The Promise and Pitfalls of Virtual Worlds to Enhance STEM Education Success: Summary of the GSAA BreakThru Model

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Abstract. The Georgia STEM Accessibility Alliance (GSAA) is a research project funded by the U.S. National Science Foundation (NSF) Research in Disabilities Education (RDE) program, grants 1027635 and 1027655. A collaborative RDE Alliance, it combines the expertise of the University of Georgia and the Georgia Institute of Technology. Launched in 2010 and projected for completion in 2016, GSAA is one of 10 RDE Alliances throughout the United States designed to broaden the participation and achievement of people with disabilities in STEM education and careers. Although the GSAA encompasses many innovative features to achieve its goals, its core features are the use of virtual worlds (Second Life) and online and smartphone technologies to enhance student success through mediated mentoring, collectively referred to as the BreakThru project. This paper will provide provide a brief summary of the status of the use of virtual worlds in STEM education, as well as an overview of the GSAA BreakThru goals, theory of change, demographics, and subject participation. It will posit conclusions that can be advantageous in future research on online, mediated approaches to enhanced education, to ensure the maximum potential for all students to complete educational goals.

Keywords: STEM education · Disability · Accessibility · Electronic mentoring · Virtual worlds · Online education

1 Introduction

The influence of digital media has changed the way students learn, play and socialize. As a result, researchers at University of Georgia (UGA) and the Georgia Institute of Technology (GT) have partnered to develop a virtual learning environment that combines creative avatars and social networking tools to assist secondary school and college students with disabilities to succeed in science, technology, engineering, and math (STEM) programs. The universities work alongside Georgia Perimeter College and the secondary school systems of Georgia's Greene, Clarke and Gwinnett counties to serve targeted students.

The GSAA BreakThru project provides Second Life Mentoring Islands where students meet and interact with mentors to address their STEM education needs. Students have the option to create avatars that simulate their disability realities (e.g., wheelchairs

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for mobility, orientation tools for blindness, etc.) or create a personal avatar that is entirely different from their physical self. BreakThru has constructed a virtual environment in Second Life that exemplifies the best of accessible and universal design, with special care taken to accommodate assistive technologies and non-standard browsers. The Mentoring Islands are the primary meeting space for mentoring and teaching, social networking, academic support, transition assistance, and research participation for the initiative, but the project makes extensive use of common social networking tools (SMS, Skype, audio calls, etc.) to supplement the virtual interaction. BreakThru teachers and faculty can also virtually access custom training modules on universal design and evidence-based teaching strategies for their classrooms and labs.

The project serves as a pipeline between secondary and postsecondary institutions to strengthen students with disabilities' capacities to access and succeed in STEM programs across critical junctures: high school | two-year college | four-year college | graduate school. The overall project goals are to increase the retention of students with disabilities who are enrolled in STEM classes and majors and the number of students participating in BreakThru mentoring activities.

Ongoing efforts are focused on Georgia pipeline schools and students with disabilities, but outreach and dissemination efforts can potentially extend beyond to all students who need assistance in STEM, with or without disabilities. BreakThru has been created to provide broad impact through its applicability to students and faculty who are separated geographically and through its potential to gather a national/international network of STEM stakeholders. The digital media model is scalable to secondary and postsecondary institutions broadly. Its foci on universal design for learning and inclusion of accessible materials are aimed at assisting all students in need.

The United States National Science Foundation and National Science board have recognized the need for a larger and more diverse STEM workforce [1–4]. To date, various minority groups, chief among them students with disabilities, have not been properly included in attempts to promote a more successful STEM workforce. The GSAA BreakThru project, in cooperation with colleagues from related NSF efforts, seeks to address that imbalance.

