# Adapting Vertically-Scaled Solutions Across Many Georgia Tech Classes

*Jeonghyun (Jonna) Lee[a], Matt Lisle[b] and Troy Courville[c]*

## Abstract

The coronavirus pandemic prompted the Georgia Institute of Technology (Georgia Tech) to design a set of innovative trials focused on novel problems in delivering at-scale learning horizontally. This chapter provides insight into two specific technological tools that adapt solutions for vertical scaling and how these tools can be scaled across many classes. We explain how Georgia Tech identified strategic needs that emerged from the remote learning environment based on faculty survey findings. We then explore existing solutions that have displayed promise in a vertical scaling context, with a focus on early attempts to scale these solutions across the campus in order to enhance online learning environments. Finally, we discuss how Georgia Tech plans to continue scaling of these innovations.

*Keywords*: At-scale learning, remote teaching, horizontal scaling, higher education

## Introduction

On March 12, the Georgia Institute of Technology (Georgia Tech) announced a campus closure for the Spring 2020 semester due to the public health crisis caused by the SARS-CV-2 (novel coronavirus) and the resulting disease, COVID-19. The resulting response to this crisis caused Georgia Tech to rapidly prepare faculty and students for emergency remote course delivery. While this response caused many issues across campus, Georgia Tech was in the fortunate position of having numerous faculty and staff who are accustomed to inventing and/or applying readily available technologies in innovative ways to solve novel problems. Many of these solutions have been piloted in limited at-scale classes, where the environment is set up to scale a vertical growth of enrollment, or “vertical scale” (Gazi & Baker, in this volume). The remote learning environment provided an interesting opportunity to select solutions that a) met a strategic need in the Georgia Tech remote learning environment, b) had positive pilot test results, and c) had one or more aspects that could transfer across many classes and faculty (i.e., horizontal scaling).

This chapter will discuss the research behind the selection and implementation of two educational tools specifically designed to support online learning and instruction at Georgia Tech. The ultimate goal of our paper is to provide practical insight into the usage of

[a] Georgia Institute of Technology, jonnalee@gatech.edu, ORCID: 0000-0003-1497-0561
[b] Georgia Institute of Technology, matt@c21u.gatech.edu, ORCID: 0000-0002-0820-3377
[c] Georgia Institute of Technology, troy.courville@pe.gatech.edu, ORCID: 0000-0002-2064-7405

technological tools that can help enhance the ability to operationalize the horizontal scaling process across many online courses in the campus community. The first section covers how Georgia Tech identified strategic needs that were emerging from the remote learning environment. Specifically, Georgia Tech used faculty surveys to capture snapshots of how faculty have responded to the sudden transition from face-to-face to remote delivery of courses due to the novel coronavirus pandemic. Informed by the survey findings, we identify key issues and strategic needs in the areas of online instruction and learning. The second section explores existing solutions that have met a strategic need and displayed promise across a limited number of classes. The third section describes early attempts to scale these solutions across many faculty members, classes, and/or disciplines to enhance learning environments at Georgia Tech. The final section looks into the future and discusses how Georgia Tech might continue to scale these innovations.

## The Emergency Pivot to Remote Learning

Between mid-April and early May, the Center for 21st Century Universities (C21U) at Georgia Tech invited all faculty who were teaching Spring 2020 courses on the Atlanta campus to participate in an anonymous online survey, which was designed to capture a snapshot of faculty experiences and challenges during emergency remote teaching. This survey study included only those faculty members who taught in-person class meetings prior to the pandemic-related emergency move to remote teaching during mid-March. The survey consisted of 20 questions with 18 closed-ended and two open-ended items, which asked participants about their demographic and course information, types of instructional adjustments, and general perceptions about the remote delivery of courses.

