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Process and Pitfalls of Online Teaching and Learning with Design Study "Lite" Methodology: A Retrospective Analysis

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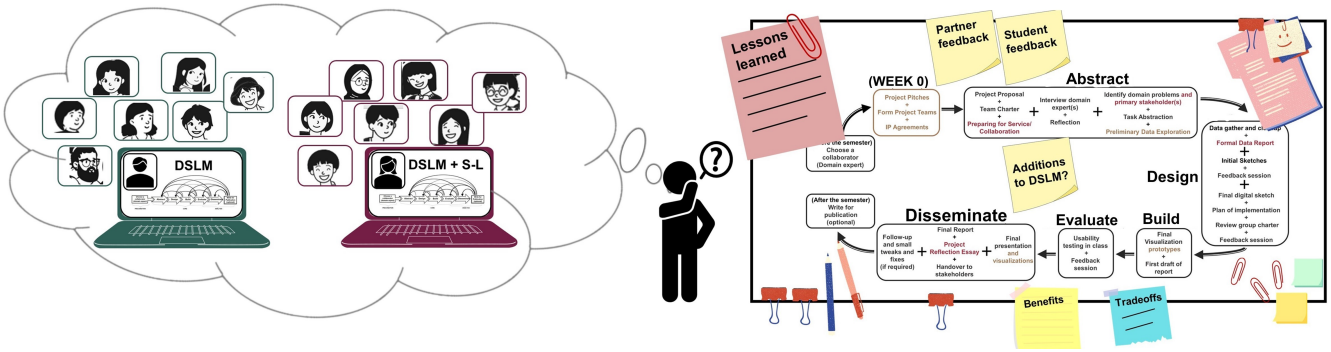

Figure 1: *We present and evaluate two online implementations of the Design Study "Lite" Methodology (DSLM) for which one implementation included Service-Learning (S-L), and the other did not. This figure illustrates our study workflow in which we reflected on our remote DSLM experiences, validated the theory, and provide implementation recommendations for visualization instructors.*

Abstract

Design studies are an integral method of visualization research with hundreds of instances in the literature. Although taught as a theory, the practical implementation of design studies is often excluded from visualization pedagogy due to the lengthy time commitments associated with such studies. Recent research has addressed this challenge and developed an expedited design study framework, the Design Study "Lite" Methodology (DSLM), which can implement design studies with novice students within just 14 weeks. The framework was developed and evaluated based on five semesters of in-person data visualization courses with 30 students or less and was implemented in conjunction with Service-Learning (S-L). With the growth and popularity of the data visualization field—and the teaching environment created by the COVID-19 pandemic—more academic institutions are offering visualization courses online. Therefore, in this paper, we strengthen and validate the epistemological foundations of the DSLM framework by testing its (1) adaptability to online learning environments and conditions and (2) scalability to larger classes with up to 57 students. We present two online implementations of the DSLM framework, with and without Service-Learning (S-L), to test the adaptability and scalability of the framework. We further demonstrate that the framework can be applied effectively without the S-L component. We reflect on our experience with the online DSLM implementations and contribute a detailed retrospective analysis using thematic analysis and grounded theory methods to draw valuable recommendations and guidelines for future applications of the framework. This work verifies that DSLM can be used successfully in online classes to teach design study methodology. Finally, we contribute novel additions to the DSLM framework to further enhance it for teaching and learning design studies in the classroom. The preprint and supplementary materials for this paper can be found at https://osf.io/6bjx5/.

CCS Concepts

• ***Human-centered computing*** → ***Visualization theory and methods;*** *Visualization pedagogy;*

1. Introduction

Data visualization is quickly becoming the new norm for analyzing the data-centric world around us, with fields ranging from technology and science to arts and communication orienting themselves to more data-driven approaches. The growing popularity of the field has therefore attracted new learners [DB18] with more institutions offering visualization courses [GCB12, Wol15]. However, some essential research skills may not be covered in these courses, including how to execute "design studies." Design studies are an integral part of data visualization

research [BNTM15, ZCD18, PSY*19], in which researchers collaborate with domain experts to investigate and solve real-world problems through visualizing their data [SMM12]. Designing and implementing an effective real-world visualization is a valuable skill for students to learn. Although taught as a theoretical concept, actually practicing a design study is typically excluded from visualization pedagogy due to the lengthy time commitments required [SMM12]. This exclusion deprives students of learning to implement design studies and creates a rift separating promising visualization students from capable researchers.

We recently addressed this gap by contributing an expedited design study framework—the Design Study "Lite" Methodology (DSLM)—in which novice students are able to conduct a design study in 14 weeks [SMR*20]. DSLM was developed based on five in-person data visualization courses, each with $\leq$30 students. Students collaborated with local nonprofit organizations and met their data needs through their final course projects. Each course combined DSLM with Service-Learning (S-L), which is an experiential learning model that aligns community service with classroom learning objectives to meet pedagogical and community goals [Fur96, Sig79]. Through S-L, students implement their course concepts by solving real-world problems and reflecting on how their academic skills are transferable to the real world. We demonstrated that DSLM could enhance the learning experience of students in small in-person visualization courses, but left to future work how to scale the methodology for larger classes—as well as whether DSLM could be effective for online learning.

Online teaching has been on the rise [Sor14, LNJ*19] and a prevalent research topic for decades [HNS21]. Online classes can make learning more accessible to a wider audience [BMR*20], and, without the physical barriers of a classroom, can accommodate more students [LNJ*19]. The global COVID-19 pandemic in 2020 only accelerated this adoption of online teaching methods. With this shift towards online teaching, we set out to answer the question: *Can we adapt the DSLM framework to effectively teach design studies in online classes?* Design studies inherently require human-centered design techniques, meetings, and collaborations—all concepts traditionally executed with in-person interactions. Would these traditionally face-to-face activities work in a completely virtual setting? Multiple factors can affect the performance of a class such as teaching environments, assignment complexity, and the total number of students. Giving adequate guidance and support to each student can be challenging for larger classes. Consequently, the total number of students can impact learning and engagement [Ake95, Sch14]. Therefore, we also asked: *Can DSLM be implemented for classes with more than 30 students?* Finally, previous iterations of DSLM were implemented in conjunction with Service-Learning (S-L). Institutional support for S-L may not be available for many instructors, or they may simply prefer not to incorporate it into their courses. Therefore, the final question we address: *Is it possible to teach DSLM without S-L?*

