the in-person learning conditions, but the same consequence didn't appear in the online education setting (Marchand & Gutierrez, 2012). Without direct physical contact and interaction, students have reported losing their interest or motivation during online learning compared with face-to-face learning (Roper, 2007; Roseth et al., 2011; Stark, 2019). Additionally, students have indicated a higher need for autonomy support in online learning (Jones, 2010). Previous studies also delineated that the successful completion of online education largely depends on students' active engagement in the learning activities and increased autonomy (Herbert, 2006; Lee et al., 2015).

Within STEM subjects, lower academic performance has been reported in online mathematics classes compared to face-to-face classes, so it is critical for instructors to find a way to motivate students (Francis et al., 2019). In particular, during the COVID pandemic, students' motivation has experienced a decline, which might be affected by the emergency shift of the learning environment (Corpus et al., 2022; Wester et al., 2021). Prior studies have revealed that students' perceived motivation and their academic performance encountered a decrease due to the online learning environment (Roper, 2007; Roseth et al., 2011). However, the reasons that caused those declines have not been fully investigated yet.

In general, instructors play an essential role in supporting students' competence and value in online education (Fryer & Bovee, 2018). In particular, during the COVID-19 circumstances, teachers' teaching strategies are vital in supporting students' interest (Sutarto et al., 2020), learning engagement (Rapanta et al., 2020), as well as enhancing students' in-class academic motivation (Chiu et al., 2021). And with respect to online education in higher education, students also perceived teachers as an important factor in optimizing students' learning outcomes (Jones, 2010; Lim & Karol, 2002; Lim et al., 2008; Wallace, 2010). For example, results show that even though online classroom settings might influence students' academic motivation, students responded positively to instructors' motivational support offered in class (Jones, 2010). Additionally, students in online courses rated higher ratings for instructors' motivationally supportive behaviors like providing clear rationales than students in face-to-face classes (Lim et al., 2008). Prior studies also indicated that students can report higher motivation in online learning environments when their instructors can effectively support their motivation through useful in-class motivationally supportive strategies (Kumar et al., 2018; Vaccani et al., 2016). Because of that, students' academic motivation in the online learning environment can be supported by adequate and effective teacher support.

Therefore, instructors may actually be more supportive of students' autonomy and show more enthusiasm to maintain students' attention in online classes.

In summary, with the potential for differing student needs and differing teaching strategies, how exactly instructors use strategies in both settings respectively are essential to observe. However, there is a lack of studies comparing instructors' motivational support between online and in-person learning environments in university-level STEM courses by analyzing observational data. Additionally, within the limited articles discussing the comparisons (e.g., Roseth et al., 2011; Stark, 2019), those studies focused more on students' perceptions than instructors' perspectives and teaching practices. In particular, little is known about how instructors' instructional strategies might change under the transition of learning environments, even when the instructors themselves and the general format and content of the course remained the same. Therefore, this study will focus on evidence from classroom observations in order to assess whether there is a difference across two learning environments in instructors' directly-observed motivational support with the same instructors and general course's format.

Different learning environments can impact both the perceived motivation of students and instructors' in-class motivational support (Jones, 2010; Lee et al., 2009; Lim & Karol, 2002; Lim et al., 2008). Nevertheless, to my knowledge, there is no published mixed-method study that focuses on in-class evidence of instructors' motivational support in different learning settings. Moreover, current literature also lacks observational research to understand the nature and extent of motivationally supportive practices in natural classroom settings. Considering the previous studies, autonomy support strategies tend to be measured by students' or instructors' self-reported surveys (Black & Deci, 2000; Reeve et al., 2004). But the results of self-reported surveys might be influenced by instructors' and students' subjective factors, including teachers' teaching self-efficacy, their openness to applying educational theories into teaching, teachers' self-serving bias and students' halo effects (Hascher & Hagenauer, 2016; Lietaert et al., 2015; Remmers, 1934). Hence, collecting evidence from direct observational data is needed to describe instructors' motivationally supportive strategies based on self-determination theory.

How To Capture Instructor's Motivational Support: Coding Schemes

There are many different ways to measure instructors' motivational support behaviors and strategies in STEM courses. The most widely used approach to measure these varied forms of motivation is through questionnaires that ask students about whether it is motivationally supportive for them (Jang et al., 2010; Kulakow, 2020; Rosenzweig & Wigfield, 2016; Yu & Singh, 2018). From the literature I gathered for this study, I found that most research utilized student-reported scales or experimental methods (e.g., Black & Deci, 2000; Patall et al., 2008); observational data are seldom used in measuring instructors' in-class motivational support, perhaps due to the difficulty of using these methods and the lack of well-established observational measurement tools. Using self-reported questionnaires to collect students' or instructors' perceptions of motivational support are all based on personal perspectives. Unlike the data obtained from students' or teachers' perspectives, observation data more objective and systematic. Directly observing instructors' natural teaching behaviors and speech in class can provide the ecologically valid perspectives to understand the differences between online and offline learning environments in instructors' motivational supports. In other words, observational data can have a better record on the aspects of behavioral and affective teachers' support through collecting what instructors' actual did in teaching practices (Frensley et al., 2020; Torres et al., 2017). The fidelity of the data can help other university-level STEM instructors by offering direct strategies that they can use in their teaching practices.

Based on a previous literature review examining theoretically-driven coding schemes for motivational teacher practices, I found that validity evidence was inconsistent or lacking (Zheng, Potola et al., 2021). Based on 10 coding schemes that met inclusion criteria, only four of them had available evidence of their effectiveness and applicability to diverse learning settings (Zheng, Potola, et al., 2021). In a follow-up study, even with minimal training, the most suitable coding schemes (Cheon et al., 2018; Robinson, 2019; Schmidt et al., 2019; Turner et al., 2014) of relevance, enthusiasm, and autonomy can achieve reasonably acceptable interrater reliability and alignment with students' survey reports (Potola et al., 2021). Hence, I selected these same coding schemes to capture observational data in instructors' in-class motivational support.

Most studies using coding schemes to measure motivational teaching strategies assessed only one type such as relevance or autonomy (Cheon et al., 2018; Schmidt et al., 2019). To my knowledge, no studies to date have measured relevance, autonomy support, and instructors' enthusiasm at the same time (Cheon et al., 2018; Schmidt et al., 2019). Focusing on those three constructs simultaneously can help us gain a holistic view of the quantitative and qualitative differences in instructors' motivational support between two learning environments. Given the combination of the aforementioned research, students are likely to show engaged behaviors (e.g., attendance and concentration) and engaged emotions (like enthusiasm, interest, and enjoyment) when they are intrinsically motivated and their needs are adequately satisfied (Deci et al., 1991; Eccles & Roeser, 2009). The effective teacher support including teachers' enthusiasm (Patrick et al., 2000), autonomy-supportive behaviors (Zee & Koomen, 2020), and increasing content and goal relevance (Albrecht & Karabenick, 2018; Frymier & Shulman, 1995) can work together as proximal classroom factors in supporting students in class.

Present Study

This study compared instructors' in-class motivational support across online and in-person university-level STEM courses in order to provide rich, detailed descriptions of in-class teaching practices that were associated with instructors' motivational support. Specifically, this study focused on differences and similarities in the amount and nature of the strategies that instructors used to support students' academic motivation across pre-pandemic in-person and during-pandemic online learning environments using classroom observational data. Toward that end, the proposed study addresses following research questions:

1. How did instructors support students' academic motivation in pre-pandemic in-person and pandemic online university-level STEM courses?

2. What similarities or differences can be observed in instructors' in-class motivational support across pandemic online and pre-pandemic in-person learning environments?