A total of 266 faculty members, who teach in one of six colleges at Georgia Tech, volunteered to respond to the survey. 55% of the total participants were tenure-track and 46% were non-tenure-track academic faculty (e.g., Academic Professional, Lecturer, Adjunct). In terms of total years of teaching experience at colleges or universities, responses were almost evenly distributed amongst respondents: 21% of the respondents reported 0-5 years, 20% 6-10 years, 17% 11-15 years, 11% 16-20 years, and 31% 20 years or more. On average, the respondents taught two classes during the Spring 2020 semester and had up to 60 students in their classes. Regarding the primary methods of instruction after the transition to remote teaching, nearly a half of total respondents (47%) reported that they used a combination of asynchronous (e.g., uploading pre-recorded lecture videos) and synchronous methods to deliver instruction (e.g., having a live session through a web conferencing tool). 35% reported that they mainly used synchronous methods while another 18% relied on asynchronous methods.

In this chapter, we focus on reporting the faculty responses that were related to their challenges that arose during the emergency remote delivery of courses. We observed several salient themes that emerged from faculty responses regarding challenges in online instruction. Most notably, many faculty commented on issues related to time management for instructional teams and challenges associated with receiving regular feedback on students' learning and progress. These findings served as a foundation that guided research questions in which we sought to identify effective tools to support horizontal at-scale learning.

**Time Management**

One of the survey questions in particular asked respondents to identify the primary source of any difficulties they might have experienced while teaching remotely. Among 257 total responses, 23% responded that there were no issues; while the remaining 77%, who did experience some difficulty, reported one of several possible sources of issues: "Internet connectivity" (19%), "Technical issues outside their control" (14%), "Teaching equipment issues" (12%), and "Other" (31%). Those who chose "Other," the most frequently reported response, were asked to specify their problem(s). One common refrain from faculty was their instructional teams' time management challenges. The increased demands on faculty impacted their ability to provide the same level of quality instruction they were accustomed to providing. For example, one instructor commented:

> It's taken more time than I expected to develop new material for online presentation. Previously I could just walk in to class and teach new material directly; if there were a few rough spots it was okay. Now I tend to want to fix all the rough spots.

Another mentioned that:

> It takes probably three times as long: I pre-record in multiple segments, and doing that takes longer and is mentally more demanding than just lecturing for a continuous block of class time. Then I'm online with the students during the class period, when we play the videos and I answer questions...

Three areas that affected instructional teams' ability to manage their time were content creation, grading, and student communication. Theoretically, we could improve the efficiency of one of these areas, such as student communications, to allow additional time to be devoted to the others. Researchers at Georgia Tech have had previous success with Jill Watson, an AI-enhanced virtual teaching assistant designed for an online degree program at Georgia Tech (Schroeder, 2018). Jill Watson answers common course questions from students, freeing faculty time to focus on student learning outcomes and engagement. Initial versions of Jill Watson are an example of vertical scaling, where many hours were spent developing a tool for a small group of courses with high enrollment. We seek to examine whether such an AI-based tool can help large groups of faculty resolve time constraint problems. Also, can the up-front development time and effort, which is typically large, be reduced without sacrificing the tool's quality?

**Student Progress Assessment**

Another notable issue that emerged from the faculty survey was the difficulty of assessing students' learning and progress in (or near) real-time. On the same survey, faculty were asked to rate their remote teaching experience in several aspects, including delivering learning content, communicating with students, and assessing students' learning. We found that faculty reported the lowest level of satisfaction in student assessment, with less than half reporting that they were either "very satisfied" or "satisfied" (this was contrary to other areas in which more than 60% of faculty reported positive ratings). When these responses were disaggregated by the primary method that faculty used to deliver instruction, it showed that difficulties in getting spontaneous feedback from students tended to be salient particularly among those instructors who relied on using an asynchronous mode to deliver instruction. Interestingly, such challenges in the feedback process were also occasionally noted by those who adopted synchronous methods (e.g., having a live lecture session via a web conferencing tool). For example, in response to the survey question about issues in remote teaching, one instructor mentioned, "*Students are muted. Chatting is OK but few do it. Cannot get the "feel" for the students' comprehension of topics.*"

This issue in particular calls for attention because it is closely related to students' learning experiences. According to the results from an institutional survey distributed to students at Georgia Tech during the emergency online course delivery, when asked whether they were still achieving course learning outcomes with the change in delivery, only 23% (total n=5,379) responded that this was true in all their classes. Additionally, although many students felt satisfied with remote academic activities (44%), there was still a significant portion of students who felt either dissatisfied (22%) or extremely dissatisfied (7%).