In this paper, we investigate the adaptability and scalability of the DSLM framework by implementing and evaluating it in two consecutive online data visualization classes with 47 and 57 students. We tested two variants—the first without Service-Learning (S-L) and the second with S-L—and demonstrate that DSLM can be applied effectively in both cases. We reflect on these implementations and provide a detailed retrospective analysis using grounded theory methods, leading to practical recommendations for using DSLM in online courses. Finally, consolidating our experiences, we contribute novel additions to the framework to further bolster it for teaching and learning design studies. While the primary contributions of this paper are the demonstration, evaluation, and reflection of online DSLM implementations, the additions to the original DSLM demonstrate the importance of revisiting previous methodologies. By revisiting, we strengthened and further validated the epistemological foundations of the framework by applying it to online teaching and learning. Specifically, we contribute:

1. Validation that DSLM can be applied to other conditions beyond the original framework implementation, including (1) online classrooms, (2) more learners, and (3) without S-L.
2. A critical reflection on our experience teaching these courses, including recommendations for instructors on implementing DSLM in an online setting.
3. Novel contributions to the DSLM framework which further enhance, clarify, and improve the framework.

In the field of data visualization, we rarely question or test previously-published theories and methodologies [KH18]. Validating a methodology under different conditions and environments is essential for building trust and investigating its credibility, rigor, and generalizability. This work is an example of the value in testing our theories for validation and contributing novel theories.

2. Related Work

2.1. Background and Summary of DSLM

Design studies in visualization are based on HCI research methods and methodologies, including interviews, [CRTB09], brainstorming [Cri92], participatory design, and collaboration with end users [Wis10]. Munzner's nested model [Mun09] guides each stage of the design process. A seminal work based on the nested model is the 9-stage Design Study Methodology framework by Sedlmair et al. [SMM12]. Although the theory of this framework is commonly taught in visualization pedagogy, its practice is largely absent in curricula due to their conventionally-long duration. Therefore, Syeda et al. [SMR*20] developed the Design Study "Lite" Methodology (DSLM), an accelerated and modified version of the design study process by Sedlmair et al. [SMM12], which can be incorporated in visualization courses to teach design studies to novice students within just 14 weeks. With some additional scoping and preconditioning, DSLM maintains the foundational and key elements and steps of a typical design study (Fig. 2). This includes interviewing a domain collaborator, iterative design process, building and evaluating the prototype, and final product handover to the domain collaborators. Implementing DSLM in a visualization curriculum allows students to reflect on how their academic skills might be put to good use in the real world by collaborating with actual clients.

2.2. Design in HCI and Visualization pedagogy

Wilcox et al. [WDHW19] identified two main approaches to design in HCI education: formal iterative [GL85] and creative design [WRSK06]. The latter utilizes project-based activities, collaboration, and creative practices, like sketching, brainstorming, and self-reflection [WDHW19] and has many benefits [KVSK18, VGPR17]. Yet there is no guidance on incorporating creative design education in traditional HCI courses [WDHW19, MdOGG*15]. Within the field of data visualization, Roberts et al., [RBB*22] identify, discuss, and reflect on nine strategies

for creative visualization activities to teach data visualization. McKenna et al. [MLM17] and Roberts et al. [RRJH17] created detailed worksheets and explanatory framework to guide the design process for learners. Challenges [BRS*04] associated with introducing design education in HCI courses include the lack of scalability, dependence on physical classrooms [OLM*20, WDHW19], and balancing traditional lecture format and hands-on practice [OLM*20]. These concerns have inspired efforts to construct curricula that effectively combine both practices [VGPR17, AT07]. We assert that successfully implementing DSLM in a large online class utilizes both formal iterative and creative design methods, as well as addressing issues of creative design regarding scalability and physical space. DSLM is the first formal model to bring the entire design study experience and real collaborators into the classroom, a concept that was absent in the visualization literature [SMR*20]. Our work focuses on increasing the accessibility and scalability of the framework by implementing it in online learning environments and larger classes.

2.3. Online teaching and learning

Reasons abound for the rapid growth and popularity of online education [MTW21, BMR*20], including learning from anywhere [HML*20]. In 2020, the COVID-19 pandemic prompted many institutions to adopt online education [MTW21, Har21, DHC*20]. There are established best practices for online teaching [BC21, Mah21], as well as challenges associated with it [MBM14, FGG20]. Most relevant to this paper is the study by Ozturk et al. [OAP21], which reports that students find it more challenging to work and collaborate in online design processes. Diehl et al., [DFTW*21] propose a community-driven and participatory methodology where both the classroom and the visualization community mutually benefit. They describe activities that engage students in the use of visualization guidelines to support teaching, learning, and discussion around visualization guidelines using the online VisGuides forum [DAREA*18]. Schwab et al. developed a tool to use for online synchronous collaboration [SSB*21], and Aerts et al. [APB*21] reported on their experience of running online design workshops for a master's-level visualization course where students were taught to ideate, create, and discuss hand-drawn sketches. However, the concept of teaching and implementing the whole design study process in an online visualization class is not yet explored. In terms of class size, there is little consensus on what a large online class is [LNJ*19, Sor14], with many different definitions for small [EBSBW11, Ber08, Buc07], medium [EBSBW11] and large [ABF05, DD08, EBSBW11] online classes. 47 or 57 students could be considered a large [RS06] or a medium class [EBSBW11]. In our work, we demonstrate that DSLM, which requires collaboration with domain experts and teammates, can be successfully implemented in an online setting with up to 57 students without compromising the learning quality and experiences of the students.

3. Online Implementations of DSLM

In order to validate that DSLM can be applied to other conditions beyond the original framework's implementation, we incorporated DSLM into two online instances of a data visualization course. Herein we describe these instances, which were taught by two different instructors, and how the methods the instructors used varied. In particular, one was taught with S-L and one without S-L. The course, Data Science (DS) 4200, is the introductory visualization course at Northeastern University offered to undergraduate students and is required of all DS majors. Both instances of the course incorporated the DSLM framework into the final project component, in which students collaborated with local, national, and international organizations using DSLM. Details about the two 15-week semesters are given in Table 1. These courses used Canvas and Zoom software platforms to orchestrate and run the classes.