Grounded in self-determination theory and expectancy-value theory, autonomy-supportive teaching, relevance statements, and teacher enthusiasm in class are effective in improving students' academic motivation. Previous research has indicated that instructors' autonomy-supportive and relevance-supportive teaching practices can be captured via in-depth observational studies (Schmidt et al., 2019; Wallace & Sung, 2017) and findings from previous studies have provided a well-defined set of autonomy-supportive and relevance-supportive teaching practices (Jang et al., 2012; Schmidt et al., 2019; Skinner et al., 2009). Thus, I expected that I would be able to capture evidence that instructors used these strategies at least occasionally in both learning environments via in-depth observation of the data. Regarding the prior studies (Bowers & Kumar, 2015; Wang et al., 2019), students reported significantly lower scores in the learning climate and need satisfaction in the online learning environments and higher scores in in-person learning settings due to the relatively lower quality of teaching they perceived during online learning and lack of interactions between instructors and students in online courses. Moreover, the further psychological and physiological distance between students and instructors in online environments also influences the teaching quality and the course climate (Mandernach et al., 2006; Yang et al., 2015). Thus, I expected that, even the same instructors in the same course, instructors' overall motivational support in online STEM courses during pandemic and on-campus learning before pandemic might be varied.

The other key aim of this study is to investigate the differences and similarities in using certain motivationally supportive strategies across pandemic online and pre-pandemic face-to-face learning environments via classroom observation. In terms of the previous studies (Chen & Jang, 2010; Shroff & Vogel, 2009), students reported higher ratings on perceived autonomy in online classes compared to the traditional classroom settings, since online classes are typically more self-guided and don't require you to be adherent to a certain time or place. In this case, I surmised that instructors' autonomy support in online education settings would be observed more frequently than in face-to-face STEM classes. Due to the lack of social presence, real-time interaction, and synchronous communication between instructors and students, I further assumed that instructors' enthusiasm might encounter the biggest reduction due to the switch of learning environments. In addition, students preferred traditional face-to-face learning rather than online learning when they were required to utilize the domain-specific conceptual knowledge or skills in the application (Paechter et al., 2010; Paechter & Maier, 2010), so instructors might also add more real-world connections in the in-person learning environments compared with the online environments. Therefore, I hypothesized that there would be significant differences in the relevance statements and showing enthusiasm across two learning environments before and during the global pandemic.

Method

Sample and Setting

In order to compare the online and in-person learning environments, I used existing data collected from a broader project on students' experiences and motivation in large STEM courses. As part of the project, instructors shared their digital lecture recordings with the research team. Data was gathered during two separate years for one introductory chemistry course at a large university in Canada during Fall 2019, when instruction was conducted in person in a large lecture hall, and Fall 2020, when instruction was conducted online due to the COVID-19 pandemic. Each fall semester lasted for 13 weeks and the two female instructors provided all the video lecture recordings for use in this study. In both 2019 and 2020, Instructor A taught the first 8 weeks, and Instructor B was in charge of the final 5 weeks in this course. This allocation of teaching remained the same across both years.

Because this is a general and introductory chemistry course, the class population in the Fall 2019 semester was 604 undergraduate students from STEM-relevant majors. Among them, 91.2% of the students were in their first year, while 8.8% of them were not the freshman. The class size in Fall 2020 semester was 642 students, 91.1 % of them were first-year undergraduate students, while 8.9% of them were not in their first year. According to the final grades that instructors provided, the average final grades in the Fall 2019 semester were 80.06, whereas the average final grades in the Fall 2020 semester were relatively higher at 91.84.

Data for this study consisted of the lecture recordings, which contained lecture slides on the screen along with instructors' voices. Any students' behaviors or student speech accidentally captured in lecture recordings was not coded during the coding process. For analysis, lecture recordings were divided into segments of approximately 10 minutes each, then matched across 2019 and 2020 by the topic and instructor (see Table 1). This resulted in a total of 173 video segments, 107 from Fall 2019 and 66 from Fall 2020.

In Fall 2019, face-to-face teaching was conducted within a large lecture hall with the capacity of 650 students. There were 33 lectures throughout the whole semester. Every lecture lasted for approximately one hour. Instructors typically briefly reviewed the content from the previous class and made some announcements in the first 10 minutes, and then started introducing new content. After the explanation of the new content, the instructors typically provided relevant examples and practice questions, allowing time for students to work together on examples and questions. In these contexts, instructors had physical interactions with students, such as walking around the class, and asking students to raise their hands. Students could interrupt instructors at any time when they had questions. In order to give all students opportunities to rewatch the lectures when they were needed, instructors recorded the lectures using an automated system provided by the university, with lecture videos automatically uploaded to the online course management platform after class.

In Fall 2020, teaching throughout the semester happened via Zoom. Both instructors and students had no opportunity to participate in in-person classroom activities within that semester. All the lectures were pre-recorded using Zoom recording functions. Instructors uploaded the lecture videos, also called concept videos, to the online course management platform for students to watch. Concept videos were each approximately 25 minutes long. These short concept videos replaced formal lectures, but students still had opportunities to attend short problem-solving tutorials synchronously via Zoom. Through the Zoom platform, they could interact with instructors synchronously during that session. There was no mandatory participation for the problem-solving tutorials, so students could also communicate with their instructors asynchronously via Zoom online course management system or emails. In the present study, I didn't include tutorial videos for two reasons: one is that we didn't have corresponding tutorial recordings in the Fall 2019 semester, and the other is that there were not sufficient numbers of tutorial video recordings to analyze.

Procedure

Video Segment Selection

In order to better achieve the research goals and constrain as many potential influencing factors as possible aside from the factors that this study explored, I only selected video lecture segments that represented parallel topics and instructors across the two semesters. In other words, lecture segments were included in the study when the combination of topic (i.e., Chapter 7: periodic trends) and instructor were the same across 2019 and 2020. Some of the lecture video recordings in Fall 2019 semester (n = 5 1-hour lectures) were lost due to technical reasons (such as no audio or slide view). A total of 66 10-minute video segments for Fall 2020 and 107 10-minute segments for Fall 2019 were retained for coding.

Training and Trial Coding

In this study, taking the previous results into consideration (Potola et al., 2021; Zheng, Potola, et al., 2021), the observational measures of relevance, enthusiasm, and autonomy were selected as those that were likely to achieve acceptable reliability and correspondence with students' perceptions in measuring instructors' motivational support.

Before formal coding, I trained a team of coders so that I could obtain baseline evidence of reliability and validity for the observational coding schemes. First, I conducted training and trial coding for a team of two graduate student coders, in addition to myself. All the coders were required to read the codebook and coding scheme carefully before the training. The coding examples, definitions, and coding items were clearly displayed in the coding scheme. During the 3-hour training sessions, the definitions and situations that could be coded as showing enthusiasm, supporting autonomy, and communicating relevance were well-defined in the training slides. Slides also showed the detailed explanations of each coding item, as well as the examples adapted from chemistry teaching practice which were selected from the recordings. And the examples that I used in the training sessions would not be included in the subsequent coding.

Next, I randomly selected six video segments for coding practice from among those segments that wouldn't be used in the formal coding. After the trial coding for the first two video segments, we met to discuss and refine our coding definitions and criteria for some of the sub-categories in rating the instructors' autonomy due to low to moderate inter-rater reliabilities in a previous study (Potola et al., 2021).

After the trial coding, I found that the inter-rater reliabilities between three coders (Kappa for the relevance statements) have reached substantial to perfect agreement (κ = 0.83). We achieved substantial agreement in observing instructors' enthusiasm, κ = 0.67. Because we had one coding sub-category which achieved just fair to moderate acceptable inter-rater reliabilities in rating autonomy support, we coded two more backup videos for autonomy-supportive rating scales. We had a further discussion to solve the conflicts. Finally, the inter-rater reliabilities for coding autonomy support were shown within perfect range (ICC = 0.921, $p < .001$, 95% confidence interval from .863 to .957). Following the establishment of reliability, I coded the rest of the video segments alone.

Qualitative Data Collection through Coding

Adapted from Schmidt et al (2019), Cheon et al (2018), and Robinson (2019), I built an adapted coding scheme to code the instructors' enthusiasm, and autonomy support during teaching. I will describe the instruments and procedures used to code for relevance, autonomy support, and enthusiasm one by one in the following paragraphs.

Coding for Relevance.

To capture the number and quality of instructors' relevance statements in chemistry courses, I used a coding scheme adapted from Schmidt et al. (2019). Relevance statements occur when instructors make connections between learning materials and real-world situation, meaningful application, or value beyond the instructional context (Schmidt et al., 2019). This coding scheme involved counting how many relevance statements were made in every 10-minute segment, then classifying the domain (type) of each relevance statement for describing different dimensions of relevance.

