Research Statement  
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My research background is in Artificial Intelligence for Education (AIED), gamification, and CS education. Thus, my research goals involve using advanced algorithms to further education, and continuing to study the role of play and gaming in the learning process. Recently, I’ve attempted to focus these efforts specifically in CS education. My current research agenda can be understood as three parallel branches: a large, developing project in computer science education, a continued involvement of undergraduate students on several smaller but developed works, and collaborations outside of SEAS.

### Computer Science Education

My research vision involves using Artificial Intelligence, Intelligent Tutoring Systems, and Gamification to advance problems in Computer Science education. I’ve observed that there can be a lack of mastery students reach in my courses. Anecdotally, I see students struggle with an assignment (e.g., building a linked-list in C++) and either turn in incomplete work (perhaps the student earns a 4 or 5 points out of 10) or receive large amounts of help. This is evident by noticing the gap between exam scores and homework scores. In one of my courses, the average difference between these two is 20.76 percentage points (with homework averages being higher). This gap is more significant among average students. Those who earned a C- through B+ showed a 25.9 percentage point gap. This, to me, means that students are completing homework but not mastering the material. I also observed that students tend to struggle the most on early concepts in a course. Low grades on early difficult topics (e.g., pointers in C++, Linked Lists) lead to lower grades. These students are struggling to grasp early concepts and then forced to push through more difficult topics anyway.

To address these issues, I developed a set of course design principles and a piece of software called the Advanced Collegiate Assessment System (ACAS) to support novel course designs that incorporate mastery learning, flexibility, and gamification strategies (my teaching statement contains more details on the principles of this course design). The software assists instructors in modeling a course as a set of topics with interdependencies between topics (usually a DAG). The system can handle grading by mastery of topic instead of percentages, assessments beyond what Collab supports (e.g., Parson’s Problems are supported), and contains advanced tutoring algorithms for assessing mastery (I use Bayesian Knowledge Tracing to assess students by topic). This system and a novel course design were piloted during my Fall 2019 course on Data Structures and Algorithms I (DSA1). An undergraduate student assisted with this work, and we found that students had very positive reactions to the course (via multiple qualitative surveys), that grades / requirements focusing on mastery led to higher averages on homework assignments, and that students were given the flexibility and indeed did reach their goals using a variety of unique paths through the course.

These findings are very encouraging, and I am working to reproduce them in all of my courses and polish this overall course design with continued study. The pilot did continue during the Spring 2020 semester, but was interrupted by the COVID-19 outbreak and the move to online instruction.

As I continue to explore the utility of both my flexible course designs as well as the ACAS software, I intend to investigate the following:

* ***Learning at Scale:*** *ACAS allows students to practice and work on homework and visualize how their efforts are affecting their knowledge in the course. Exams can be generated automatically and assessed within the context of the course’s structure. This means flexibility to allow mastery-based learning and retaking of exams becomes scalable.*
* ***Properly Assessing Students:*** *ACAS allows instructors to assess students based on the breakdown of topics they have mastered and the breadth / depth of student knowledge. This more properly contextualizes assessments. Letter grades map directly onto student knowledge, meaning letter grades are more telling of a student’s exact progress.*
* ***Personalization of Education:*** *ACAS allows every student to work or make progress on the topics they struggle with most. Students see the course structure, and the system will suggest what topics the student studies. It is now possible to investigate more advanced algorithms to assess student learning and progress through a course in a personalized way.*
* ***Cheating in CS:*** *High personalization may lead to less cheating. If every student takes a unique exam, then it becomes difficult to cheat on that exam. If practicing / homework is meant to be done collaboratively, then assessment calculations can take that into account.*
* ***Accreditation:*** *Accreditation is currently a laborious task in our department. Theoretically, ACAS can output a visual representation of all the content of a course (or set of courses) and display how well the student body understands the concepts across the curriculum with the click of a button.*

### Smaller Projects and Undergraduate Involvement

I believe that involving undergraduates in research activities is an excellent way to provide them with a unique educational experience. I have advised dozens of capstone projects, some of which have led to publication. Most notably, I advised a project with undergraduates who built a Civil War history game. I helped the students understand the design process of such a game, and how to organize and structure a theoretical foundation as well as experiments based on these theories. I spearheaded two publications on these projects, and am proud of the achievements of these undergraduates. One publication was presented at the Games and Learning Alliance (GALA) conference in Rome, Italy and a follow-up publication was invited and accepted into the International Journal of Serious Games (IJSG).

I have also engaged undergraduates to implement advanced algorithms for assessing students within the ACAS system (Carrington Murphy, 2020), developing online tools for learning about game engine development (Laura Maimon, Kasey Price, 2019), using virtual reality simulations for engaging middle school students in history lessons (Anthony Uitz, 2017), and gamifying insomnia interventions for adults (Cindy Park, 2017). When advising a capstone, I attempt to ensure that the student acquires experience developing software, tools, interventions, etc. while also understanding how to study the efficacy of those tools. For that reason, almost all of my undergraduate capstone projects involve some form of simulation study or human study of the utility of the student’s work. While students often struggle a bit with this component (they are more familiar with developing software then they are studying it), I think the experience helps them understand how research is fundamentally different than software development.

### Cross-Disciplinary Collaborations

I’ve also made inroads by collaborating on research projects with colleagues outside of SEAS. Most notably, I’ve worked with Dr. Lee Ritterband at the Center for Behavioral Health Technology to consult on projects involving internet interventions. These interventions are technology based health applications used to deliver care to patients without the need for a human clinician. I’ve consulted on UI / design considerations for interventions for insomnia, and utilized my background in gamification to study whether or not game-like mechanics can be used to enhance these systems. Our article theorizing on the use of gamification on these interventions was published in the journal Translational Behavioral Medicine, and presented at the International Society for research on Internet Interventions (ISRII) meeting in Berlin, Germany. We continued the work by studying how our theoretical model predicts the successes and failures of various mental health applications that exist in the market today. Our conclusions were recently published in the Journal of Medical Internet Research (JMIR). We plan to continue the work by seeking funding to develop an internet intervention for either mental health patients or cancer patients and continuing to study how gamification and other design considerations can be utilized to optimize treatments.

I’ve also been lucky to collaborate with Dr. Jennifer Chiu in the Curry School of Education. I consulted with a graduate student of hers and assisted them in designing algorithms to handle large datasets for an experiment involving students using an experimental version of CAD. The project also involved applying Machine Learning to understand the behavior of students within this space so that the system can eventually provide rich contextual feedback to students as they learn and approach the activity. This work led to a publication at the International Conference of the Learning Sciences (ICLS).

### Conclusion

In conclusion, my research agenda focuses on an aggressive new project to solve real problems in CS while also continuing to involve undergraduate students in the research and publication process. In addition, I plan to continue fostering collaborations across departments so that my contributions can be made in areas outside of Computer Science. I feel incredibly honored to have access to the UVa network. Without thoughtful colleagues and talented undergraduates, I would not have been able to make progress on my CS education ideas. Without open-minded colleagues around grounds who are willing to work with me, I would not be able to benefit from their experience and have resources to apply my research ideas. Although teaching is the primary focus of my position, I truly believe that UVa is an incredible university where scholarship can be mutually beneficial for faculty and students alike. Students benefit from acquiring research experience, no matter how big or small. Faculty like me benefit from tenure-track colleagues who are willing to embrace others and allow them to contribute to projects. This culture has truly helped me make some progress in the area of scholarship, and I look forward to continue to push this work forward in future years.