A possible explanation for this outcome may be found in Moore's (1993) theory of transactional distance. According to Moore, as the transactional distance—psychological or communicative space between the instructor and students in a distant learning environment—increases, students need to become more autonomous in their own learning. Critical to supporting students' autonomy is feedback based on formative and/or spontaneous assessments, which in online learning situations is challenging. The lack of available tools to assess students' online learning and engagement in real time makes it difficult for the instructor to provide appropriate support in timely fashion to students who fall behind. Subsequently, students who seek guidance on whether they are on track or how to improve their learning performances may feel lost.

One Georgia Tech faculty member has had previous success meeting this challenge in his online courses by creating custom tools to quickly identify students in need of an intervention from his instructional team. However, these tools required a great deal of technical expertise and up-front development time, which limits their ability to be scaled horizontally across campus. Can a campus-wide tool be created to achieve similar results in all Georgia Tech courses? In the following section, we provide detailed information about this particular example and discuss implications for how such feedback tools can be adapted to the context of horizontal scaling.

## Lessons-Learned from Vertical At-Scale Solutions

As alluded to in the previous section, our analysis of the survey findings led us to search for related vertically-scaled solutions at Georgia Tech. In particular, we focused on two large-enrollment online courses: Knowledge-Based Artificial Intelligence (CS 7637) and Introduction to Computing Using Python (CS 1301). In these courses, faculty developed labor-intensive custom tools and processes to increase the quality of instruction. By highlighting the success and lessons-learned from the vertically-scaled solutions in these courses, we can explore the feasibility of horizontally-scaling these solutions across a large number of courses. These examples include the “Jill Watson 2016” Teaching Assistant for the CS 7637 course and customized student progress tracking tools used in the CS 1301 course.

### “Jill Watson 2016” Teaching Assistant

Developed by Dr. Ashok Goel’s Emprize research team at Georgia Tech in 2016, the first version of the Jill Watson Teaching Assistant (“Jill Watson 2016” for short) served as a virtual assistant that supports both teachers and students in the CS 7637 online course. Jill Watson 2016 was initially trained by pairs of frequently asked *student* questions and *instructor* answers using previous semesters’ course discussion posts.

Jill Watson 2016 was able to answer a fraction of students’ questions quickly and efficiently (with its confidence value greater than 97%), freeing the rest of the instructional team to spend more time engaging with students and answering deeper questions (Goel & Polepeddi, 2018). Likewise, students could benefit from Jill Watson’s ability to address their inquiries in a prompt manner. Without support from Jill Watson, it would have been challenging for students to receive timely feedback that addresses individual concerns, given that OMSCS courses typically have large class sizes. Jill Watson 2016's success in CS 7637 led to its deployment in five additional large, online classes in Georgia Tech's College of Computing over subsequent semesters.

Despite its success, Jill Watson 2016 had several shortcomings. Most notably, it required >1,000 hours to build the first instance and >100 hours to build each subsequent instance. This up-front investment would prove to be an obstacle to the Emprize team's goal of expanding Jill Watson 2016 into many classes across Georgia Tech. It also required a large set of question and answer pairs from previous semesters, which was not available for many courses.

In addition, Jill Watson 2016's use of previous discussion posts introduced bias into its algorithms (Eicher, Polepeddi, & Goel, 2018). In one example, a male student was asked to introduce himself in the course discussion forum at the beginning of a semester. He mentioned that he "will become a father for the first time," which would require him to miss some classes during the semester. Jill Watson responded by welcoming him to the class and congratulating him on the new addition to the family. In a later semester, a female student offered a similar introduction–saying that *she* was pregnant and would be missing some classes. Jill Watson responded by simply welcoming her to the class, but did not congratulate her growing family. This is because–in Dr. Goel's male-dominated course rosters–Jill Watson had previous question and answer pairs in which male students announced that their families were expecting the birth of new children. However, there were no previous question and answer pairs in which female students announced their own pregnancies. As a result, Jill Watson did not know how to respond to the female student.

