Evaluating Factors for Effective Flipped Classroom Instruction in an Advanced Data Management Course

Shamima Mithun
Department of CIT
IUPUI
Indianapolis, USA
smithun@iupui.edu

Morgan Vickery
School of Education
Indiana University
Bloomington, USA
moravick@iu.edu

Xiao Luo
Department of CIT
IUPUI
Indianapolis, USA
luo25@iupui.edu

***Abstract*—The following Research-to-Practice full paper presents the outcomes of a remote synchronous flipped classroom implementation of a senior-level data management course.**

As flipped classroom models of instruction have gained popularity in higher education, it has prompted the need for an investigation into content-specific methods for flipped curriculum design. Our work identified and implemented flipped classroom design factors in an Advanced Database Design (CIT 44400) course to address a gap in research around flipped classroom models within undergraduate data-science courses. Through literature review, we identified a set of eight factors of effective flipped classroom instruction and evaluated them via survey, focus group, course evaluation, student performance, and interview data.

We segmented designed course activities which incorporated these eight factors with a set of learning objectives that emphasized collaborative iterative practices to position students as designers and evaluators of solutions to industry-authentic problems. Instructional design factors were evaluated via course evaluations and student surveys followed by an activity-based qualitative analysis of focus group, instructor interview, and student free-response data to understand student perceptions of instructional approaches, intended versus practical outcomes of such activities, and guidelines for future course design iterations and research. We argue instructional design must be student-centered and consider student goals alongside those that are 'scripted' into the course structure to best serve, motivate, and engage students. During the Fall 2020 implementation of CIT 44400, we prioritized learner independence, peer collaboration, and critical thinking in the instructional design, selecting flipped methodologies with the intention of fostering these skills in senior students. In light of Covid-19, the course was adapted to be synchronous online. Regardless of these unforeseen constraints, student performance and course evaluation data indicate that with peer and instructor feedback, students were able to apply course content appropriately in their final independent project as evidenced by a 12% increase in assessment scores and an improvement in students average overall final course grades from a 'B' to an 'A-' as compared to the previously taught Fall 2019 lecture-based section of the same class. Course evaluation scores also improved from 3.22 to 3.66 from Fall 2019 to Fall 2020.

Self-reported survey data from students indicate that (a) feedback from the instructor, (b) small group work, (c) revision of work based on feedback, and (d) solution evaluations were the most positively impactful instructional design elements throughout the course. In particular, students mentioned one-on-one scaffolding from the instructor as beneficial for their learning. Students also communicated challenges faced during the pandemic, complaints, and recommendations for future course iterations. Data from focus group discussions conveyed that students (a) generally had positive learning experiences despite the constraints of learning exclusively online and (b) developed the industry-specific collaborative practices which were designed into the forefront of our instructional model. The flipped classroom design and implementation process in this research is transformative and can be employed by other STEM disciplines to design a domain-specific flipped model for their classroom which considers the needs of one's students, the challenges of the current time, and the state of the field at large.

***Index Terms*—Flipped Classroom, Data Management Education, Activity Theory**

I. Introduction

Flipped classroom approaches to instructional design have garnered attention throughout higher education, however there is a lack of research on its affordances for engineering education - in particular data management and data science instruction. Despite constant technological innovations and an increasingly competitive job market for data scientists, traditional and outdated instructional approaches have persisted in undergraduate classrooms.

The current study builds on our previous work [1] in which the factors for effective flipped classroom instruction were identified and adapted into concrete instructional design elements and implemented in an advanced data management course for seniors within a Computing and Information Technology (CIT 44400) course at an urban Midwestern university (Indiana University–Purdue University Indianapolis) with the goal of understanding which of these elements were most advantageous for students' data science learning. The flipped classroom model is particularly conducive to these aims as it enables students to engage in active learning, peer collaboration, and sense-making through practice rather than pure observation. These elements were further designed into course structure in alignment with learning objectives consistent with industry expectations and program prerequisites for graduation. We then evaluate these factors in regards to student motivation, performance, perception, and engagement and offer some recommendations for iterative course design and future research through investigation into the following research questions:

1) Which instructional factors of flipped instruction are most / least impactful for students' data science learning?
2) What do these factors accomplish for students?
3) How might we revise the design of course activities to better serve students and their goals?