	Without S-L	With S-L
Semester	Fall 2020	Spring 2021
Total students	47	57
Total projects	16	20
Type(s) of Collaborators	Government, educational, nonprofit, for profit, and research organizations	Nonprofit organization

Table 1: *Details of the two online implementations of DSLM*

Both implementations completed all the steps of the DSLM framework and the methods used to accomplish these steps are illustrated in Figures 3 to 9. These methods should be taken as recommendations rather than prescriptions. It is worth mentioning that lessons learned in the first online DSLM implementation without S-L in Fall 2020 (e.g. how to use the online technology, improving instructions for students, etc.) were taken into account and implemented into the second semester (DSLM with S-L in Spring 2021). It should also be noted that we do not intend to endorse any specific software platforms that were used in our online DSLM implementations. Further details along with the course syllabi and all project assignments are provided in the Supplemental Material at `https://osf.io/4bjfs/`.

In the following subsections, which follow the 7-stages of DSLM (Fig. 2) [SMR*20], we compare and contrast the two online implementations and discuss the novel adjustments and adaptations required to ensure DSLM could be executed in an online setting.

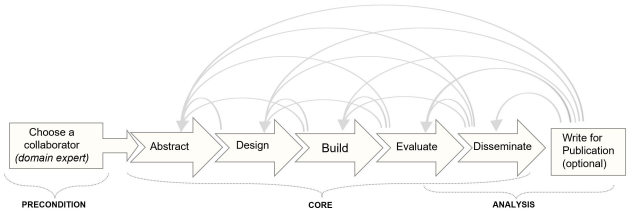

Figure 2: *The DSLM framework [SMR*20].*

3.1. Before the semester (Precondition stage)

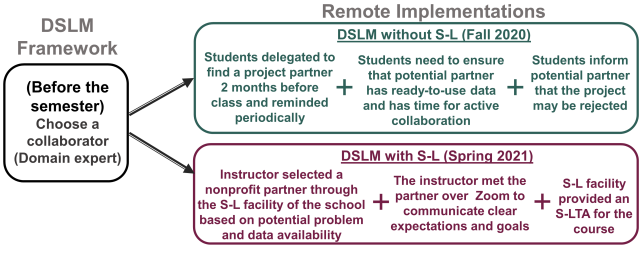

Figure 3: *Steps executed before the semester (precondition stage).*

In the precondition stage, a domain expert is chosen as the partner for the design study. For DSLM without S-L, each student was delegated 2 months before the start of the class to identify a potential project problem and corresponding partner as part of their first project assignment. The project problem could be anything relevant to the student's career, research, public, or personal interests that could be potentially solved by data visualization. The collaborating partner could be an individual, a group, or an organization. For DSLM with S-L, the instructor of the course identified a suitable nonprofit collaborating partner through the Service-Learning (S-L) facility of the school a month before the start of the class.

It is crucial to ensure that the chosen partner(s) can provide appropriate datasets and are clear about the expectations and goals of the course. In DSLM without S-L, the students were instructed to ensure that their potential partners had ready-to-use, clean data and were willing to invest the necessary time for interviews and follow-up feedback throughout the semester. To set clear expectations, students were to inform potential partners that only a third of the proposals would be selected. In contrast, in the DSLM with S-L course, the instructor selected the partner and virtually met with them over Zoom to communicate clear expectations and goals, check data availability, and discuss potential project questions.

3.2. Between Precondition and Abstract Stages

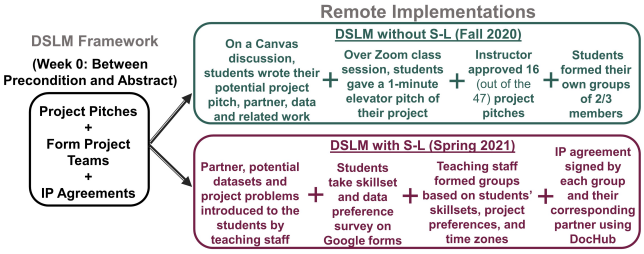

Figure 4: *Steps between the precondition and the abstract stage.*

Between the precondition and abstract stages of DSLM, some logistics need to be completed, including forming project groups. In an online setting where students cannot interact with one another as effectively as in an in-person classroom, planning and executing this step can be challenging. In DSLM without S-L, students pitched potential projects both in written form (Canvas discussion post) and orally as an elevator pitch in class (over Zoom). The instructor then helped students winnow to 16 out of the 47 initial project ideas. Students whose pitch was rejected then commented on other students' pitches on Canvas, expressing their interest in joining the project, and then coalesced around ideas to form their own project groups of 2 to 3 members. The elevator pitch in class helped facilitate this step, as students could remember the projects that sparked their interest and comment immediately (though Canvas does not show new posts without refreshing the page).

In DSLM with S-L, the S-L facility-provided teaching assistant (S-LTA) formed student groups of 3 or 4 members based on their skill sets, including programming experience and their preference for a particular project. This information was collected via an online survey in the first assignment after students were introduced to their partnering organization, potential projects, and the 5 available datasets. Upon forming the groups, an IP agreement was sent to all the groups and their partner using DocHub. No IP agreement was signed in the DSLM without S-L course, though students were instructed to ask for one if the partner was uncomfortable releasing the project and data under an open-source license (we specified BSD, though would now recommend the Apache License v2.0).

3.3. Abstract Stage

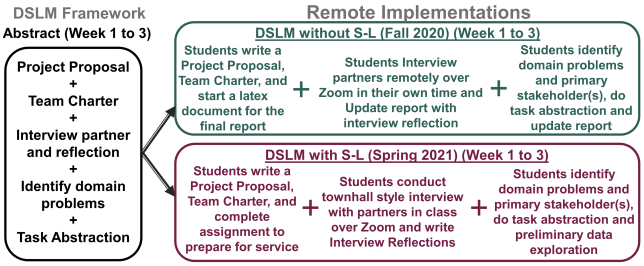

Figure 5: *Steps executed in the abstract stage.*

In the abstract stage, students in both implementations wrote a project proposal to explain the goals of their project, interviewed their partners to identify the domain problems and primary stakeholder(s), and then finally conducted task analyses. Student teams were also required to prepare and agreed upon a charter to manage expectations, logistics, and responsibilities of their collaboration.

The interview was conducted differently: In DSLM without S-L, each group was instructed to interview their domain partner virtually over Zoom, in their own time, within the assignment's deadline. In DSLM with S-L, a townhall-style interview was conducted in class in which three representatives from the single partner organization joined scheduled class Zoom session. Each group (20 in total) had the chance to ask their most important questions to the partner. Additional questions were included in a shared Google document that the S-LTA then sent to the partner to answer in writing. Some groups with more complex data conducted a second interview later with the partner over Zoom.