In the present study, I coded the different domains of relevance statements from instructors in-class speech including linking chemistry learning with careers or jobs, future education, routine activities, health or safety, understanding or explaining natural phenomena, explaining the advances of chemistry, hobby or pastime, bridging to understand a concept in chemistry class, bridging to understand other STEM courses, and understanding or advancing social relationship in order to find which kinds of real-world connections are frequently supported by instructors in the chemistry classes from the lecture recordings for university-level chemistry courses.

Coding for Autonomy Support.

Support for autonomy is the second category of the coding scheme I used in this study. Instructors' autonomy support was measured using six items adapted from Cheon et al. (2018). The items included: takes the students perspectives, vitalizes inner motivational resources during instruction, provides explanatory rationales, uses non-pressuring, informational language, acknowledges and accepts negative affect, and displays patience. Because I didn't include any student behaviors or reactions in class, all codes were based on instructors' speech during teaching alone. In particular, coding for "acknowledges and accepts negative affect" was based not on observed expressions of students' negative affect, but rather on instructors' verbal, proactive acknowledgements of negative affect as normative and expected.

For every 10-minute segment, raters scored instructors' autonomy support using a 7-point Likert-type scale: 1= *never, not at all*, 4 = *occasionally, sometimes yes, sometimes no*, and 7 = *always, very much*. Each rating of "4" is a moderate category, which means that instructors offered autonomy support occasionally throughout this segment. Additionally, as we discussed in the trial coding, we set the criteria as "1-2" autonomy supportive behaviors in the 10-minute segment aligns with a rating of 2-3, "3-4" autonomy supportive behaviors can be aligned with a rating of 4-5. And if we observed 5 or more than 5 times of autonomy supportive behaviors, we can give them a rating of 6-7.

Coding for Enthusiasm.

Coding for enthusiasm was adapted from Robinson's dissertation (2019). Similar to the relevance coding scheme, coding for enthusiasm consisted of a counting system to capture instructors' behaviors and statements. The indicators I measured for instructors' enthusiasm includes exclaiming, smiling while talking about the materials, verbally noting something is interesting or exciting, and gesturing broadly (Robinson, 2019). Because we didn't have the lecture recordings on instructors' views, I coded "gesturing broadly" category only when the instruction said aloud that they were gesturing. For example, *I will use my body to show you the structure of enantiomers*.

Building Dataset and Quantitative Data Analyses

Building datasets via data transformation is a critical part in this study. In this part, I directly utilized the counting or rating results from all 10-minute segments to build the SPSS dataset. Taking the comparison into consideration, every paired variable within the dataset has been named in a corresponding way across two learning environments, such as "online relevance" and "offline relevance." The preliminary analyses of the coding data gave me a descriptive overview of instructors' in-class motivational support in different learning environments and indicated what kind of motivationally supportive strategies were frequently used by instructors in different scenarios.

Because of the various length of lecture recordings across two years, I obtained 107 10-minute video segments of Fall 2019 semester and 66 10-minute segments of Fall 2020 semester. The number of video segments in Fall 2019 is significantly larger than the number of video segments in Fall 2020. Therefore, according to the corresponding content of every section, I calculated the means of several segments' data in Fall 2019, matching topic and instructor, to align with the number of cases that appeared in Fall 2020. For example, in Chapter 8.6, the teaching content was drawing Lewis Structures. Due to the different lengths of lecture recording videos, the Fall 2019 semester had four 10-minute videos about this topic (i.e., A1, A2, A3, A4), but the Fall 2020 semester only had two (i.e., B1, B2). Therefore, I took the mean of the four 10-minute segments according to the teaching contents and made them into two 10-minute segments, such as taking the mean of A1 and A2 video segments to make a new A1 video segment to compare with the B1 and taking the average of A3 and A4 video segments to make new A2 video segment to compare with the B2. Table 1 demonstrates how the topics and numbers of videos are aligned across two years. After restructuring the dataset, I obtained 66 pairs of 10-minute video segments across two years and they were prepared for the future analyses. Thus, means can be interpreted as counts or ratings of motivational support per ten minutes of instruction, thus making datasets from 2019 and 2020 comparable to each other by reducing the possibility that observed differences are due to differing lengths of instructional videos.

Analytic Plan

In order to answer the research question, data from each semester were first analyzed independently, and then integrated together. Preliminary analyses started with conducting descriptive statistics using the dataset directly obtained from the coding results. Combined with the coding evidence, I gained an overview of instructors' motivational support separately in Fall 2019 and Fall 2020 semester.

To further investigate the differences and similarities across two learning environments, I used SPSS version 26 on the restructured data; I conducted a repeated-measures MANOVA to compare instructors' in–class motivational support involving support for relevance, support for autonomy, and showing enthusiasm across two semesters. Those analytic processes helped to determine whether there are some significant differences in the amount of motivational support across two time periods and delivery modes. Followed by the overall multivariate tests, using paired sample *t*-tests as post hoc tests, I also examined the specific differences of every coding item under the three main measures so that I could know what sub-categories should be responsible for causing the differences of instructors' motivational support across online and on-campus learning.

Results

Preliminary Analyses

Preliminary analyses were conducted to investigate differences obtained from coding results in all the variables. Descriptive statistics for the study variables appear in Table 2 and Table 3.

In the pre-pandemic face-to-face delivery mode, I observed 78 relevance statements or behaviors in the 107 10-minute segments, for an average of 0.73 relevance statements per 10-minute segment. According to Table 4, the most frequently used domains in relevance were connecting to routine activities and everyday life (32% of the overall relevance statements). For example, Instructor A used the example of sunglasses to explain a molecular structure in order to let students acknowledge the daily application of the principle of polarization of light. Instructors also often bridged previous content to understanding a new concept, unit, or experience in the current chemistry class, comprising 22% of total relevance statements. For instance, the instructor said “thinking about the content in Chapter 8” when explaining connections between prior chapters and the new content in Chapter 10. In contrast, instructors appeared to seldom use relevance statements connecting the content to other STEM learning materials (1% of relevance statements connected the content to other STEM learning materials), health and safety (5%), or hobbies and pastime (5%). No instances of job or career relevance statements (0%) or relevance statements related to advancing social relationships (0%) were observed in Fall 2019.

As for instructors’ enthusiasm, I counted 61 instances of verbally mentioning the learning materials were interesting (e.g., “The materials here is super interesting.” or “The transition model is very very interesting”) in 2019, when instructors were physically present with students, with an average of 0.57 per 10-minute segment. For autonomy support, the mean of the composite autonomy support indicator (average of all individual autonomy support items) was fairly low on the 7-point scale (M = 1.69, SD = 0.37), indicating that overall autonomy-supportive teaching evidence was seldom captured. Five of the six autonomy-supportive strategies were rarely identified in the lecture recordings. Among them, instructors rarely mentioned or responded to students’ negative emotions during the class (M = 1.12, SD = 0.41). In contrast, taking students’ perspectives, including answering students’ questions and responding to students’ needs, appeared to have the highest mean (M = 3.67, SD = 1.64), indicating that instructors appeared to be more likely to support students’ autonomy by caring students’ perceptions. For example, in one video segment of Chapter 9, Instructor A immediately responded to a student request for resources for simulating models “You will have the link so that you can try the simulation, and that will help you to visualize the model.”

For Fall 2020, I observed 83 relevance statements in total from instructors in the online pandemic delivery mode within 66 video segments, for an average of 1.26 relevance statements per 10 minutes of instruction. Unlike the results from Fall 2019, in the online learning environment, instructors often connected the content to previous knowledge (28% of the relevance statements). But making connections between course content and routine events (21% of relevance statements in Fall 2020) was the second most common type of relevance statement among the ten in the coding scheme. For example, in the lecture video, the instructor used the statement of dancing postures to help students understand the structure of molecular geometry: “Just like you are dancing with your partner, you put one hand on his/her shoulder and the other hand on their waists.”