**CS 1301 Student Progress Tracking**

For the second solution, we discuss an interesting example that comes from an online undergraduate course, CS 1301 (*Introduction to Computing Using Python*) offered at Georgia Tech (Joyner, 2018; 2019). The CS 1301 course has a quite large class size with an average of 220 students per section in the past three years. In general, the student body primarily consists of first- or second-year students who are pursuing majors other than computer science, and it is almost evenly distributed by gender. Students who are enrolled in this 17-week course, are expected to watch lecture videos, complete online problem sets and receive live feedback, and take tests asynchronously, which all take place in the edX platform. Dr. David Joyner, the instructor for this course, used custom Excel formulas and the edX gradebook to quickly identify and contact at-risk students in his course. This set of tools and processes enabled Joyner to find individual students who fell behind on the recommended course schedule on a weekly basis.

The technical solution for these analytics tools generally relied on a manual process, as illustrated in the following step-by-step description. First, as up-front development work, the instructor creates an initial set of ~300 auto-graded homework problems (currently with ~500 problems). Next, the instructor exports a gradebook from edX in an Excel spreadsheet, and filters students by multiple variables. In the end, the instructor uses the spreadsheet to identify all students who are behind on some section and labels them according to their current status. Finally, the instructor created a formula in Excel that allows him to quickly send email messages to students. The tone of emails can be either personalized or formulaic depending on each student's particular circumstances.

As a consequence of this outreach, students are expected to be informed about how far they fell behind and seek available resources that can help overcome any learning challenges. Further, the instructor expects that the tool can increase students' awareness that someone in the course (either the instructor or a TA) actually cares about them. Despite these advantages, there are some obstacles to overcome in order for another instructor to use the same tools in a different course. For example, in addition to having at least intermediate-level skills in the Excel software, instructors are expected to make a substantial investment in time. Joyner noted that it typically takes about four hours to get the setup ready at the start of the term as well as about two additional hours every time he sends out a batch of emails (D. Joyner, personal communication, July 22, 2020). The method that he used to contact individual students who were at-risk was faster than writing hundreds of individual emails, but using something more automated would help instructors save more time.

## Leveraging Vertical Solutions for Horizontal Challenges

After identifying previous examples of vertically-scaled solutions to the challenges identified by students and faculty during the Spring 2020 semester, the question remains how these could be horizontally-scaled across a large number of courses at Georgia Tech. Both vertical examples are from faculty members who are computer scientists–could they prove useful to less technical faculty? Both examples are used in computer science courses–would they be as effective in a variety of subject areas? Both examples were used in a small number of courses– could they be quickly implemented in a large number of courses? In both cases, early efforts are underway to answer these questions and make the solutions available to a large number of courses.

### "Jill Watson 2019" Teaching Assistant

As previously mentioned, Jill Watson 2016 presented several challenges, including up-front development time, reliance on large data sets of previous course discussion posts, and indications of algorithmic bias. In response to these challenges, Goel's team began working on a new iteration of Jill Watson, coined Jill Watson 2019. They hoped to reduce the data bias by reducing the reliance on previous semesters' question and answer pairs. They planned to lessen the necessity of a large data set of discussion posts by training Jill Watson 2019 using a common document type found in most courses. Finally, they aimed to make the tool more scalable by reducing the amount of up-front development time required by faculty.

As a result, Jill Watson 2019 was launched during the summer 2019 semester at Georgia Tech. This new iteration of the agent answers students' questions about the courses based on its knowledge organized around a general ontology of course syllabi that the Emprize team has developed. Faculty members use a web-based application to generate thousands of question and answer pairs using their course syllabus. As a result, it requires approximately five hours of up-front development time, rather than 100 hours.