II. Rationale

A. *Affordances of the Flipped Classroom Model*

The flipped classroom model integrates active and collaborative learning practices into synchronous class time and allows students to gain exposure to new concepts individually and asynchronously often in the form of pre-class video lectures and low stakes assessments. This approach allows valuable synchronous class time to be spent uncovering student misconceptions, discussing complex topics, and collaboratively applying this knowledge to practical and authentic problems [2], [3]. These interactions provide students opportunities to mentor each other [2], [4], give and receive feedback, and develop soft skills related to collaboration and iteration.

However, the affordances of the flipped classroom model are dependent on robust instructional design and the gradual (rather than sudden) shift to flipped methods from traditional approaches [5] at risk of "flipping" incorrectly [6] and frustrating students. Recurring factors present in successful flipped implementations include but are not limited to pre-class video lectures alongside an individual activity, low-stakes assessments on pre-class work, and both small and large group in-class activities. Further recommendations and takeaways from the flipped classroom literature includes the intentional alignment of out-of-class and in-class outcomes, shortened pre-class video lectures, and frequent low stakes and formative assessments to check student understanding [5].

B. *Problematizing Traditional Instructional in Data Science Education*

Despite the evidence supporting the efficacy of the flipped classroom model in higher education [2], [4], [7], [8], [9], its uptake within science, technology, engineering, and mathematics (STEM) has been slow [10] in lieu of traditional lecture-based instructional approaches [6]. These traditional approaches rely on a model where students observe walk-throughs and explanations to problems during synchronous class time and then apply these findings through practice asynchronous and individually; this model does not provide students adequate opportunities for peer collaboration and student-instructor interaction [6]. In addition to providing space for these interactions to occur, the flipped classroom model furthermore aids instructors in addressing issues with classroom management, student engagement, and student performance.

While the flipped model has been adopted in computer programming and engineering contexts, there has been little work done within the data management and data science domains. The recent emergence and prioritization of 'Big Data' across industries and domains justifies the need for data sciences instructors in higher education to critically examine their teaching practices and course content to reflect the innovations happening in industry and thus, the competitive job markets that their students will be entering. New graduates are expected to demonstrate a mastery of skills and concepts in data acquisition, management, and analysis. Current curriculum for students in higher education studying data science or data management includes courses in data management / processing, data-driven application design / implementation, data modeling / analysis, machine learning algorithms, and visualization tools to name a few.

We have a duty to consider how our current instructional approaches might be failing to prepare students to enter the real-world. Rather than assuming a single instructional method is effective across domains and content areas, we must consider the different instructional elements which are most suitable for different course contexts to avoid essentializing and pathologizing entire approaches to teaching. What instructional design elements are most effective and in what contexts? To what ends? The implementation of new instructional approaches must further be grounded in evaluation, consideration of student experience, and iterative revision.

C. *Applying a Sociocultural Approach to Understanding Student Experience*

As design and implement these evidence-based approaches within our senior-level data management and database design course, we must also consider the unique context in which we are evaluating these factors. We acknowledge the importance of socialization and interaction in learning, and thus lean on sociocultural theories of learning [11] - particularly Engeström's [12] activity system to describe how students experiences within the flipped classroom environment can be conceptualized as an system in which a student works towards an 'object' (e.g. goal) while interacting with tangible and conceptual mediators to succeed.

Particularly relevant to this analysis, we consider how structuring of flipped activities might constrain how students engage with the learning objectives. Wilson [13] discusses the importance of aligning "scripted" learning objectives with students' prior knowledge and motivations; successful activity designs must allow for students to bridge in-class and out-of-class knowledge. He concludes that by coupling "scripted" learning objectives with student's goals, we might enhance students' agency and engagement with course content.

While quantitative metrics such as student performance and self-reported survey data provide a basis for our findings, we draw upon qualitative data such as student focus group findings, instructor interview data, and written student responses to contextualize these instructional factors in students motivations and aspirations inside and outside the course - a vital consideration if we are to design curriculum and instruction which prepares them for success in the competitive world of "Big Data."

III. METHODS

Our investigation into active and collaborative activities for flipped instruction had three phases:

1) factor identification through literature review
2) course design and implementation
3) analysis

Our goal was to implement evidence-based activities for flipped learning contexts, implement them in a senior-level database management course context, evaluate their effectiveness based on a predetermined set of learning objectives, and identify themes regarding student engagement and collaboration to inform future instructional design decisions.