In the pandemic online learning environment, instructors still demonstrated their enthusiasm by verbally noting the learning materials were interesting, using engaging tones of voice, and/or broadly gesturing during almost every 10-minute segment ($M = 0.94$, $SD = 1.29$). However, the ratings of autonomy support appeared to be lower in 2020 compared to the lectures conducted 2019 ($M = 1.53$, $SD = .34$), meaning that even more limited evidence of autonomy-supportive teaching was found in the pandemic online teaching. The specific ways that instructors supported students’ autonomy in class also appeared to differ according to descriptive means. For instance, the average score of taking students’ perspectives in pandemic remote learning appeared to be lower than in pre-pandemic in-person learning environments ($M = 2.02$, $SD = 0.93$). Although the ratings appeared to be lower than in the on-campus context, taking students’ perspective still appeared to be the method that instructors most frequently used in class. Additionally, providing explanatory rationales for students in remote delivery classes, such as offering reasons for the class procedures, were the second most frequently-used strategies that instructors chose to support students’ in-class autonomy ($M = 1.86$, $SD = 0.72$).

From the preliminary analyses, Table 2 and Table 3 reveal that there is no evidence to show that instructors used relevance statements to build connections between chemistry learning and students' career choices in both pandemic online and pre-pandemic in-person learning environments. Likewise, instructors did not utilize relevance statements that applied learning content to explain the advancement of social relationships across two learning conditions. Similarly, instructors seldom made connections between chemistry learning materials and other courses in STEM fields like mathematics or engineering. The results also indicated that in both teaching scenarios, there were no observed instances of instructors displaying patience for students and trying to respond to students' negative emotions towards the learning material. In addition, the frequency of supporting students' autonomy in class was all relatively low across two delivery ways (M_{2019} = 1.53, M_{2020} = 0.94).

Quantitative Analyses: Comparing 2019 and 2020

In order to test whether there were any statistically significant differences in instructors' in-class motivational support across the two learning environments, the quantitative data were analyzed using a repeated-measures MANOVA for all three measures. Following the omnibus repeated-measures MANOVA, post-hoc tests involved paired-sample *t*-tests to examine differences for each sub-category under instructors' relevance statements, enthusiasm, and support for autonomy.

The initial analyses of the quantitative data consisted of repeated-measures MANOVA across two years for the three motivationally supportive strategies in order to compare the amount of instructors' support for students' academic motivation in pandemic online and pre-pandemic in-person learning environments. The means and standard deviations for relevance statements, enthusiasm, and autonomy ratings are presented in Table 5. Looking at the means, it appeared that instructors tended to more frequently utilize relevance statements and show their enthusiasm in the pandemic online learning environment as compared to the pre-pandemic in-person learning conditions. Indeed, the repeated-measures MANOVA was significant, F (3,63) = 5.29, p = .003, partial η^2 = .201.

Respectively, three repeated-measures univariate tests revealed that relevance statements, F (1, 65) = 4.84, p = .031, partial η^2 = .069, autonomy support, F (1, 65) = 7.78, p = .007, partial η^2 = .107, and enthusiasm, F (1, 65) = 7.56, p = .008, partial η^2 = .104, were all significantly different across the two years. These results suggested that instructors supported students' academic motivation differently by using differing amounts of relevance statements, autonomy support, and enthusiasm across the two learning environments. Specifically, instructors made more relevance statements during teaching in the pandemic online learning environments than that in pre-pandemic in-person learning environments (M_{2019} = 0.85, SD_{2019} = 1.17, M_{2020} = 1.26, SD_{2020} = 1.60). Similarly, instructors were also more likely to demonstrate their enthusiasm in class during pandemic online learning in Fall 2020 semester compared to Fall 2019 semester (M_{2019} = 0.54, SD_{2019} = 0.71, M_{2020} = 0.94, SD_{2020} = 1.29). Conversely, statistical results showed that instructors' autonomy-supportive teaching obtained higher scores in pre-pandemic in-person learning environments than the online learning environments during pandemic (M_{2019} = 1.69, SD_{2019} = 0.37, M_{2020} = 1.53, SD_{2020} = 0.34).

Paired-samples t-tests which served as the post hoc tests were conducted to explore which detailed supporting strategies have the most salient differences between online and in-person learning environments under the three nuclear categories. For relevance statements, among ten sub-categories of instructors' relevance statements, there was only one significant difference: in bridging to understand a concept in current chemistry class across two semesters, t (65) = -2.03, p = .047. The results indicated that instructors were more likely to connect the current learning materials to prior knowledge in the course during 2020 online lectures. Significant differences were also detected in the specific sub-facets of autonomy support across remote and face-to-face teaching. Specifically, in the in-person learning environment, the rating scores were significantly higher for caring about students' hopes, needs, and questions, t (65) = 7.39, p < .001, indicating that instructors were more likely to take students' perspectives during offline schooling. In addition, there was a significant difference in providing explanatory rationales for procedures across two delivery modes, with t (65) = -2.68, p = .009. The result reveals that instructors tended to offer more explanations and identify the value and utility of a request for students in online learning environments.

The overall repeated-measures MANOVA featured a significant difference in instructors' motivationally supportive strategies between online and in-person learning environments. However, there are also some commonalities that existed under the three main categories.

For relevance statements, the results from post hoc tests shown that there were not significant differences in using relevance statements connecting current learning to future education, t (1) = -.17, p = .862, health or safety, t (1) = -1.03, p = .308, routine activities, t (1) = .13, p = .901, understanding natural phenomena, t (1) = -1.30, p = .199, advancing chemistry or society, t (1) = -1.136, p = .260, hobbies or pastimes, t (1) = -.47, p = .641, or connections to other STEM disciplines, t (1) = -1.00, p = .321. Meanwhile, results revealed that in both online and offline learning environments, there were no relevance statements pertaining to future career inspirations or making social connections.

For autonomy support, the paired samples t-tests assessed the differences across Fall 2019 and Fall 2020 semesters in six subcategories of the instructors' autonomy support rating systems. The rating scores of vitalizing inner motivational resources during instruction in online learning environments were not significantly different from those in face-to-face classrooms, t (1) = -1.40, p = .165. Similarly, the non-significant differences also occurred in using non-pressuring languages, t (1) = -1.30, p = .199, acknowledging negative affect, t (1) = -1.67, p = .099, and displaying patience in class, t (1) = .60, p = .554, across online and in-person learning environments. These results indicated some motivationally supportive strategies only slightly differed or even remained the same across pre-pandemic in-person and pandemic online learning conditions.

Discussion

Teachers' in-class motivationally-supportive instructions and in-class motivating style have been recognized as essential components in supporting students' academic motivation in both online and in-person learning conditions (De Loof et al., 2021; Wladis et al., 2014). Theoretical and empirical evidence have demonstrated that students themselves also value instructors' motivational support in class (Hulleman et al., 2017; Kunter et al., 2008; Reeve et al., 2004). However, prior studies have indicated that teachers' in-class motivational support can be different in diverse teaching contexts (Brophy & Good, 1974; De Meyer et al., 2016; Rosenzweig & Wigfield, 2016). Aiming at providing rich and detailed practical evidence pertaining to instructors' in-class motivational supportive instructions in university-level STEM disciplines, this study proposed two research questions in order to capture and compare instructors' in-class motivational support across pre-pandemic in-person learning environments and pandemic online learning environments.

In the present study, to answer those research questions, I designed a mixed-method investigation to map out how instructors supported students' academic motivation in university-level STEM courses across during-pandemic online and pre-pandemic in-person learning environments grounded on self-determination theory and expectancy-value theory (Eccles & Wigfield, 2020; Ryan & Deci, 2020). Capturing evidence from directly observed teaching practices is an important highlight of this study.

I acknowledge that students' perspectives are essential to understanding what strategies and instruction were effective in supporting their motivation, but direct observations of authentic teaching practices provide a critical complement to our understanding of instructors' in-class motivational support (Butz & Stupnisky, 2016; Parr et al., 2021; Schmidt et al., 2019; Smart, 2014). Furthermore, I captured instructors' motivational support from both in-person and online teaching modes rather than only one classroom setting, while the instructors and course content remained constant, so that we can have a concrete and comprehensive view about the differences and similarities of instructors' motivational support across two learning environments. Therefore, although the passage of time and the stressors of the pandemic likely also contributed to the observed differences, such differences in instructors' in-class motivational support revealed from the coding can also be at least partially attributed to the differences in learning environments.