The tool has recently been tested and used in thirteen large courses at Georgia Tech since Summer 2019. Since the onset of the novel coronavirus pandemic, the need for Jill Watson Teaching Assistants in Georgia Tech courses has only increased. While Jill Watson 2019 has taken great strides towards scalability by reducing the up-front time investment, it still has not reduced the amount of resources required *during* a semester. For an effective implementation, Jill Watson 2019 requires a full-time instructional team member to spend approximately 25% of their time monitoring, analyzing, and facilitating the use of Jill Watson 2019 in every single course. Otherwise, the agent might be intentionally or unintentionally derailed by student questions that Jill Watson 2019 finds itself unable to answer. Going forward, this will be a critical obstacle to overcome in order to truly scale horizontally across a large number of courses.

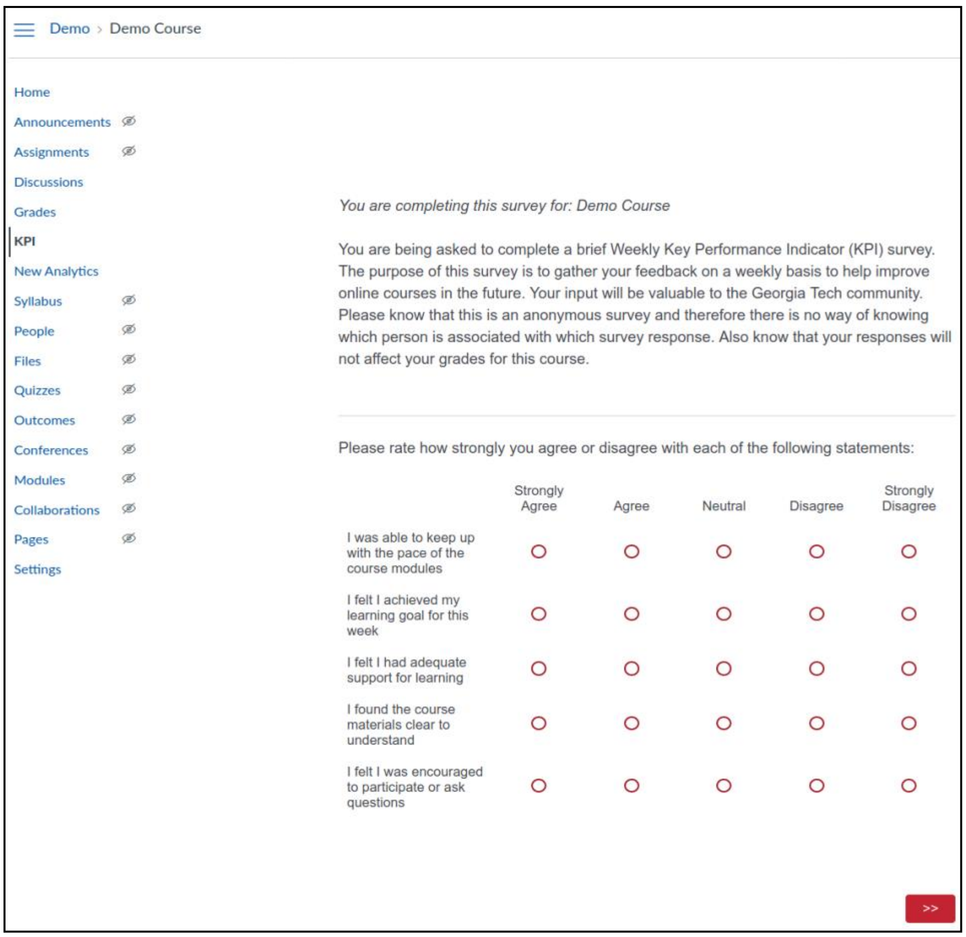
### Key Performance Indicator (KPI) Tool

Upon learning about the tools and processes that Dr. Joyner used to monitor his students' progress in CS 1301, C21U set out to build a tool that would enable all faculty to quickly and easily monitor students' learning and progress in near-real time. C21U created the Key Performance Indicator (KPI) tool in Canvas, a learning management system (LMS) platform. KPI is an easily accessible tool designed to give instructors continuous weekly feedback from students and to help provide a sense of how students are performing in their course over time.