A. Factor Identification

We build on our previous work [1] in which we gathered twelve pieces of literature addressing flipped models of instruction within STEM and identified instructional factors which the literature suggested would be most effective for flipped settings. A systematic review of this literature addressing flipped methodologies revealed a set of common evidence-based recommendations for activities in flipped instruction:

1) pre-class activities
2) individual work (in-class)
3) small group discussions (in-class)
4) peer feedback (in-class)
5) instructor feedback (in-class)
6) design revision based on feedback (in-class)
7) solution evaluations (in-class)
8) large group discussion (in-class)

Furthermore, we developed a system for designing instruction which incorporated the above recommended activities, the course learning outcomes and objectives, the course structure, and the target content areas. We additionally considered the context in which these activities were proven to be effective, making sure that our implementation structured them in an appropriate order, ensure they followed the necessary prerequesite activities, and were designed with appropriate learning objectives.

B. Instructional Design

We implemented our senior design course, CIT 44400 in Fall of 2020 with these eight factors under consideration in addition to designing around the implications of Covid-19, political and social upheaval, and remote learning on our students. Students repeatedly conveyed the negative effects of these events on their ability to learn including but not limited to inequitable access to resources, a lack of human contact and interaction necessary for such collaborative design courses, and mental health concerns as evidenced by the following quotations from the student focus group:

- "I agree that the group projects have been a very good learning tool. But I think that the fact that we're online kind of hurt our bigger project, like group collaboration, it's just harder to work with other students[online]."
- "... And we're missing, even with all the technology that we have now, we're missing the human contact, or interaction with older professors with older students, asking questions, so we only had the professor. She has been helpful, but it will be better, like if we had, you know, like I'm the kind of person that I'm used to go to other professor and asking questions or, you know, asking to other students or having like, more resources, like being at them, library. I don't know. Like, for me, it's been like, tough."

These challenges and factors in mind, we adopted an approach to design which sought to use the eight instructional factors to address both students' challenges and five learning objectives (see Table I). Each learning objective was embedded into a series of activities informed by our literature review. We also ensured that outcomes of particular activities aligned and were cohesive across content areas, course prerequisites, and students' post-graduation aspirations.

Pre-class activities consisted of short assignments which prompted students to analyze design requirements, complete design tasks, consider implications for information retrieval, evaluate solutions, review projects, and design prototypes. Students furthermore completed an end-of-semester project in which they applied the skills gained from previous readings, homework, assignments, and low-stakes quizzes as a formative assessment. We offer a sample class session activity flow shown in Figure 1. Activities were adapted to better suit the synchronous remote learning setting by encouraging the use of video conferencing features (i.e. chat, screen-sharing, breakout rooms), pre-recorded asynchronous video lectures. This online setting provided students a space to engage both in small group and large group settings, collaborate using common artifacts (i.e. their designs and documentation), and exchange feedback with their peers.

This reconceptualized course format was implemented in the Fall of 2020 to a class of 12 students (compared to the 15 students who enrolled in Fall of 2019 prior to the redesign).

C. Analysis

In addition to university-mandated end-of-semester course evaluations, all twelve students from the Fall 2020 implementation completed a questionnaire (see Appendix A) which collected students insights regarding the instructional factors identified above, behavioral, social, emotional, and cognitive dimensions of engagement within small and large group activity contexts, and student ownership of individual and collaborative work. Student evaluations were collected from both the Fall 2019 and 2020 implementations, while the student engagement and factor evaluation survey was only collected from the Fall 2020 flipped class. We used students' rankings of the "most valuable" instructional factors to categorize into the following: factors that were (a) ranked moderately high with little disagreement between students, (b) ranked moderately low with little disagreement between students, and (c) those that elicited divisive or dramatic reactions from students. Four

TABLE I
CIT 44400 LEARNING OBJECTIVES, OUTCOMES, AND ACTIVITIES

Learning Objective	Intended Outcomes	Example Activity Prompt
Logically design of a database	• Students will study and understand database requirements. • Students will design a conceptual and logical data model. • Students will evaluate a model solution.	Students will design database for the home security system.
Information retrieval	• Students will search for and retrieve information given some criteria.	Students will retrieve a hotel rating given the hotel name and location.
Mathematical thinking	• Students will use given criteria to compute some value.	Students will calculate the rating for a hotel given a dataset of customer ratings.
Application of database concepts	• Students will import given data into a pre-existing database.	Students need to import a large number of customer reviews collected from open source datasets (e.g. opinRankData[1])
Development of industry-authentic practices	• Students will implement, test, and revise the design of a prototype. • Students will evaluate data modeling standards and industry approaches. • Students will understand the challenges of enterprise data models.	Students will design a working prototype for the home security system iteratively by collaborating with their peers.