To answer the research questions, analyses of the qualitative coding data have yielded an overview of instructors' in-class motivational support in both learning environments. Various aspects of differences and similarities in relevance, autonomy support, and enthusiasm measures and their implications are discussed in the following sections.

Different Learning Environments, Different Motivationally Supportive Strategies?

Prior studies indicated that teachers' teaching behaviors and instructional strategies can be varied in different learning environments (Brophy & Good, 1974; De Meyer et al., 2016; Rosenzweig & Wigfield, 2016). The results of this study revealed a similar conclusion that there was a significant difference in some motivationally supportive strategies across pandemic online and pre-pandemic face-to-face learning environments. These results support a conclusion that even within the same teaching topics, instructors' motivationally supportive strategies would be varied and adjusted based on the learning environments. By examining the three measures respectively in the post hoc tests, salient differences also appeared within every category and even sub-categories of the measures.

In the pandemic online learning environments, instructors had limited interactions with students physically. This may at least partially explain why results showed that they tended to show more enthusiasm such as verbally mentioning that they were excited about the materials and trying to grasp students' attention. On the contrary, in the in-person learning environments, instructors may appear to have more opportunities to show non-verbal enthusiasm through gestures. For example, one instructor said that she would use her postures to show the chemistry models instead of just looking at the pictures shown on the slides in the classroom.

Similar to showing enthusiasm, different patterns of the types of relevance statements used across the two contexts suggested that the differing learning environments also appeared to shape different applications of motivationally supportive strategies. In this study, for example, the online lecture recordings were much shorter than the on-campus recordings. Instructors instead aimed to cover all the teaching contents in the pre-recorded concept videos. In this case, the limited length of the lecture videos in pandemic online learning environments may have prompted instructors to abridge some practical questions or learning activities that would highlight relevance connections. Therefore, as the results show in Table 4, in pandemic online teaching conditions, instructors were more likely to bridge the learning contents with previous knowledge in order to build a clear but brief scaffolding for the current materials rather than connecting the concepts more with daily routines and events. Perhaps they had to be more direct in their communication because the pre-recorded and asynchronous video could not let them informally assess their students' knowledge as they could in a longer and synchronous classroom environment. Additionally, perhaps the difference in frequency, such as how often the instructors used relevance could at least partially be explained by the need to allow time for students to ask questions and interact with the students in Fall 2019, where that wasn't needed in Fall 2020.

Based on the findings from my study, instructors tended to make more frequent relevance statements in pandemic online learning environments than in in-person learning environments. By examining the final grades across the Fall 2019 and the Fall 2020 semester, I found that students in Fall 2020 pandemic online learning environments achieved higher academic performance in their final grades than in the pre-pandemic in-person learning environments (M_{2019} = 80.06, M_{2020} = 91.84). This finding seemed to be aligned with prior studies (Watt & Richardson, 2013; Wentzel & Wigfield, 1998) which also indicated that students' learning and performance can be motivated by teachers' in-class instructional practices and their interpersonal relationships with students. Hence, this might be one of the reasons that can explain the average final grades in pandemic online learning environments were higher than in-person learning environments in Fall 2019 semester. However, although assessments were the same across 2019 and 2020 in this setting, it is also possible that grading standards were relaxed due to the pandemic, as has been observed in other studies (Aziz et al., 2022; Pogrebnikov et al., 2021).

As for supporting students' autonomy, in alignment with the previous studies (Johnson et al., 2015; Summers et al., 2005), the online learning environment reduced the teacher-student interactions which appeared to limit opportunities to show caring for students' needs compared with the in-person classroom. Therefore, the ratings of instructors' autonomy support in responding students' needs were relatively lower in online learning environments, which compared with the in-person learning environments (M_{2019} = 3.67, M_{2020} = 2.02). Conversely, instructors used different strategies to support students' in-class autonomy. As the results shown, in the online learning environments, instructors tended to obtain higher scores in providing clear rationales for procedures and identifying the importance of the content, compared to lectures conducted in the lecture hall (M_{2019} = 1.49, M_{2020} = 1.86).

Based on the literature review, results from some studies indicated that online learning appeared to be lower in teaching quality, lacking in teacher-student interaction, and prompting lower student satisfaction (Kelly et al., 2007; Summers et al., 2005; Young &

Duncan, 2014). Thus, I also hypothesized that in-person classes would be more motivationally supportive than pandemic online learning environments. However, my findings were contrary to those hypotheses and conclusions. Instead, findings indicated that the online learning environment can also be quite motivationally supportive and obtain higher students' performance. Even though we have assumed there were some challenges for instructors to support students' motivation in online learning environments, adjusting the utilizations of various motivationally supportive strategies and making the maximum use of them appears to be possible. This finding also aligned with findings from a recent comparative study, which showed that online learning during the global pandemic tended to produce equivalent or better academic performance for students compared with the pre-pandemic in-person learning (Zheng, Bender, et al., 2021). Thus, both online and in-person learning environments may have effectively supported students' motivation, perhaps due to instructors' effective adaptation of their strategies. Future studies are needed to examine the effects of differential motivational supports across different learning environments.

For example, other studies also highlighted that the effect of online teaching is different between pre-pandemic online learning environments and during-pandemic online learning environments (Boardman et al., 2021; Feng et al., 2021). Due to the sudden outbreak of the global pandemic, universities were forced to switch their teaching activities from in-person classroom learning conditions to online learning via Zoom or other platforms (Boardman et al., 2021; Daniels et al., 2021). In other words, current during-pandemic online learning is a kind of emergency online learning. Instructors, students, and school administrators were all unlikely to be well-prepared for the emergency online education (Coman et al., 2020; Wisanti et al., 2021). In this case, Zoom or other online platforms have become a lifeline for students and teachers. This emergency and necessity might have different impacts on instructors' motivation as compared to the purposeful and planned use of online learning modes and tools. Findings from studies that focused on teachers' perspectives towards during-pandemic online teaching indicated that this kind of emergency education negatively affected their motivational job characteristics but improved their teaching abilities (Aras & Wulandari, 2021; Beardsley et al., 2021; Kulikowski et al., 2022). Therefore, it is important to be careful in applying the conclusions of this study to traditional and purposefully planned online teaching settings.

As for the implications gained from this study, I acknowledged that instructors had different preferences in supporting students' relevance and autonomy in difference delivery modes by calculating the usage frequency for every motivationally supportive strategy. Prior research indicated that it is quite important for instructors to implement diverse motivationally supportive strategies flexibly in different learning environments (Dhawan, 2020; Young & Duncan, 2014). Considering the current findings and previous implications, it is important that teachers and instructors identify and apply the most appropriate motivationally supportive strategies into their teaching practices in order to enhance in-class engagement and students' academic motivation. This is also a critical point I would like to point out for future teacher education and teacher professional development training.

Similar Motivationally Supportive Patterns Detected in 2019 and 2020

The results from repeated-measures MANOVA and three univariate tests for autonomy support, relevance statements, and instructors' enthusiasm revealed significant differences in the amounts of instructors' in-class motivation support. Nevertheless, some similarities were also observed. For example, both in online and in-person learning environments, taking students' perspectives was the most frequently used strategy in supporting students' autonomy in class. Additionally, in both learning environments, I observed no evidence that instructors connected learning materials to a job or career in their relevance statements. Apart from that, from the preliminary analysis, guest coders and I noticed that instructors used fairly analogous slides across two semesters, even though their interpretations of materials and class components differed due to the changes of delivery modes. For instance, in the pre-pandemic in-person learning environment, the instructor used the same slides to explain the molecule structure, and instructor B remarked verbally that she was using her body postures to help students visualize the model during teaching in the classroom. However, in online teaching, she did not use gestures, but introduced and explained it by using the image in the slides. Because of the similar slides they used across two years and similar teaching contents, the similarities of motivational support can be detected from the coding evidence and results of the study, especially in the aspect of relevance statements and supporting for autonomy.