Two other differences in the implementations existed in the abstract stage. Unlike the DSLM without S-L course, the DSLM with S-L course included an extra assignment in the abstract stage which was aimed to ensure that students practice professional and responsible conduct while they collaborate with partners online. This is especially important for online DSLM to alleviate the risks of "online disinhibition", which is the lowering of self-regulation in online settings resulting in potential unethical and insensitive conduct or language [Sul04, STB*18]. For collaborations with nonprofit organizations, there is also a risk of students perceiving their collaboration as helping those in need and their collaborators as weak and powerless [GMG14]. The assignment can be found in the supplemental material of the paper. This implementation also did a preliminary data exploration at this stage.

3.4. Design Stage

In DSLM without S-L, students did their preliminary data exploration in the design stage. However, since this data exploration was already done in the abstract stage in the DSLM with S-L, the students in this implementation instead created a formal data report summarizing their data and the insights they gained from it. This report was then graded

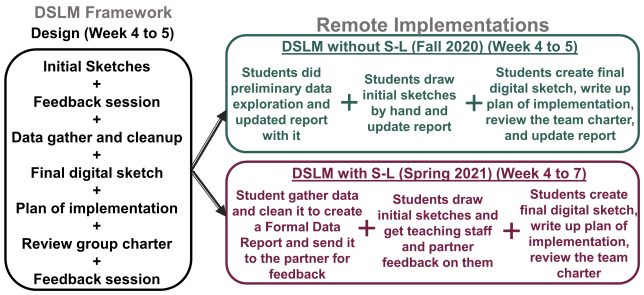

Figure 6: *Steps executed in the design stage.*

and shared with the partner for feedback. This allowed the partner to intervene or steer the students in the right direction if they were missing out on important aspects of the data or were focusing on redundant or unnecessary data.

In both implementations (with S-L and without S-L), each student then created 3 hand-drawn visualization design sketches for their project as, even in an online setting, sketching design ideation by hand allows for more freedom of expression and creativity [KFB17] than electronic tools support. In addition to written instructor feedback as was done in DSLM without S-L, students in DSLM with S-L also received two other forms of feedback on their sketches: First, the teaching staff virtually sat with each group for 15 minutes on Zoom to give live feedback on their scanned sketches. Second, the sketches were sent to the partner via email for feedback. However, due to staff limitations from the partner's side, they were delayed in providing feedback on the sketches which caused the timeline of the design stage to be extended to the start of week 7 as shown in Figure 6. For the other DSLM implementation (without S-L), partner feedback was encouraged but not required thus partner feedback varied for each group.

In both implementations, each group chose their three best sketches and then created their final prototype's digital sketch(es). They also reviewed the group charter, discussing how their group dynamics and communications among the members and with the partners were going. This is important, especially in an online class, as it helps the instructor intervene if groups face communication-related issues, which may be common in a setting where they cannot build rapport with their team members as in an in-person class.

3.5. Build Stage

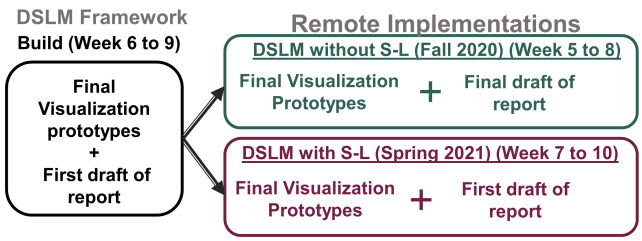

Figure 7: *Steps executed in the build stage.*

In this step, students build their final visualization prototype using D3.js and prepare it for usability testing.In DSLM with S-L, the students wrote their first draft of the report whereas in DSLM without S-L, they finish their report in this stage.

3.6. Evaluate Stage

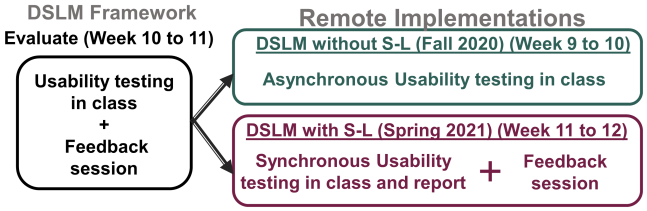

Figure 8: *Steps executed in the evaluate stage.*

The two instances of the course implemented online usability testing in two different manners: one with asynchronous and one with synchronous testing. In DSLM without S-L, the usability testing was done asynchronously using Canvas. All project teams shared their visualization link with the class as individual comments under a discussion forum in Canvas. Each student was responsible to use the visualization(s) and leave feedback for at least 5 other groups. This way in one hour all the student project groups received approximately 15 reviews. In DSLM with S-L, synchronous usability testing was conducted during class with Zoom breakout rooms. One breakout room per project group (20) was created by the teaching staff and six 15-minute usability sessions were executed. At the start of each session, one member from each group came to the main room of the Zoom session and then joined a different breakout room to test their peers' visualization.

3.7. Disseminate Stage

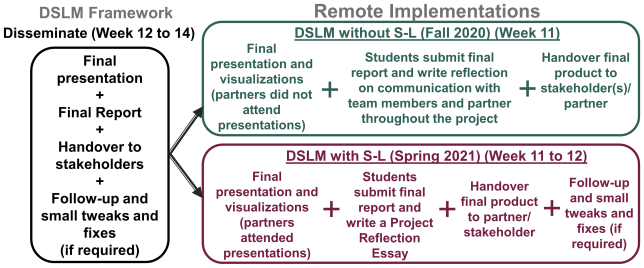

Figure 9: *Steps executed in the disseminate stage.*

In this stage, the students in both implementations prepared their final visualization and report to hand over to their partners. For DSLM without S-L, the students wrote a reflection regarding the communication aspect of the project which provided valuable feedback for the instructor. Students in the DSLM with S-L course also wrote a reflection essay but it was focused on critical reflection of their experience with the project in general and expressed their thoughts on what worked and what did not. Reflection is also an important component of Service-Learning as it helps students to look back at their experience with the design study and helps them connect/relate their service with their course materials [EGJ99].