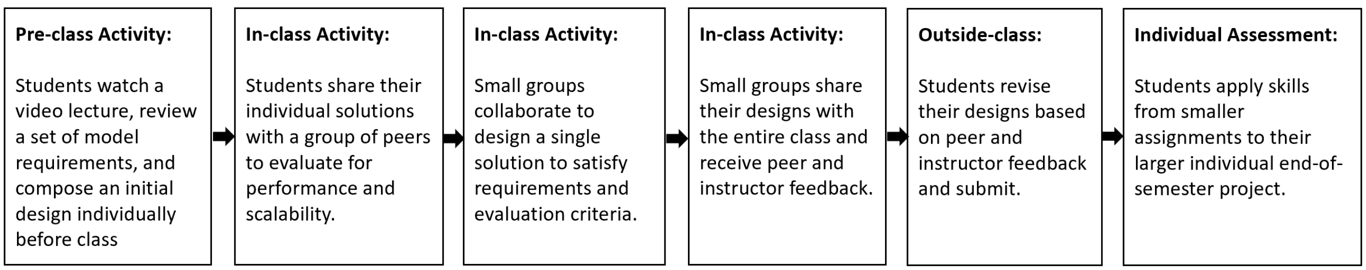

Fig. 1. Sample Activity Flow of Class Session

of the eight factors fell into this third category and will be detailed below.

All twelve students from the Fall 2020 implementation furthermore participated in a focus group facilitated by an unaffiliated education professional. The focus group facilitation protocol (see Appendix B) was developed to attain insight regarding students experiences in large, small group, and individual study contexts, their engagement with the course material relative to their final projects, and their experiences with collaboration in a synchronous remote educational setting in light of Covid-19.

We additionally conducted an interview with the instructor of the course facilitated by a research assistant to understand instructor perceptions of student collaboration, the success of the eight factors of interest, and student transfer of course material to their weekly assignments and final projects. The protocol for this instructor interview (see Appendix C) was developed to understand where instructor and student perceptions did and did not align. We drew upon Cultural-Historical Activity Theory, particularly literature which had used such theoretical and sociocultural approaches to understand instructor perceptions of instructional design. We adapted Duignan, Noble, and Biddle's [14] protocol for CIT undergraduate instructional contexts and drew upon Marquez's [15] approach for designing activity-based and context-specific interview protocols. The interview was conducted with the instructor following the completion of the Fall 2020 semester.

Instructor interview responses, student focus group findings, and student questionnaire responses were coded using the following three coding schemes:

1) An emergent scheme to identify the instructional design elements and intangible factors relevant to students experiences. These codes included references to student motivations, obstacles, insights, strategies, frustrations, and preferences.
2) A scheme based on the original eight instructional factors from our previous work [1]
3) An Activity Theory-inspired scheme to identify students perception of activity objects (i.e. goals and outcomes), tools, communities, divisions of labor, and rules (explicit and implicit)

These coding schemes provided us a robust framework for understanding the larger activity system within which students were learning including but not limited to their goals, (un)intended outcomes, community members (i.e. peers, instructors, third parties), (in)tangible tools used, im/explicit rules present, class culture, and the means by which students collaborated and took ownership over their various assignments. Particular attention during analysis was additionally given to the four instructional factors of interest that divided/polarized students in the end-of-semester questionnaires. Contradictions between instructor and student perceptions of these instructional factors were identified and informed the development of the following considerations for flipped classroom implementation.