Previous studies indicated that instructors' in-class motivational support including instructors' relevance statements (Durik et al. 2015; Schmidt et al., 2019), autonomy support (Cheon et al., 2019; Jang et al., 2010; Jang et al., 2016), and enthusiasm (Gaspard & Lauermann, 2021; Lazarides et al., 2018) were positively associated with students' academic motivation. In terms of the findings in this study, there was an average of 0.85 relevance statements and 0.54 instances of enthusiasm per 10-minute segments in offline STEM classrooms. The averages of both relevance statements and showing enthusiasm during in-person instruction were both lower than the averages in pandemic online learning for supporting relevance and autonomy. Thus, it's possible that STEM instructors, especially in the traditional face-to-face delivery modes, might feel that they teach in their comfort zones so that they might pay less attention to designing how to support students' motivation and grasp students' attentions during lecturing. This explanation would align with the implications from Smith et al. (2000) and Dell et al. (2008, 2010)'s article, which indicated that teachers were more likely to be well-prepared and used effective instructional methods in the online learning environments.

In addition, although the average rating of autonomy support in the in-person learning environment (M = 1.69) was significantly higher than in the online environment (M = 1.53), the rating of scores were still quite low on the scale. According to the 7-point Likert-type scale used to code for autonomy support, “1” means that nothing relevant to instructors’ autonomy support appeared in the 10-minute video segment. Therefore, the average ratings less than “2” in both two learning environments indicated infrequent autonomy-supportive teaching in this STEM course. These findings may explain the average declines of students’ academic motivation in STEM courses over time (Jacobs et al., 2002; Watt, 2004). On the other hand, it may be that only a few instances of autonomy-supportive teaching are sufficient for supporting students’ motivation, particularly in online environments which are typically structured to provide students with a great deal of choice over when and how they engage with the course. Future research is needed to further investigate and even quantify that how many motivationally behaviors and statements in the one single 10-minute video segment or entire lecture are appropriate and effective in supporting students’ academic motivation and enhancing classroom climate.

Secondly, some types of motivational support in other settings (e.g., Schmidt et al., 2019) were not observed here. In the lecture recordings from both Fall 2019 and Fall 2020, I observed no evidence of relevance statements that connected the learning materials into a job or future career choices. Similarly, there is also no evidence to show that instructors used the relevance statements to bridging the chemistry learning with understanding social relationships and advancement. In addition, I also found that there were few relevance statements that were associated with other STEM disciplines, health or safety, and hobby or pastime. Among them, previous empirical evidence indicates that relevance statements relevant to a job or career were quite essential in supporting students' academic motivation grounded on the expectancy-value perspectives (Assor et al., 2002; Schmidt et al., 2019).

Students may value chemistry learning more if they would like to pursue a chemistry or STEM career and they can see how the current lecture will help them with that goal; meanwhile, the expectations of pursuing a chemistry career would also enhance their intrinsic motivation (Durik et al., 2006; Eccles et al., 1998; Wang & Degol, 2013). Therefore, more motivationally supportive strategies in boosting relevance can be used by instructors in their daily teaching, and those aspects I mentioned above can be served as the potential areas that help them to expand their in-class motivationally-supportive toolkits. As an instructor, it might be especially beneficial to attach importance to every type of motivationally supportive method, balance the application of them, and try their best to integrate into the learning materials. With respect to future pre-service teacher programs and teachers' professional development, it also worth trying to add more training contents and workshops in motivationally-supportive aspects to let them become more and more familiar with how to support students' academic motivation by using different strategies in diverse learning conditions.

Additionally, I also explored some similarities in some of the sub-categories in autonomy measures. I captured almost no evidence of instructors' acknowledging and responding to students' negative emotions in class. This finding may be unsurprising as I did not have access to students' expressions of negative emotions, and in addition this is a very large introductory STEM course, so it might not be feasible for instructors to notice or attend to students' emotions in such a large-group setting. It might also be quite hard for students to share their negative emotions in front of the whole class, which give no chance for instructors to offer their emotional support during lecturing. However, prior studies (Becker., 2014; Lei et al., 2018) suggested that instructors' support of students' academic emotions can positively predict better learning outcomes and stronger teacher-student relationships. In addition, the ratings of displaying patience while teaching was lower than other measures in both learning environments. Therefore, grounded on self-determination theory and the effective interventions in need-supportive teaching, instructors could try to reduce students' psychological need frustration and build a closer sense of belongingness with their students in the big introductory STEM courses (Cheon et al., 2018; Knee, 2002; Ryan & Connell, 1989). Even though instructors might not be able to recognize and respond immediately to individual students' negative emotions during teaching, in particular in such sizeable introductory STEM courses, they could demonstrate that they anticipate and normalize feelings of anxiety about exams or the difficulty of the material, for example. Instructors could actively anticipate or ask about students' emotions and then respond to students in real time during schooling.

Potential Limitations, Innovations, and Future Directions

Reflecting on the whole study, capturing evidence directly from teaching practices is an important highlight of this study. I captured instructors' motivational support from both in-person and online teaching modes rather than only one classroom setting, while keeping the instructors and course contents constant, so that we can have a concrete and comprehensive view about the differences and similarities of instructors' motivational support across two learning environments at the same time under the same topic and instructors. Therefore, the differences in instructors' in-class motivational support revealed from the data might be most readily explained by the switch of learning environments, while also acknowledging the additional stressors and constraints of pandemic learning, aside from online instruction.

Apart from that, I noted four potential limitations in some respects of this study. These limitations can also be regarded as the starting points for future research to extend the study of instructors' motivational support and need-supportive teaching practices.

Firstly, in this study, I focused on capturing and evaluating instructors' in-class motivational support using the video data and observational coding results. However, students might perceive instructors' motivationally supportive strategies differently, even within the same situation (Ruzek et al., 2019; Schenke et al., 2017). I did not include any interviews or survey data from the perspectives of students in the same class. Even though some studies have already offered promising clues to show that supporting students' relevance, autonomy, and displaying enthusiasm were effective in supporting students' academic motivation, different groups of students (such as students from various levels of universities, genders, etc.) and diverse demographic backgrounds also might influence how they perceive motivational support from their instructors (Cheon & Reeve, 2015; Hotaman & Yüksel-Sahin, 2010; Kunter et al., 2013; Robinson & Lee, 2022; Rosenzweig & Wigfield, 2016). Additionally, it is important to note that all coders did not have chemistry backgrounds, and thus may have missed some subtleties of motivational support that would be noticed by those with more chemistry knowledge. Therefore, if possible, I recommend that further investigations of instructors' in-class motivationally supportive strategies examine the effectiveness of motivational support in both learning environments, including complementary self-report and observational data. Also, it may be fruitful to include coders with subject matter expertise in addition to those with expertise in motivation theory.

Second, during the process of video sample selection, I have designed the study to minimize other potential influencing factors to ensure that the delivery modes can be the main difference throughout the two years' video samples. However, practically speaking, online and face-to-face learning environments were not the only difference across the two data groups. All the lecture video recordings in the Fall 2019 semester were in the pre-COVID situation, while the Fall 2020 videos were during global pandemic. COVID-19 has introduced extra stresses and challenges to both students and instructors in maintaining their teaching/learning passion and motivations (Daniels et al., 2021; Toto & Limone, 2021). Therefore, all the findings in this study can not only be interpreted as the differences caused by online and in-person delivery ways, but need to consider the potential influence addressed from the COVID situation and its side effects. For future directions, I suggest taking deeper investigations and analyses into distinguishing between the differences induced by the switch of learning environments or/and the appearance of the COVID situation.

Third, the enthusiasm measures in the present study were adapted from Robinson (2019)'s dissertation with the sub-categories including smiles while talking about materials, verbally noting something is interesting or exciting, exclaims, gesturing broadly, and so on. However, videos only included a slide-view on the screen to keep instructors' identities confidential. In this case, I faced some difficulties in capturing and counting instructors' enthusiasm demonstrations to their students, especially their facial expressions, gestures and body language, and even some of their behaviors. Hence, in the present study, the coding evidence from instructors' enthusiasm was recorded mainly by their statements. For example, they said this concept was very interesting, and the molecule model was quite cool. This kind of enthusiasm measures limited the coding of instructors' in-class passion, and thus I may have missed several incidences of enthusiasm as expressed through gestures. Therefore, I recommend using an advanced and more holistic coding scheme including gestures and facial expressions for instructors' enthusiasm in future research.