4. Validation of the Online DSLM Implementations

In order to assess whether the online DSLM implementations were successful, in this section, we present evidence that validates that **DSLM can be implemented successfully in online settings**. Our validation evidence includes qualitative and quantitative feedback from the students in both online implementations detailed in Sec. 3 as well as quantitative analysis of course metrics to compare the online implementations to the previous in-person iterations of the framework. We also assess the qualitative feedback from the collaborating partners. For the validation methodology, the responses of both students and partners were open-coded and axial-coded [HS05] by the first author and high-level themes were identified using thematic analysis techniques [BC06].

4.1. Feedback from Students

In the DSLM implementation without S-L (Fall 2020), student feedback was solicited in two ways: a university-administered survey, and the reflection on communication in the students' reports (Sec. 3.7). Further insights were gained from analyzing the students' final reports. In the remote DSLM implementation with S-L (Spring 2021), student feedback was solicited in four ways: the university-administered survey, the S-L program-administered survey, the project reflection essays, and an additional survey to assess their online project experience. Our thematic analysis resulted in five high-level themes in the students' responses from both courses:

Sufficient support and feedback for project completion: Students reported that *"the online course environment was handled very well"* with *"a lot of helpful opportunities for feedback from the partner, TAs, and classmates"*. Others echoed similarly saying that *"the completion of the project wouldn't be possible without the instruction and feedback from [the teaching staff]."* Most attested that the *"virtual learning did not affect"* their ability to successfully *"complete the project(s)."* Previous iterations of DSLM with $\leq$30 students each had approximately 10 project groups. By grouping students, we could reduce assignment complexity by distributing the workload amongst the group members. For a larger class, managing more than 10 project groups can be challenging in terms of giving proper support and feedback from the teaching staff. By demonstrating that DSLM can be applied to classes with up to 57 students without compromising the quality of feedback and support given to students, we also validate the scalability of the framework.

Better acclimatization and learning of course concepts: Students overall agreed that the project experience was a *"useful translation of the course concepts"* and it *"helped reinforce what (they) have learned during class"*. Many also felt that the course concepts were made clearer through the application in the project: *"I think that it forced me to better understand and apply everything that we covered in class."* Others similarly expressed comments of the effect: *"I never realized before how much work goes into creating visualizations and now that I know, I'm thankful for this final project to have taught me so much"*.

Effectiveness of the project timeline and nature: Students overwhelmingly appreciated the structure and timeline of the project and felt that *"despite being virtual, the schedule of having deliverables throughout the course proved really effective, and prevented any components from being rushed at the end"*. Many believed it helped them produce *"a higher quality end result"*, while others expressed that *"even if other projects did not have such a schedule required, (they) would still aim to maintain one"*. Overall, students felt positively about the realistic nature of the projects and deemed it as *"a great hands-on experience in the area of data visualization"* and an opportunity to work with *"actual datasets"* and *"real clients instead of usual fake or pre-cleaned data."* Many felt it gave them *"a greater purpose than just trying to get a good grade"*.

Influence and impact of the project on a personal level: The final project cultivated several important skills and boosted students' confidence: *"I'm now excited to work with more clients and community partners in the future, and I'm confident knowing that I can model my work off of what I learned from this course."* Working on the project prompted *"personal reflection"* and instilled a sense of community and civic responsibility in the students. This was reflected widely in their responses: *"I understand how I can use Data Science to help my community and I hope to do so in the future"*. It also motivated many for future endeavors: *"Moving forward, I would be really interested to look into other ways that I can use my technical skills for community service since I found this experience so fulfilling."* This theme was seen more in the DSLM implementation with S-L due to the very nature of S-L and how it is designed to prompt reflection. However, even in the DSLM implementation without S-L, students overall liked the experience of working with a partner and many groups expressed *"future plans"* of continuing to work with their partner *"by conducting more research"* expressed intentions *"to remain in contact with the research team [partner]."*

Satisfaction and concerns regarding communication with team members and partners: Some students reflected that they did not utilize the course resources fully and in the future, they would be *"more proactive"* in *"reaching out to TAs and the partner."*. They left comments of the effect that *"it's easy to go up after class and ask a quick question but it's a little awkward in a [online] class."*

Regarding team communication, student responses indicated that the *"teams worked and communicated effectively"*. Most groups claimed that they were *"very professional"* and that *"there were never any challenges from communication problems."* In the DSLM without S-L course, every group confirmed that *"all members contributed to the project deliverables adequately"* even though few groups had to overcome the challenges of working from *"different timezones making it difficult to satisfy every group member's daily schedule"*. In DSLM with S-L course, a few student groups struggled with *"balancing team contribution."* Regarding communication with partners, most groups reported that the partners *"provided useful feedback and were happy to assist."* In DSLM without S-L, all of the groups agreed that the *"interview process was extremely helpful and informative"* but some confessed in their reflections that they *"could've done a better job"* at *"communicating more with the partner as the project went on."* This was because, in this implementation, partner feedback was encouraged but not mandated. Therefore, there were inconsistencies in the amount of feedback each group received from their partners: *"multiple times"*, *"bi-weekly zoom meetings"*, or only in the *"initial meeting"*. In DSLM with S-L course, most reported that the town hall meeting *"provided great feedback for the final project"*, but some students felt they *"didn't get to ask all their questions"*. However, all groups attested that *"once [they] had further 1:1 guidance from the partners, the project progressed smoothly"* and that they had *"a clear vision after personal feedback"*. Few groups also raised concerns about delay in partner feedback in the design stage and felt that they *"received feedback much later than expected."*

These themes align with the previous in-person iterations of

DSLM [SMR*20], aside from the last theme of an online setting, which is indicative of the effectiveness and consistency of implementing DSLM online for teaching design studies to students. However, we also received some feedback regarding challenges faced which indicate room for improvement. This feedback informed some of the suggestions we provide in Sec 5.

Quantitative Evaluation Metrics: In the university-administered end-of-semester evaluation survey, students were asked about the course and their learning experience on a 3-item, 5-point Likert scale. The mean scores for learning effectiveness of the online DSLM implementations (shown in Table 2) are comparable to the previous in-person DSLM implementations with a mean of 4.3 across 5 semesters [SMR*20]. The lessons learned in the first iteration of online DSLM (without S-L) translated to the second (DSLM with S-L). Therefore, the scores for the second iteration were higher for both the learning effectiveness and online experience of students. These underscores our efforts to improve the online DSLM implementations iteratively.