IV. Findings

Overall, student performance and course evaluation data indicate that the Fall 2020 implementation of the senior-level data management course was a success. Despite the unforeseen constraints of virtual learning due to Covid-19 and impact of social and political upheaval on students lives, students managed to apply course concepts and practices appropriately in their end-of-semester independent projects as evidenced by a 12% increase in project scores and an increase in the average final course grades from a 'B' to an 'A-' as compared to the Fall 2019 lecture-based implementation of the same course (see Table II). This improvement in student performance can be attributed to the affordances of the flipped classroom model including but not limited to the ample opportunities to utilize class time for collaborative sense-making and design activities, evaluate their peers' solutions, give and receive feedback, and revise their solutions. Although not statistically significant, the improvement in quality of students' final projects, overall course grades represent a larger trend indicating the flipped classroom model as more effective for and preferred by students compared to the lecture based model.

Students course evaluations appraised students' perceptions and attitudes regarding the course instructional design, instructor effectiveness, and students' overall learning experiences. These responses are summarized in Table III and illustrate an increase in the overall course rating from 3.22 to 3.66 (on a scale of 4) compared to the previous year. In Fall 2020 the response rate was 87% and in Fall 2019 the response rate was 84%. In a t-test, this difference is significant. Students were furthermore asked to rank the eight instructional factors in order of helpfulness for each of the content areas covered in CIT 44400. Table IV illustrates students' rankings across content areas.

TABLE II
STUDENTS PERFORMANCE COMPARISON

Students Performance Data	Fall 2020	Fall 2019
Homework (10) Average Scores	97.4%	89.5%
Project (6 deliverable) Average Scores	91.6%	79.36%

Students overwhelmingly ranked instructor feedback, revision of designs, and solution evaluations as the most helpful factors across content areas, while individual work, peer feedback, and large group discussion were consistently ranked low although slightly more controversial. We identified four factors that warranted further qualitative analysis (see Table IV):

1) **Small group work**: students opinions were strong but varied - this factor tended to polarize students

TABLE III
STUDENTS COURSE EVALUATION RESULTS

Evaluation Criteria	Fall 2020	Fall 2019
Overall rating for instructor	3.66	3.2
Overall, I learned a great deal from this class	3.67	3.2
The instructor provided timely feedback that helped evaluate progress	3.62	3.5
The instructor provided a motivating environment for learning	3.61	3.0
The instructor helped me fulfill the course goals	3.62	3.2
Overall, this instructor was effective at teaching this course	3.81	3.1

2) **Peer feedback**: all students strongly asserted that peer feedback was one of the least valuable instructional factors
3) **Large group discussions**: most students agreed that large group discussions were one of the least valuable instructional factors
4) **Individual work**: students were very polarized regarding the value of this factor. The value of individual work time also varied heavily between contents areas

Our qualitative analysis provided us deeper insight regarding students experiences, instructor perceptions, and considerations for future iterations of the flipped classroom model. The following three themes are the product of our contextualization of student survey responses and evaluations through the systematic qualitative coding of student focus group responses and instructor interview transcripts using a set of both emergent and predefined coding schemes grounded in student data, our prior research, and Cultural-Historical Activity Theory.

A. Context Matters: Peer-Feedback as Conditionally Beneficial

Student end-of-semester surveys indicated that peer feedback was a divisive instructional factor for students; while small group work's rank varied amongst students but included several overwhelmingly positive responses peer feedback ranked as one of the least valuable factors by the entire group (see Table IV). This prompted us to understand which characteristics of these two activities were producing this polarization. Upon analysis of student focus group data, it became apparent that the valuation of peer feedback as "bad" was superficial and inaccurate to students' experiences; students considered feedback as inseparable from the contexts and modes that peer feedback was shared in. For instance, in reference to small group activities, one student commented:

- "...it was very helpful having other students asking me questions, and vice versa, it helped us solve the many challenges of the project."

Whereas in their surveys, students critiqued the large group feedback sessions, citing them as "not helpful" and "not productive." This lead us to the conclusion that students value