The KPI tool has close relevance to the above-mentioned example from CS 1301 in which Joyner developed a method to quickly identify when students are struggling in his class. The main difference is that the KPI tool can be quickly scaled to all Canvas courses at Georgia Tech without requiring extensive effort by faculty. When installed, the KPI tool appears in the course navigation of each course. When a student clicks the tool, they are directed to a short survey where they provide regular feedback on the pace of course modules, self-mastery of learning goals, support for learning, clarity of course materials, and class engagement (see Figure 1 for a sample screenshot).

**Figure 1**

*Sample Screenshot of Student Survey View*




When instructors click the tool, they are directed to a dashboard that shows the students' submissions for their course (see Figure 2 for a sample screenshot). As a result, faculty can make adjustments throughout the semester based on the KPI ratings they are receiving on a weekly basis. A feature that we believe particularly helpful in this regard is a color-coded heat map. As shown in Figure 2, as an average rating for a dimension increases from the lower to the higher end of the scale, the background color of a cell can change from red to green. This heat map allows instructors to easily track trends over time and across dimensions.

**Figure 2**

*Sample Screenshot of Faculty Report View*


Our key question is how much this tool can contribute to empowering faculty in the process of understanding student needs and taking actions at the right time in an online course environment. According to preliminary feedback from Summer 2020 pilot testers, faculty reported that they used students' responses mainly to adjust their instruction methods. Regarding the usage of the tool, other responses included monitoring students' progress and receiving more frequent feedback from students. One faculty member mentioned during an informal interview session that this tool was generally helpful for two primary reasons. One was that the tool was "simple" to use for both the instructor and students while it tapped into key aspects of online learning (i.e., the five dimensions about which the students submitted their responses). The other reason was that the tool provides feedback every week, and thus helps the instructor make the instruction better throughout the semester. The instructor further compared the KPI tool with the end-of-semester course evaluation survey, commenting, "(...) *knowing about the issue at the end of the semester… some part is like what is the point, you know?*"

As expected for a new tool, there were some challenges that need to be addressed in the future. One issue was low participation rates by students. For example, in one course, there was only one student who submitted responses, which severely limited the representativeness of the data. Another related issue was a short duration of data collection for more than a half of all participating courses. As an example, some courses had the reasonable number of student responses but for less than three weeks. This made it difficult to detect meaningful temporal trends. It is possible that these issues were due to the shortened summer semester in which it was piloted, unfamiliarity with the platform, insufficient encouragement to participate, or the purely voluntary nature of adoption by the faculty and students.

## Next Steps

In the previous sections, we identified recent successes of horizontally-scaling educational technologies that were previously designed to solve problems of vertically-scaled learning. These achievements will position Georgia Tech well for future online, hybrid, and even in-person courses and programs. However, challenges remain and must be considered going forward. This section outlines our strategies to continuously improve these tools and broaden their use throughout the Institute and the broader higher education community.

### Jill Watson Teaching Assistant

Jill Watson 2019, the latest iteration of the virtual teaching assistant, has substantially automated the process of generating a Jill Watson agent before a class begins. However, it has not yet substantially automated the process of deploying, monitoring, and analyzing Jill Watson during a course. This remains the largest obstacle to wider adoption of the technology.

The solution might not be a technological one. As previously mentioned, the tool is still resource-heavy because the agent might be derailed by student questions without proper implementation. The Emprize team has started exploring the possibility of carefully onboarding new students to the concept of conversing with Jill Watson. In other words, a teacher might create a new thread in the course discussion forum that focuses on learning how Jill Watson works–a chatbot tutorial, so to speak. Students might ask Jill Watson what types of questions it can answer, what it cannot do, how it finds answers to questions, and so on. Potentially, this onboarding will reduce the urge by some students to “hack” the virtual agent, and improve other students’ comfort-level with working alongside the agent throughout the semester.