Last but not least, this is a mixed-method study, so I analyzed the same data using qualitative coding and quantitative data analyses. Due to the unequal numbers of 10-minute video segments across the two years, I restructured the data based on the corresponding topics across two years so that the number of cases can be the same across two settings (see Table 1). Grouping and using the average scores of several video segments according to their topics might have potential impacts and/or conflicts to the final results. For example, I considered that the number of lecture videos in Fall 2019 was more than those in Fall 2020, so I had to take means between two to three video segments only for the data gathered from Fall 2019 to make the number of video segments aligned. Thus, this might potentially affect the distribution of the data collected from the in-person learning environments, since the standard deviations would differ from the original data. While the current study did not use the original data to investigate whether statistically significant differences existed across two learning conditions due to the unequal number of video segments, it would be critical for future studies to reexamine the results using the data directly from the observation.

Conclusion

Motivationally supportive social contexts, especially teachers' in-class motivationally supportive instructions, played an irreplaceable role in supporting students' in-class motivation (Filaka & Sheldon, 2008; Linnenbrink-Garcia et al., 2016; Turner et al., 2014). Indeed, the outbreak of the pandemic introduced additional challenges and uncertainty, including the emergency switch of the delivery methods and extra psychological stress among teachers and students, in-class motivational support from teachers still had a positive impact on improving students' academic motivation (Arslan & Allen, 2021; Camacho et al., 2021; Daniels et al., 2021; Naseer & Rafique, 2021). The purpose of this study aimed at comparing instructors' in-class motivational support across pre-pandemic in-person learning conditions and pandemic online learning conditions in the university-level STEM discipline in order to expand our understanding of how instructors supported students' academic motivation in those two environments and whether instructors' motivationally supportive behaviors and statements looked differently across online and in-person education.

Grounded in the situated expectancy-value theory (Eccles & Wigfield, 2020) and self-determination theory (Ryan & Deci, 2020), the present mixed-method study utilized both qualitative and quantitative methods to address the research objectives via comparing the coding evidence from lecture video recordings in Fall 2019 and Fall 2020 semester. Overall, findings from both qualitative and quantitative results revealed that instructors' in-class motivational support differed from pre-pandemic in-person learning environments and pandemic online learning environments in using relevance statements, providing autonomy-supportive instructions, and displaying their enthusiasm. Surprisingly, instructors tended to apply relevance statements and demonstrated their enthusiasm more in online learning environments than in in-person ones. But higher ratings of autonomy-supportive instructions appeared in the pre-pandemic classroom teaching. Given the differences and similarities between pre-pandemic in-person learning environments and pandemic online learning environments in undergraduate STEM disciplines, it is essential to provide STEM faculty with a holistic overview of how they supported students' academic motivation. Such rigorous descriptions might also encourage them to implement more targeted and effective in-class motivationally supportive instructions in both learning conditions in the near future.

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Appendix A: Tables

Table 1

Video Topics and Corresponding Video Segments across Two Years

Topic	Instructor	2019 Week	2020 Week	2019 Clips	2020 Clips
6.1 Wave-like Properties of electromagnetic radiation/light	A	1	0 & 1	1-2	1
6.2 Blackbody Radiation and Photoelectric Effect	A	1	0 & 1	3-5	2
6.2 & 6.3 Bohr's Model & Atomic Model of 1-Electron Species	A	1	1	6	3
6.3 Bohr's Model & Atomic Model of 1-Electron Species	A	1	1	7	4
6.3 Bohr's Model & Atomic Model of 1-Electron Species	A	1	1	8	5
6.3 Bohr's Model & Atomic Model of 1-Electron Species	A	1	1	9	6
6.4 Wave, Wavelength & Particle nature of Matter and Light	A	1	2	10-13	7
6.5 Schrodinger Equation, Wave Function & Orbitals	A	2	2	14	8
6.5 Schrodinger Equation, Wave Function & Orbitals	A	2	2	15	9
6.5 Schrodinger Equation, Wave Function & Orbitals	A	2	2	16-17	10
6.6 Bohr's Model from H atom	A	2	2 & 3	18	11
7.1 Many Electron Atoms	A	2	3	19	12
7.1 Many Electron Atoms	A	2	3	20	13
7.1 Many Electron Atoms	A	2	3	21	14
7.2 The Periodic Table and Quantum Theory	A	2	3	22	15
7.2 The Periodic Table and Quantum Theory	A	2	3	23	16
7.2 The Periodic Table and Quantum Theory	A	2	3	24-25	17
7.3 Periodic Trends	A	3	4	26	18

7.3 Periodic Trends	A	3	4	27	19
7.3 Periodic Trends	A	3	4	28-29	20
7.4 Atomic Properties and Reactivities	A	3	4	30-31	21
7.4 Atomic Properties and Reactivities	A	3	4	32-33	22
7.4 Atomic Properties and Reactivities	A	3	4	34-35	23
8.5 Electronegativity & Drawing Lewis Structures	A	5	5	36	24
8.5 Electronegativity & Drawing Lewis Structures	A	5	5	37	25
8.5 Electronegativity & Drawing Lewis Structures	A	5	5	38-39	26
8.6 Drawing Lewis Structures	A	5	6	40-41	27
8.6 Drawing Lewis Structures	A	5	6	42-43	28
9.1 Molecular Geometry using VSEPR Theory (up to 4 electron groups)	A	5	6	44	29
9.1 Molecular Geometry using VSEPR Theory (up to 4 electron groups)	A	5	6	45	30
9.1 Molecular Geometry using VSEPR Theory (up to 4 electron groups)	A	5	6	46	31
9.1 Molecular Geometry using VSEPR Theory (up to 4 electron groups)	A	5	6	47-48	32
9.2 Molecular Geometry using VSEPR Theory (5-6 electron groups)	A	6	6	49	33
10.1 & 10.2 Valence Bond Theory (Hybridization): Formation of Covalent Bonds	A	6	7	50-51	34
10.1 & 10.2 Valence Bond Theory (Hybridization): Hybridization of Orbitals 1	A	6	7	52-54	35
10.1 & 10.2 Valence Bond Theory (Hybridization): Hybridization of Orbitals 1	A	7	7	55-57	36
10.1 & 10.2 Valence Bond Theory (Hybridization): Hybridization of Orbitals 1	A	7	7	8-60	37
10.1 & 10.2 Valence Bond Theory (Hybridization): Hybridization of Orbitals 2	A	7	7	61-63	38
10.3 Molecular Orbital Theory: Preparing MO Diagrams for Period 1	A	7	7	64-65	39
10.3 Molecular Orbital Theory: Preparing MO Diagrams for Period 1	A	7	7	66-67	40
10.3 Preparing MO Energy Diagrams for Simple Diatomic Molecule (Period 2)	A	8	8	68-69	41
10.3 Preparing MO Energy Diagrams for Simple Diatomic Molecule (Period 2)	A	8	8	70-71	42
10.3 Molecular Orbital Theory: Using MO Theory to Explain Resonance	A	8	8	72	43

10.3 Molecular Orbital Theory: Using MO Theory to Explain Resonance	A	8	8	73	44
10.4 Metallic Bonding and Physical Properties Using Band Theory Models	A	8	8	74	45
10.4 Metallic Bonding and Physical Properties Using Band Theory Models	A	8	8	75	46
11.3 Types of Intermolecular Forces	A	8	8	76	47
11.3 Types of Intermolecular Forces	A	8	8	77	48
11.3 Types of Intermolecular Forces	A	8	8	78-79	49
20.4 Stereochemistry and Isomers	B	9	10	80-81	50
20.4 Stereochemistry and Isomers	B	9	10	82-84	51
20.4 Stereochemistry and Isomers	B	9	10	85-87	52
21.1 Overview of Organic Reactions	B	10	11	88	53
21.1 Overview of Organic Reactions	B	10	11	89	54
21.2 Reaction Mechanisms	B	10	11	90-91	55
21.3& 21.4 Substitution and Elimination Reactions	B	10	11	92	56
21.3& 21.4 Substitution and Elimination Reactions	B	10	11	93	57
21.5 Additions to Alkenes	B	10	11	94-95	58
24.1 & 24.2 Properties of Transition Elements	B	11	12	96	59
24.1 & 24.2 Properties of Transition Elements	B	11	12	97-98	60
24.1 & 24.2 Properties of Transition Elements	B	11	12	99-100	61
24.3 Coordination Compounds	B	11	12	101	62
24.3 Coordination Compounds	B	11	12	102	63
24.3 Coordination Compounds	B	11	12	103-104	64
24.4 Bonding and Properties of Complexes	B	12	12	105	65
24.4 Bonding and Properties of Complexes	B	12	12	106-107	66

Chapter number shown in the table refers to the chapter in the text (i.e., Chapter 6.1 means Chapter 6 Section 1). The same text used in both Fall 2019 and Fall 2020 semester.