The DSLM generated final projects count towards 40% of the total course grade and were calculated by combining all the project assignments in each stage of the framework. The grading of the final projects does not depend on the partner's feedback and is solely dependent on the technical expertise demonstrated by the students in the projects. In order to assess whether students successfully mastered the required technical skills of the class and successfully executed their final projects to the same level as previous in-person implementations, we compare the final project grade percentages of the five previous in-person implementations of DSLM with the two online DSLM implementations in Fig. 10. The final project grades of the online implementations of DSLM performed comparable to and even better (for Spring 2021) than the previous successful in-person iterations of the framework. This demonstrates that the students were able to learn the course concepts from their design study projects implementing DSLM. Overall these scores, as well as the previously discussed student and partner feedback, demonstrate the **effective execution of DSLM in an online setting without a decline in performance or effectiveness**.

4.2. Feedback from Partners

In the first iteration (DSLM without S-L), partner feedback was solicited through surveys after the semester ended. This resulted in a poor response rate of 2 out of 16 partners; hence, the feedback may not be representative of the entire class. Both partners were satisfied with the projects which *"gave interesting insights into [their] data"*, although one of them expressed that communication could have been better. In the second iteration (DSLM with S-L), we made conscious efforts to solicit as much partner feedback as possible through semi-structured interviews at the end of the semester. Overall the partner expressed that the *"the students did their best and really tried to think about what [the partner] would want"*. They thought many of the visualizations were *"useful as a tool to put on [their] website"*, and many provided them with *"insights they had not known before"*. However, this iteration had its own limitation and lesson to learn from: as only one organization was collaborating with 20 different student groups, they felt that *"doing 20 projects was way too much"* and that they were not *"able to give the depth in terms of feedback and involvement"* as they would have desired. This indicates that the partner(s) were generally satisfied with the students final projects, and is another important indication of the successes of the online DSLM projects.

	DSLM without S-L (Fall 2020)	DSLM with S-L (Spring 2021)
Online experience	3.9	4.2
Learning effectiveness	4.0	4.1

Table 2: *Mean response scores for learning effectiveness and online experience of students in both the DSLM implementations.*

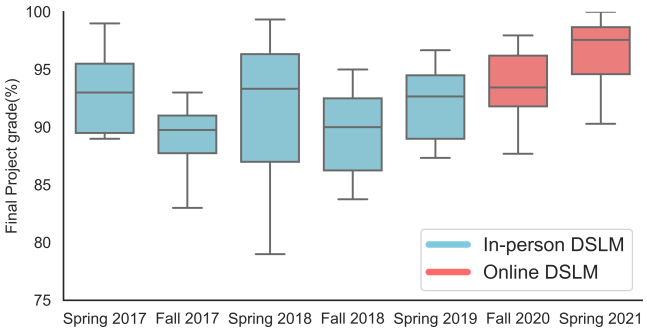

Figure 10: *Comparison of in-person and online DSLM final project grades.*

5. Reflections and Recommendations for Online DSLM

In this section, we reflect on our experiences with online DSLM implementations and provide helpful guidance and recommendations for various steps of implementing the framework. We assert that these seemingly simple guidelines can go a long way to successfully teaching DSLM online and envision that these will provide useful insights and directions to others who plan to implement DSLM in their online courses.

5.1. Overarching good practices for online DSLM

• **Preparedness and flexibility** are paramount to managing unexpected situations and alleviating technological, pedagogical, and social challenges of online teaching. This may include performing mock-up test runs of the software platforms used to orchestrate the class online, having backup AV and internet setup, anticipating possible hiccups, and having alternate solutions as backups. For example, having backup project ideas or potential collaborators to reach out to in case the selected collaboration falls through.

• **Providing a safe space and encouraging proactivity** in students is important as they can feel reluctant and shy to reach out in online classes. In efforts to realize this challenge, the teaching staff should regularly and persistently remind and assure students that they can reach out with any questions or requests. Options for private messaging the teaching staff or platforms that allow anonymous questions, like Piazza, can also be availed to encourage proactiveness.

• **Extra support and detailed instructions** can be very helpful to mitigate confusion, especially for those who might be reluctant to ask for help in online settings, even if they are confused. Ways to do this can include, but are not limited to, having sufficient teaching assistants (TAs) for the course depending on enrollment, proofreading and getting feedback (from the TAs or the students) on the clarity of the assignments, recording each class session, or having additional tutorials for students. Having separate discussion boards for each topic of the class in Canvas (or other platforms like Piazza), where students can

ask questions about it, can also be useful. For implementations where students find their own project partner, a pre-written email seeking collaboration can be provided to them to make it easier for them to reach out to potential collaborators.

• **Balancing dimensionality of project workload** by carefully winnowing project partners and corresponding project problems can minimize the risk of incomparable project complexities among different groups. This can be done by the instructor through meetings with the potential partners to scope the project problems beforehand. Instructors can also intervene at any point in the semester to re-scope the project so that it is commensurate with the skills of the students and then inform the partners of these changes.

• **Ensuring accountability** of students and partners is essential as communication can be a barrier to success in an online DSLM implementation if not orchestrated properly. The teaching staff should be aware of the communication between students and collaborators/partners. This can be done by instructing students to cc the teaching staff in their emails with the partners and by communicating clear expectations and important deadlines for feedback to the partners before or at the beginning of the semester. A confidential group member evaluation can be a helpful way to ensure accountability within groups since teamwork in online settings can often be more challenging compared to in-person settings.

5.2. Before the semester

• **Reaching out to personal connections for potential collaboration** is a safe strategy and can act as a safety net or alternative for the undesirable situation of not having enough collaborator(s) as recruiting collaborators online can be challenging.

• **Recruiting more than one partner for larger classes** is a good strategy to ensure that the number of project groups is not incommensurate with the number of partners. This will allow for more effective and dedicated collaboration between the students and the partner(s) and, therefore, more streamlined projects.

• **Making the teaching staff and the students aware of the technology used in class before or at the beginning of the course** can save time and effort in debugging technological issues. This can be done through tutorials and instructions on the course websites or in Canvas so that anyone can refer to them and feel more prepared.

5.3. Between the Precondition and Abstract Stage

• **Comparable distribution of skillsets and backgrounds among student project groups** should be ensured for fair and equal distribution of expertise. The lower the variation in student skillsets, the more feasible it is for them to choose their own teammates. Otherwise, the teaching staff should assign groups to ensure that no group has any advantage or disadvantage over another.