The Jill Watson Teaching Assistant is not a technology that one can build, deploy, and forget about. Goel’s team is not simply developing a technology, they are developing a sociotechnical system that balances the needs and abilities of an artificially intelligent agent, students, instructional teams, and researchers. Each of these parties are components of the system and must learn to interact and work efficiently together. In order to effectively scale the Jill Watson technology horizontally, these parties will need to participate in the design to ensure that the benefits of such a solution outweigh the costs of implementation. Furthermore, continuous monitoring and evaluation of the impact of this technology across a wide range of online courses should be conducted. Ultimately, the evaluation will need to focus on addressing two key items, including: to what extent Jill Watson contributes to resolving time constraints among instructors and consequently whether this would benefit students' learning and their autonomy.

### Key Performance Indicator (KPI) Tool

We also plan to build upon the early success of the KPI tool. During the Summer 2020 semester, we piloted the tool with 27 faculty members in 50 courses. Going forward, we are implementing a larger pilot during the Fall 2020 semester with the launch of a self-service mechanism that allows faculty to opt-in to using the tool in their courses. If our pilots continue to go well, we plan to automatically install the tool in all Canvas courses at Georgia Tech.

Our initial research into the tool revealed that students in some courses were regularly submitting weekly KPI reports, while other courses were seeing much less activity. We intend to explore what types of faculty support and development will lead to increased use of the tool. For example, we intend to provide sample language to be used in syllabi, course announcements, and other communications (e.g., built-in reminders) to help students see the value in the KPI tool. We will also continue interviewing and surveying pilot participants to try to determine other strategies to encourage wider adoption and use of the tool.

In addition, there are several features on our future roadmap for the tool. For example, Joyner's custom analytics tool for CS 1301 allowed him to intervene with individual students. Our hope is to find ways to allow such student interventions, while maintaining student anonymity to encourage honest responses. We are still researching this feature, but one possibility is that students who regularly respond with low ratings for a particular metric might be provided generic strategies for overcoming difficulties. If one student repeatedly submits low ratings for the clarity of course materials, for example, he or she might be provided resources from Georgia Tech's Office of Undergraduate Education for decoding complex topics, or perhaps directed to remedial materials to make up for a deficit in prior knowledge. Of course, if all or many students repeatedly submit low ratings for the clarity of materials the instructor knows he or she needs to modify the content.

### Developing a Campus Roadmap

More broadly, these initiatives speak to the importance of universities' ability to monitor education technology-related challenges and initiatives across campus, allowing them to identify vertically-scaled solutions or prototypes that could be horizontally-scaled for larger numbers of courses. At the Georgia Institute of Technology, one strategy for tracking our educational technology roadmap is to regularly convene a group of campus experts, in our case the Education Technology Steering Committee, to discuss initiatives like the ones described here. The results of these initiatives are also discussed by the Education Innovation Council, a group of administrators who can assist in broad implementation of successful innovations. These collaborations allow us to regularly surface efforts from one school or department that might be applicable to others.

## Conclusion

No matter the institution, there is always a group of faculty, staff, and administrators interested in the application of innovative methods to solve novel problems. These grassroots efforts often stay housed within one or more courses, with small numbers of faculty who understand their purpose, application, and intended outcomes. The challenge becomes envisioning the solution to problems that might be somewhat related to the original problem or customizing the original work for a set of users whose level of technical experience might differ significantly from that of the original instructor. In many cases, the challenge of adapting vertically-scaled solutions across many classes is daunting. However, born out of the unique trials posed by the novel coronavirus pandemic are opportunities to explore horizontal scaling in a time where solutions to large scale problems are critical. Innovations like the newest iteration of the Jill Watson Teaching Assistant and the Key Performance Indicator (KPI) Tool are just two of the horizontally-scaled solutions that have emerged from this crisis. Moving forward, the challenge is to not let vertically-scaled solutions stay hidden within units or small but dynamic groups of instructors, but to create environments that widely foster the experimentation of these solutions across problems that impact many students and institutions.

## References


Eicher, B., Polepeddi, L., & Goel, A. (2018). Jill Watson doesn't care if you're pregnant: Grounding AI ethics in empirical studies. In *Proceedings of the 2018 AAAI/ACM Conference on AI, Ethics, and Society* (pp. 88-94).