Table 2

Descriptive Statistics for Counting System (Relevance and Enthusiasm)

Measures (Per 10-minute Segment)	**2019**			**2020**		
	Mean	**S.D.**	**Sum**	**Mean**	**S.D.**	**Sum**
Overall Relevance	0.73	1.16	78.00	1.26	1.60	83.00
A job or career	0.00	0.00	0.00	0.00	0.00	0.00
Future education	0.07	0.26	8.00	0.11	0.40	7.00
Health or safety	0.04	0.24	4.00	0.11	0.47	7.00
Routine activities/events	0.23	0.56	25.00	0.26	0.75	17.00
Understanding or explaining natural phenomena	0.10	0.34	11.00	0.18	0.52	12.00
Explaining, or solving problem OR, explaining advances in chemistry in general	0.07	0.30	8.00	0.15	0.27	10.00
Hobby or pastime	0.04	0.19	4.00	0.06	0.24	4.00
Bridge to understanding a concept, unit or experience in current chemistry class	0.16	0.42	17.00	0.35	0.62	23.00
Bridge to understanding in another STEM class	0.01	0.10	1.00	0.03	0.17	2.00
Useful for understanding or advancing social relationships	0.00	0.00	0.00	0.00	0.00	0.00
Overall Enthusiasm	0.57	0.85	61.00	0.94	1.29	62.00

Table 3

Preliminary Descriptive Statistics for Rating System (Autonomy)

Measures (Per 10-minute Segment)	**2019 Mean**	**2019 S.D.**	**2019 Range of Scores**	**2020 Mean**	**2020 S.D.**	**2020 Range of Scores**
Average Score of Autonomy	1.69	0.37	1.83-2.83	1.53	0.34	1.67-2.67
Takes the Students' Perspective	3.67	1.64	1.00-7.00	2.02	0.93	1.00-4.00
Vitalizes Inner Motivational Resources during Instruction	1.26	0.47	1.00-3.00	1.35	0.54	1.00-3.00
Provides Explanatory Rationales	1.49	0.73	1.00-5.00	1.86	0.72	1.00-4.00
Uses Non- Pressuring, Informational Language	1.34	0.60	1.00-4.00	1.45	0.66	1.00-4.00
Acknowledges and Accepts Negative Affect	1.12	0.41	1.00-4.00	1.30	0.68	1.00-4.00
Displays Patience	1.25	0.50	1.00-3.00	1.20	0.47	1.00-3.00

Table 4

Summaries of Every Percentages of Relevance Statement Strategies

Relevance Statements Measures (Per 10-minute Segment)	**Percentages of Using This Type of Relevance Statements in 2019**	**Percentages of Using This Type of Relevance Statements in 2020**
A job or career	0%	0%
Future education	10%	8%
Health or safety	5%	8%
Routine activities/events	32%	21%
Understanding or explaining natural phenomena	14%	15%
Explaining, or solving problem OR, explaining advances in chemistry in general	10%	12%
Hobby or pastime	5%	5%
Bridge to understanding a concept, unit or experience in current chemistry class	20%	28%
Bridge to understanding in another STEM class	1%	2%
Useful for understanding or advancing social relationships	0%	0%

Table 5

Descriptive Statistics for Repeated-Measures MANOVA

Measures (Per 10-minute segment)	**Mean**	**S. D.**
Relevance Statements in 2019	0.85	1.17
Relevance Statements in 2020	1.26	1.60
Autonomy Support in 2019	1.69	0.37
Autonomy Support in 2020	1.53	0.34
Showing Enthusiasm in 2019	0.54	0.71
Showing Enthusiasm in 2020	0.94	1.29

Appendix B: Coding Schemes

The Coding Scheme for Comparing Instructors' In-class Motivational Support across Online and In-Person STEM Learning Environments							
Fall 2019 CHEM110 Sept. 26th 0:00 - 10:00							
Support for Relevance Definition: Relevance is a kind of instructional strategy which the instructor used in class in order to highlight the meaning, applicability or usefulness of course content beyond the instructional context							
Example	1	1	1				
Total Number of Relevance Statement							
Instructor connects course material (or asks students to connect course material) to a real-world situation, jobs/careers, or personal example.							
Domain of Relevance: Connection is made between chemistry and:							
A job or career							
Future education in chemistry (college majors, graduate school etc.)							
Health/safety (physical or mental)							
Routine activities/events (eating, driving etc.)							
Understanding or explaining natural phenomenon							
Explaining, or solving problem that is relevant to a specific current event, news, or historical event (includes global warming/environmental issues). OR, explaining advances in chemistry in general; emphasizing usefulness for progressing as a society							
Hobby or pastime (e.g., sports)							
Bridge to understanding a concept, unit or experience in current science class							
Bridge to understanding in another STEM class (e.g., math, computer)							
Useful for understanding or advancing social relationships (e.g., cooperation, conflict, competition)							
Notes:							
Instructor's Enthusiasm Definition: Instructor expresses enthusiasm for the material to students in class							
Example							

Instructor expresses enthusiasm for the material (e.g., exclaims, smiles while talking about material, verbally notes something is interesting or exciting, gestures broadly)							
Notes:							

The Coding Scheme for Comparing Instructors' In-class Motivational Support across Online and In-Person STEM Learning Environments
Fall 2019 CHEM110 Sept. 26th 0:00 - 10:00
Support for Autonomy **Definition: Support for autonomy refers to nurturing sources of intrinsic motivation, relying on non-controlling informational language and acknowledging students' perspectives and feelings.**

Categories	**Never, not at all**			**Occasionally, sometimes yes, sometimes no**			**Always, very much**	**Score**	**Instructor' Actions or Statements/ Coder's Notes**
Takes the Students Perspective - Invites, Asks for, Welcomes, and Incorporates Students' Input - Is Aware of Students' Needs, Wants, Goals, Priorities, Preferences, and Emotions	1	2	3	4	5	6	7		
Vitalizes Inner Motivational Resources during Instruction - Vitalizes and Supports Students' Autonomy, Competence, Relatedness - Provides Interesting Learning Activities - Frames Learning Activities with Students' Intrinsic Goals	1	2	3	4	5	6	7		

Provides Explanatory Rationales for Requests, Rules, Procedures, and Uninteresting Activities - Explains Why; Says, "Because...", "The reason in.... " - Identifies the Value, Importance, Benefit, Use, Utility of a Request	1	2	3	4	5	6	7	
Uses Non-Pressuring, Informational Language - Flexible, Open-minded, Responsive Communication - Provides choices, options - Verbally and Nonverbally says. "You may.", "You might..."	1	2	3	4	5	6	7	
Acknowledges and Accepts Negative Affect - Students' Negative Affect ("Okay"; "Yes") - Accepts Complaints as Reasonable, as Valid	1	2	3	4	5	6	7	
Displays Patience - Calmly Waits for Signals of Students' Initiative, Input, Willingness - Allows Students to Work at their Own Pace, in their Own Way	1	2	3	4	5	6	7	