• **Time zone consideration while forming project groups** to ensure students can meet with their project partners easily from different geographical locations. In addition, it is also worthwhile to ask students to inform the teaching staff about any potential travel plans to a different time zone during the course of the project.

• **Use asynchronous signing software for IP agreements** to make the process go smoother and avoid the bottlenecks of synchronous signing tools where each person needs to wait for the preceding one to finish signing the document.

5.4. Abstract and Design Stage

• **Dedicated interviews with the partner(s)** is more useful. Reflecting on our implementations, we conclude that dedicated interviews with partners for each group is a better strategy than having multiple groups interview the partner at the same time. Besides preserving the integrity of realistic interviews, it also allows the students enough time to ask the necessary questions for the project.

• **Mandating and monitoring partner feedback for each group** throughout the design study project can be really helpful to ensure that students and partners are on the same page.

5.5. Evaluate and Disseminate Stage

• **Synchronous usability is more realistic** and closer to the actual experience. Both synchronous and asynchronous usability can be performed but the former allows students to interact with the users in real-time and get additional insights by watching the user interact with their visualization(s). Written feedback in the latter may miss some of the nuanced details that talk-aloud protocols can offer.

• **Solicit partner feedback at the end of the project** Soliciting partner feedback can be useful in evaluating student projects from the lens of the partner.

5.6. Additional guidelines

• **Implementations methods presented for DSLM with and without S-L can be mixed and matched** as both the implementations had successful outcomes. Instructors can also apply comparable methods of their own at various stages of the framework.

• **Service-Learning can be incorporated into a course without an S-L facility from the school** but it might be more challenging. S-L is an experiential learning model and can include methods such as volunteerism, field education, and internships [Fur96]. We would suggest delegating one TA to orchestrate the components of S-L to make the process easier to handle.

• **The possible issue of students failing to find a potential partner on their own** can be tackled in few ways. First, the instructor can reach out to potential partners on their own as backups for situations like this. Second, if the number of approved projects is very small, then the number of group members in each accepted project can be increased, or projects that may have public data or opportunities for data collection can be selected as a last resort. Finally, the assignment where students present their potential project pitches and partners can be ungraded and not count towards the final project grade in order to make it fair for all students.

6. Novel Additions to the DSLM framework

During the online iterations of DSLM (Sec. 3), we made many pedagogical choices to adapt the framework to online teaching and learning. We revised and scrutinized each step of DSLM to identify modifications/ changes necessary for effective online implementation. This process not only aided in our curricula development but also

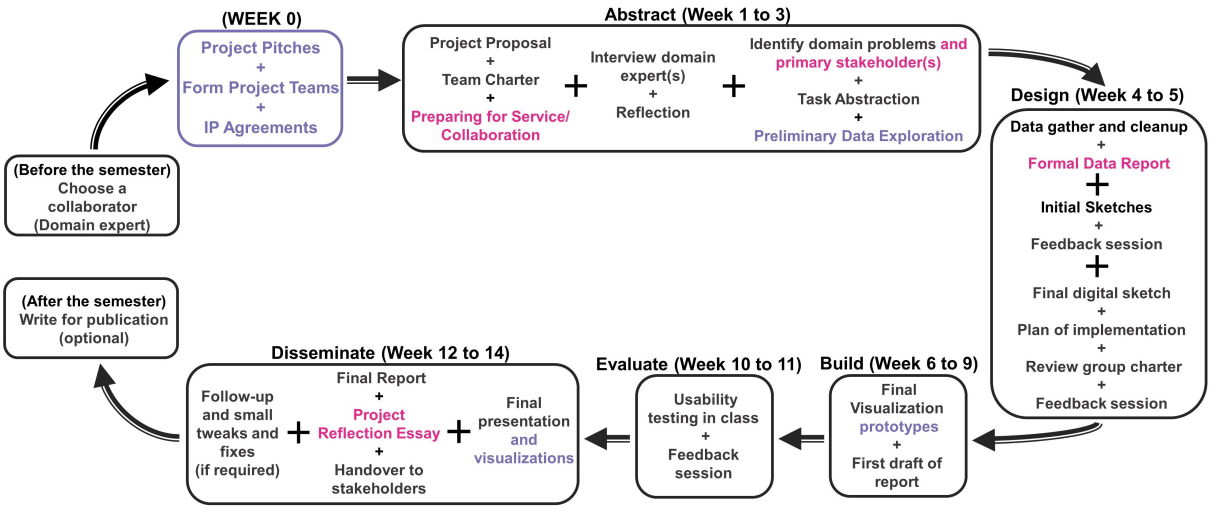

Figure 11: *Additions to the original Design Study "Lite" Methodology timeline.* ***Black*** *font indicates the original timeline. The* ***pink texts indicate the novel additions*** *to the framework and the* ***purple texts indicate clarifications*** *made to the timeline for ease of use*

revealed novel additions to the DSLM framework that are independent of the conditions under which it is executed (e.g. online or in-person). In this section, we discuss the **novel additions to the framework** (Figure 11) which enhance its usability and specificity.

Between Precondition and Abstract Stage (Week 0): This stage consists of a few logistical steps before the project starts and is not part of the design process and hence is designated as Week 0. Although implicit in the original DSLM timeline [SMR*20], we realized the explicit addition of them to the framework provides more clarity to this step. The steps consist of **(1) The project pitch** in which the students write a proposal about the project problem, their collaborating domain partner, and datasets. **(2) Group formation** which can be facilitated by the teaching staff, the students, or by both depending on the variation of skillsets and backgrounds amongst students. **(3) IP agreements** signed between each group and their partner to help define clear guidelines and agreed-upon rules on IP and data privacy to establish transparency and trust.

Abstract Stage: Before interviewing the domain partners, it is imperative to prepare students for an ethical, professional, and respectful collaboration. This is especially important for online DSLM implementations to alleviate the risks of "online disinhibition", which is the lowering of self-regulation in online settings resulting in potential unethical and insensitive conduct or language [Sul04, STB*18]. Therefore, students should approach their collaboration with components of asset-based community development, which acknowledges that all communities are asset rich, capable of growth, and are equal collaborators [MK93]. Garoutte & McCarthy-Gilmore [GMG14] and Shah et al. [STB*18] discuss how this approach can be integrated into in-person and online classrooms, respectively. Teaching and making students aware of professional behavior, cultural competency, and responsible conduct is essential for successful collaboration. This can be achieved variously via presentations, in-class discussions, and assignments.