TABLE IV
STUDENT RANKINGS OF INSTRUCTIONAL FACTORS

Instructional Factor *in order of average ranking*	**Median Rank**	**Average rank by students** *1 = highest rank* *8 = lowest rank*	**Standard deviation**	**Variance**
instructor feedback (in-class)	2.00	2.64	2.06	4.24
design revision based on feedback (in-class)	3.50	3.89	1.71	2.91
small group discussions (in-class)	3.50	4.25	2.41	5.82
solution evaluations (in-class)	4.00	4.36	1.87	3.50
pre-class activities	5.00	4.50	2.33	5.44
peer feedback (in-class)	5.00	5.07	1.65	2.74
individual work (in-class)	7.00	5.47	2.62	6.85
large group discussion (in-class)	7.00	5.82	2.21	4.89

peer feedback in low pressure and small group settings; in this course, this manifested as the difference between small group breakout rooms during synchronous class sessions and the large group discussions in which students presented their designs for critique to the entire class. Students appreciated the diversity of perspectives and social support that accompanied the small team settings. Each group managed to divide labor evenly whilst still considering the local expertise that each student offered the group, share both conceptual and tangible resources as challenges arose, and socially construct an environment of co-mentorship.

- "... this semester helped me kind of become more of a team player because I'm usually kind of a loner, but I really had to reach out in this class to ask for help on different things."

Despite the intention of the large group discussions to be the offering of diverse perspectives and broader feedback to students' designs, it became apparent that students perceived these large group feedback sessions to be high-pressure and less helpful relative to small group and instructor-only feedback. We hypothesize that the virtual learning environment is not conducive to broad participation in large group settings and that the large group activities might need to be reconceptualized to better integrate what students consider beneficial about the other collaborative activities - notably: community building, peer mentorship, and perspective sharing that comes with small group conversations and the expert feedback that accompanies instructor reviews. Future implementations might reconsider the objectives of the large group discussions, how these objectives might be met through different means, and/or how the large group sessions might be redesigned to address students' frustrations.

B. Transfer to What? Instructor and Student Goal Misalignment

Across data sources, we noticed a trend of "transfer" as a student object (i.e. goal), intended learning objective, and (un)intended outcome. Instructional factors were never discussed in isolation of the larger class objectives and context; students particularly evaluated class activities and assignments based on its potential application to their independent final projects. During the focus group in particular, students named specific activities as valuable considering their practical overlap with the skills and tools they would need for their final projects:

- "...group work [was] pretty beneficial. Because mainly, what we do in the group projects, was just preparing us for the next part in the individual [final] project."
- "That activity (in reference to an assignment where student converted into a .csv file) prepared us sufficiently for the final project submission"

During the interview, the instructor communicated that a core motivation for adopting the flipped classroom model was to provide students opportunities to engage in industry-authentic practices and develop soft skills which were invaluable outside of academic contexts but were not often addressed prior to entering the workforce such as collaboration, critique, and labor delegation.

These goals are both future facing but also include a slight misalignment between the objectives idealized by the instructor and by the students. While students navigate the course with the requirements and challenges of the final project in mind, we consider how this final project (and its framing throughout the semester and within the syllabus) might be reconceptualized to more explicitly embed the development of industry-authentic hard and soft skills to ensure that as students are attending to the skill sets they perceive as necessary for the final project, they are also knowingly developing these skillsets to be transferred to real-world settings.

C. Iterative Design as a Common Goal

Early on, a primary justification for selecting the flipped classroom model was its alignment with the instructor's objective of facilitating opportunities for iterative critique and revision of designs: practices that have been authentic to industry for over 60 years [16]. The current activity structure provided students with the opportunity to engage in collaborative design, critique, and revision as evidenced by students' discussions addressing the value of feedback from different sources and instructor observation of iterative and collaborative design practices. Students explicitly named the design, critique, and revision processes as valuable to their learning and ultimately their final projects within the survey and focus group data. They also called for future implementations of the course to feature more opportunities for iteration on their designs.

This finding is consistent with instructor observations throughout the semester. Following the feedback sessions at the end of each week, students took initiative to meet with their small group members outside of class, schedule one-on-one meetings with the instructor, and use online tools to professionally format their final submissions: practices that the instructor insisted that students had introduced to their workflow themselves. They set a high standard for their work early on, and continued iterating on their assignments until the current assignment met that high standard even if it was beyond what was expected of them by the instructor. Despite not formally requiring this extra effort, the instructor encouraged students taking such initiative and provided resources and feedback as students communicated their need.