Gazi, Y. & Baker, N. (2021). Editors' overview. In Y. Gazi, & N. Baker (Eds.), *Moving horizontally: The new dimensions of at-scale learning in the time of COVID-19.*

Goel, A. K., & Polepeddi, L. (2018). Jill Watson: A virtual teaching assistant for online education. In C. Dede, J. Richards, & B. Saxberg (Eds.), *Learning engineering for online education: Theoretical contexts and design-based examples.* New York, NY: Routledge.

Joyner, D. A. (2018). Toward CS1 at Scale: Building and testing a MOOC-for-credit candidate. In *Proceedings of the Fifth Annual ACM Conference on Learning at Scale.* London, United Kingdom: ACM Press.

Joyner, D. A. (2019). Building purposeful online learning: Outcomes from blending CS1301. In A. Madden, L. Margulieux., R. Kadel, & A. Goel (Eds.), *Blended learning in practice: A Guide for Practitioners and Researchers,* (pp. 69-96). Cambridge, MA: The MIT Press.

Moore, M.G. (1993). Theory of transactional distance. In D. Keegan (Ed.), *Theoretical principles of distance education*, (pp. 22-38). New York, NY: Routledge.

Schroeder, R. (2018). Affordable and at-scale. *Inside Higher Ed*. Retrieved from https://www.insidehighered.com/digital-learning/blogs/online-trending-now/affordable-and-scale.

## Appendix

*List of the Emergency Transition to Remote Teaching Survey Questions*

1.What is your current rank?
2. Please select the college (and school) in which you are currently affiliated and teaching at Georgia Tech.
3. What is your total years of teaching experience at college or university?
4. How many classes are you currently teaching during the Spring 2020 semester?
(Please enter the number of classes for each program level.)
5. How many students are in your class?
(If you are teaching more than one class, please indicate the average number of students.)
6. Which of the following were your primary methods of instruction in your face-to-face classroom BEFORE switching to remote teaching due to the campus response to coronavirus (COVID-19). Please choose all that apply.

Please respond to the following questions regarding your recent experience related to switching to remote teaching (or teaching online) due to coronavirus (COVID-19).

7. How do you currently deliver your instructions?
8. Which tool(s) do you mainly use to communicate with your students?
9. How would you rate your experience since transitioning to remote teaching? (1=very dissatisfied, 5=very satisfied)

- Delivering learning content
- Uploading worksheets or other learning materials
- Communicating with students (including GTAs)
- Holding office hours to address students' needs
- Assessing students' learning and progress

10. How much adjustment have you made in your current instruction for remote teaching? (1=none, 5=a great deal)
11. How well-suited is your course subject to online instruction? (1=not well at all, 5=extremely well)
12. How easy was switching in-person classroom activities to online activities since transitioning to remote teaching? (1=very difficult, 5=very easy)
13. If you have a student participation component in your grading scheme, how has this been adapted?
14. Which tool(s) have you used to adapt your assignment and exams since transitioning to remote teaching? Please choose all that apply.
15. Which of the following strategies have you used, if any, to preserve integrity and deter academic dishonesty during online exams? Please choose all that apply.
16. How would you rate helpfulness of the following resources for your transition to remote teaching? (N/A or haven't yet sought, 1=not at all helpful, 4=very helpful)

- Academic Continuity Resources from Georgia Tech Website
- Support from your department/college
- Support from OIT or other instructional technology experts on campus
- Shared tips from other faculty
- Webinars or other training opportunities

17. How would you rate your comfort level in the following areas that are recommended for a seamless transition to remote teaching? (1=very uncomfortable, 5=very comfortable)

- Updating the syllabus
- Moving quizzes and homework online
- Transitioning lectures to online
- Engaging students in discussion with online forums or chatrooms

18. If you have experienced any difficulty teaching remotely, what was the primary source of the issue(s)?

19. (open-ended) What strategy (strategies) have you used to enhance a sense of belonging/connectedness in your class since switching to remote teaching?

20. (open-ended) How have you been accounting for students in disadvantaged situations (e.g., limited access to Wi-Fi, learning devices/equipment, space for studying full-time, accessibility)?