Another key component for a successful project is the careful identification of the primary stakeholder(s), meaning the main audience or users for whom the final visualization(s) are targeted as many organizations have both internal and external stakeholders. This reduces the risk of a mismatch between partners' expectations and the final product created by the students and can also help clarify whether the final visualization should be exploratory or explanatory. Therefore, we explicitly add this concept in the timeline as a reminder not to overlook this crucial step.

Also absent from the original DSLM timeline was the mention of preliminary data exploration in the abstract stage. Becoming familiar with the project's data and conducting a preliminary exploration is important in this stage to correctly identify the tasks and visualization options in the context of the available data. This step was originally included implicitly in the design stage of DSLM as 'data gather and cleanup'. However, whether there is a need for new data gathering and cleanup should be decided prior to the design step. Therefore, we add this explicitly to the timeline for clarification.

Design Stage: We learned from our experience of implementing DSLM that data exploration can often become messy and disorganized, especially for novices. Therefore, a carefully thought-out addition to the design stage is a formal data report where students summarize the dataset(s) they will focus on and synthesize all the insights gained from their data cleanup and exploration. This helps students to be more organized, understand the data and tasks better, and also more quickly identify missing/messy data. Upon sharing with partners, the report also allows the partners to intervene regarding any issues with the data being focused on and provide meaningful feedback. Additionally, it increases transparency between the two collaborating parties.

Build Stage: In this stage, we added the word "prototype" to clarify that the visualization does not need to be perfect or finalized. "Prototype" indicates that by the end of week 9, the students are expected to have a nearly final visualization that is good enough to conduct usability testing and receive meaningful feedback on. It is acceptable at this stage for the implemented visualization to lack the polish and sophistication of a final product.

Disseminate Stage: An important addition in this stage is the 'project reflection essay', which allows the students to critically reflect

on their DSLM project experience and help them to relate their project to the learning objectives of the course. Although this reflection essay is already a required step of a Service-Learning pedagogy [SMR*20], it is valuable to any design study curriculum with DSLM. Due to this broad applicability, this essay is explicitly added to this disseminate stage.

While implementing and testing the DSLM in online settings, we revisited and reassessed each step of the DSLM framework thoroughly from different perspectives to ensure it is adaptable to different conditions. This revealed necessary additions and clarifications in the original DSLM timeline that are independent of the conditions under which the framework is executed (e.g. online, in-person, large, or small class). These additions serve to bolster the framework for future executions and were carefully selected based on their importance and relevancy to the design study process.

7. Discussion

To strengthen the epistemological underpinnings and credibility of any theory or methodology, it is imperative to test it under different conditions and reevaluate it. Therefore, to make DSLM broadly applicable to a research and pedagogical field as fast-growing as data visualization, several factors must be tested. For example, scalability and adaptability to different types of teaching styles, environments, and conditions. Adaptability to online settings is of interest because online courses can help scale the framework and make it more accessible to students and collaborators worldwide.

Two different instructors successfully implemented the DSLM framework for online classes, with and without S-L and with different teaching styles and strategies. This demonstrates that the prescribed structure and timeline are very forgiving, adaptable, and flexible to different methods of execution. For example, in DSLM with S-L (Spring 2021), despite the delay in the design stage, students were still able to complete the projects successfully within the 14-week time frame. Our goal is not to impose and prescribe execution methods—as we believe that those depend a lot on the instructor's unique teaching style, their priorities, and the context of the course in the curriculum—but to provide evidence of how the DSLM framework is accepting of these idiosyncrasies.

We acknowledge that incorporating DSLM into an academic course can be time-consuming for an in-person classroom; more so for an online environment. By demonstrating comparable results between online and analogous in-person implementations of DSLM, we show the robustness and agility of the framework and encourage educators to adopt DSLM for their online classes.

The reader should be mindful that both of these online DSLM courses were taught at a time when the world was navigating the COVID-19 global pandemic. Therefore, our results may have been affected by the pandemic in ways that we were not able to measure or evaluate. In both courses, multiple students were personally affected by the pandemic, which inevitably led to distress and degraded communication and workflow within several project groups. Another limitation of this work is that we only have two iterations of the online DSLM to study, limiting our ability to learn from any drawbacks and refine our methods. Our reflections on these drawbacks led to guidelines that should streamline future educators implementing DSLM in online settings. As a future endeavor, we plan to create additional teacher and actionable resources for the DSLM framework. We also envisage testing the framework in different universities with various levels of support and student backgrounds and invite the visualization community to do so as well.

DSLM has so far been applied to visualization pedagogy. We envision using it more broadly to support expedited research design studies, especially for starter projects, internships, and training exercises. More broadly, our research helps illuminate the general challenges of conducting design studies online. Design studies require active collaboration, ideation, and communication—all of which tend to be easier in person. Following the outbreak of the COVID-19 global pandemic, the need to revisit previously-straightforward methodologies and research pipelines of studies that require human participation at different levels has gained amplified interest. There are challenges involved in shifting user-centric studies to alternative or online methods [BAM*20]. It should be noted that many of the lessons learned while implementing DSLM online, especially those in regard to collaboration and communication, can also have implications for online design studies in general, be it in pedagogy or research.

8. Conclusion

In this work, we demonstrate that the Design Study "Lite" Methodology (DSLM) can be implemented successfully in online classes with real-world local, national, and international collaborators. We present and validate two online implementations of DSLM as part of data visualization courses, one with Service-Learning and one without. The 46 and 57 students of these courses, respectively, completed 16 and 20 design study projects with real-world partners. We evaluated the successes of these implementations based on feedback from students and partners and the final project grades achieved by the students. We then synthesized our lessons learned into recommendations that can serve as a checklist to guide educators, especially newcomers to data visualization, to implement their own versions of DSLM in online classes. We also articulate explicit requirements and novel additions that expand the original DSLM framework [SMR*20]. By providing a systematic and expedited approach to executing design studies in visualization pedagogy, we can encourage visualization educators to incorporate design studies in their in-person and online courses. This can enrich the learning experiences of students and give them the opportunity to develop visualizations that address real-world problems through a realistic visualization design process. Being able to conduct DSLM online also makes the framework more accessible to both traditional and non-traditional students and paves the way for opportunities for global collaboration and participation.

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