In this case, we see students taking agency over their learning experience to go above what is expected of them within the course - an indicator that students are meaningfully engaging with and motivated by the activity. This finding can be attributed to and is an indication that the current course effectively aligns learning objectives, activity structure, and student goals and motivations. Although students' may not be considering the industry-authentic soft skills intended by the instructor as they engage in such iterative design practices, they ultimately develop these skills as they aspire to meet self-defined expectations which have surpassed those that were originally scripted for them. Future implementations might further leverage students' motivation to iterate on design by incorporating activities that allow for more frequent and more personalized critique and revision.

V. Discussion / Implications

The current research sought to understand the following research questions:

1) Which instructional factors of flipped instruction are most / least impactful for students' data science learning?
2) What do these factors accomplish for students?
3) How might we revise the design of course activities to better serve students and their goals?

By comparing student performance data and course evaluations from previous lecture-based implementations and the current flipped-classroom implementation, we can support the claim that the implementation of the flipped model supported student learning and produced favorable academic outcomes. A comparison of student rankings of the eight factors of flipped instruction show that students perceived instructor feedback, revision of designs, and solution evaluations to be the most positively impactful factors in their learning, while individual work, peer feedback, and large group discussion were ranked the lowest overall. Further qualitative analysis which applied coding schemes grounded in Cultural-Historical Activity Theory, our prior work addressing factors for flipped instruction, and the data itself to student free response, instructor interview, and student focus group data revealed a set of three themes addressing how students engaged with these instructional factors relative to their learning and to the course structure at large. This approach for understanding elements of instructional design offered insight to how flipped approaches to teaching advanced data management through iterative design are effective for student learning, are perceived by students, and (mis)align with instructor expectations for student engagement and outcomes. We offer several takeaways for future instructional design:

1) By considering student perceptions of specific factors alongside intended outcomes, we can redesign future activity implementations to align curricular and instructional design with student motivations and needs. In the case of CIT 44400, we will consider the shortcomings of the large group discussion virtual format and adapt it to feature more opportunities for low-stakes personalized feedback and peer mentorship in lieu of the high-stakes presentation format.
2) By considering students' longer-term motivations and goals alongside the 'scripted' course objectives, we can frame course projects as in alignment with students' goals thus providing students opportunities to be agentic, engage in authentic practice, and relate course material to their lives. Within our context, this will involve framing the final project as an opportunity to develop skills and/or artifacts which will aid students in their post-graduation goals.
3) By acknowledging the diverse ways in which students make course content their own and take agentic roles in their learning, we can attain a more nuanced understanding of their motivations and thus design curriculum which engages them personally while still ensuring they develop the intended competencies. In future iterations of CIT 44400, we anticipate attending to how students iterate on their designs outside of synchronous class sessions and designing these student-proven activities into the course structure.

The flipped classroom design and implementation process in this research is transformative and can be employed by other STEM disciplines to design a domain-specific flipped model for their classroom which considers the needs of one's students, the challenges of the current time, and the state of the field at large. Here, we demonstrate the affordances and constraints of our flipped classroom implementation of a senior-level collaborative database design course and illustrate how our observations might inform the reconceptualization of instruction design decisions which are often taken for granted and considered staples in undergraduate engineering education. The quickly-evolving nature of the engineering field and the tools embedded in it insinuate that our methods for such instruction must also be innovative and consider students' experiences and perceptions within current-day contexts. The consequences of shifting to virtual instruction during the Covid-19 pandemic in combination with the social and cultural upheaval on students' learning is undeniable and further motivates the need for educators to critically examine their instruction and ground their pedagogies in the context and needs of their students. While we consider our remote implementation of CIT 44400 to be a success, we acknowledge the constraints of remote learning on student collaboration, mental health, productivity, and engagement and that these impacts are particularly salient for students who are underrepresented in computing spaces. This motivates our team to pursue more critical approaches to understanding instructional design through an equity lens and draw upon research and instructional methods from power, culture, and identity-focused scholarship in the future.

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APPENDIX

A. End of the Term Survey Excerpt

Question 1: Rank the following class activities in order of most helpful for understanding concepts related to system requirements? (i.e. 1 / the top being the most helpful and 8 / the bottom being the least helpful)

- Pre-class assignments readings
- Individual work during class time
- Small group work during class time
- Feedback from peers during class time
- Feedback from instructor(s) during class time
- Revision of designs based on feedback
- Solution evaluations during class time
- Large group discussions during class time

Question 2: If the course had been taught in-person, how do you think this ranking be different?
Note: above two questions were also asked to address the "system design" and "system implementation & testing" course topics.
Question 7: How much do you agree or disagree (Note: four options were given: Strongly Disagree; Disagree; Agree; Strongly Agree) with the following statements related to working individually?

- While individually studying system descriptions / requirements, I am focused on the task at hand.
- While individually studying system descriptions / requirements, I try to figure out what I am supposed to learn rather than just reading over the materials.
- I can solve difficult problems on my own if I try hard enough
- I apply the concepts in this course to real problems or new situations.
- There is no point in individually studying system descriptions / requirements before class.
- When individually studying system descriptions / requirements, I feel like I am learning about something that is meaningful and important.

Question 8: How much do you agree or disagree with the following statements related to working with other students?

- While working in my small group, I was focused on the task at hand.
- My group openly shared and considered feedback.
- When I encounter a difficult problem, I try to solve them with other students.
- I try to answer questions that other students ask.
- Explaining difficult concepts to my group helps me understand them.
- I appreciate when my group members explain difficult concepts to me.

Question 9: How much do you agree or disagree with the following statements about project ownership?

- Individually studying system descriptions / requirements helped me to make valuable contributions during class.
- My individual work gave me a sense of personal achievement.
- What I got out of this class was out of my control.
- I made valuable contributions in my small group discussions.
- I feel a sense of ownership over my groups' final designs.
- I am responsible for how my group's final project turned out.

Question 10: What was the biggest challenge you faced in this course?
Question 11: What aspect(s) of the course do you feel you missed out on due to the shift to virtual learning?
Question 12: Please list two things you would like to see changed in future iterations of this course.

B. Focus Group Moderation Guide Excerpt

Your professor wants to understand a bit more about your experience in learning advanced database design concepts in this course. Your input will be helpful in understanding what did and did not work and making alterations for future students who take this class! Please be honest in your answers - all data will be kept anonymous and will not be reviewed by your professor until after grades have been finalized.
Opening questions:

- Are there any questions / concerns before we get started?
- Describe your general experience in this class in 1-2 sentences.
- If you were to pitch this class to a friend, what would you say?

Let's talk about when you were working individually both in and out of class…

- Think back to moments during this course where you were 'in the zone' (time was flying, you were engaging with the material, and you were interested in what you were learning)

- What activities were you doing? Walk me through those moments.
- What did you gain from individually studying/working on the system requirements, descriptions, and design before coming to class?
- How has the pandemic and the shift to virtual learning impacted your ability to work individually?
  - What aspects of the course / instruction worked while working individually during the pandemic? What didn't work?
  - Are there any resources, tools, or changes to the course that could have helped you work individually?

Now let's cover the small group collaborative work!

- How were you able to contribute to your group's work?
  - Do you feel like your contributions were valuable? In what way?
- What were some frustrations related to working in a small group?
  - What could the instructor have done to make these experiences easier/less frustrating?
- How did the pandemic and the shift to virtual learning impact your ability to work in small groups?

Closing questions:

- If you had to change one thing about how this class is taught, what would it be?
- What one thing do you want me to take away from this conversation?

C. *Instructor Interview Protocol Excerpt*

Subject / Object

1) Can you take me step-by-step through a usual class session?
2) What goals do your students have during class activities?
3) What goals do you have during class activities?
4) How do students determine whether a solution is correct?
5) How can you tell when an activity was successful?
6) Do you notice that your students' goals ever don't align with yours?

Tools

1) What tools do students use during this activity?
2) What tools do you think students could / should use during this activity?
3) What tools aid you as you teach?
4) Did you ever introduce a new tool to the class or to your workflow?

Division of Labor & Community

1) What is your role during class? What about students?
2) When working alongside students, how do you see them dividing up the work?
3) At what point do you decide to interject to help students?
4) When problems are too complicated for students, how do they manage it amongst themselves? When you're present?
5) How do students indicate that they need your help? That they don't need it?
6) What does conversation look like during large group discussions? During small-groups?
   - How do they participate? What do they contribute?
   - How do students contribute during class? When do they not?

Rules

1) What explicit rules and procedures are present during your class?
   - When and how often are they communicated?
2) What implicit rules do you notice students following?
3) What rules do YOU follow during instruction?
4) Are there any practices that students bring with them that you didn't necessarily establish?

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