2 Need for Increased Participation in STEM

The National Science Foundation's (NSF) Research in Disabilities Education (RDE) program has sponsored research and development projects to broaden participation and increase achievement of people with disabilities in STEM education and the STEM workforce. At the heart of these efforts has been RDE's "Alliances for Stu-dents with Disabilities in STEM" (Alliances) project track. Intended to serve a specific geographic region, Alliances involve multiple institutions of higher education and secondary school systems working as a team "to employ evidenced-based practices and promising interventions to advance students across critical academic junctures, to degree completion, and into the workforce or graduate STEM degree programs." Taken together, Alliances create a unified program of change extending beyond academia to include industry and government research experiences for students with disabilities.

In addition, Alliances typically go beyond matters of STEM content knowledge to focus on underlying issues affecting the differential learning, participation, retention and graduation rates of postsecondary students with disabilities in STEM.

Considerable attention has been given to the need for educating a diverse workforce in STEM in the U.S. National Science Foundation reports [1–4] stress the critical importance of strengthening efforts to recruit and retain students chronically under-represented in STEM fields. Government and educational entities consistently emphasize broad participation and inclusion as critical factors in achieving excellence in STEM fields [5]. Individuals with disabilities are among the most marginalized of these groups [6] and face significant obstacles and barriers to accessing higher education STEM programs [2, 4, 7].

As one of the RDE's Alliance projects, the GSAA BreakThru initiative has focused on researching the use of online, especially virtual, mentoring, to retain students in STEM education and in mentoring programs. In particular, the GSAA has sought to investigate the uses of online mentoring to assist students in persistence in degrees and across critical educational junctures. The GSAA BreakThru project has also been designed as a scalable model to be replicated by other institutions to broaden participation and increase retention for secondary and post-secondary students in a variety of setting and conditions.

3 BreakThru Focus on Virtual Tools

Virtual worlds, or simulated 2-D and 3-D online environments (e.g. Second Life), have become an increasingly common software platform for education and training applications during the last decade [8–15]. They hold the promise of opening new horizons for students and educators, but can also present unexpected barriers to access, especially for students who have disabilities [16–19]. For purposes of this discussion, "virtual world" is defined as "a synchronous, persistent network of people, represented as avatars, facilitated by networked computers [20]. The GSAA BreakThru virtual Mentoring Islands have used the platform of Second Life, with appropriate instructions, modifications and use of third-party tools, where necessary, to maximize accessibility. Applying the definition of online accessibility from the World Wide Web (W3C) Web Accessibility Initiative [21] "accessibility" refers to the degree to which **people with disabilities can use the virtual world**. More specifically, accessibility means that people with disabilities can perceive, understand, navigate, and interact with the virtual world, and that they can contribute to it. "Disability" in this context can be defined as any functional limitation (physical, sensory, cognitive) that impedes a student's ability to fully engage in the educational process, as compared to similar-age norms.

Given issues of complexity, accessibility and adoption, it would be fair to question the uses of virtual worlds in educational settings. However, one common assumption about the educational uses of virtual worlds is that *immersion,* or "the subjective impression that one is participating in a comprehensive, realistic experience" [22] can enhance the learning experience. Researchers have also observed that virtual worlds offer possibilities for experiential learning; an approach that encourages students to engage in problem solving activities within a flexible environment that facilitates collaborative and constructivist learning [9]. Educators have also been drawn to the potential that virtual worlds offer for distance learning, social interaction, and learner engagement [8]. In these applications, the presence of avatars can enhance "engagement and learning beyond computer-mediated communication without such agents" [23]. Researchers have also noted the capacity of virtual worlds to facilitate experiential learning [24] via simulations, role-playing, and group work. Outputs like user created content are also of particular interest. In many virtual world environments, such as Second Life, the students themselves become the creators of content, and mediate their own interaction and learning [23]. Instructors and researchers continue to explore the potential of virtual worlds to enhance education on many levels.

While these affordances can contribute to the effectiveness of virtual mentoring and support systems in education, it must be noted that researchers have also discussed disenchantment with the limitations and complexities of using virtual world environments [10]. Concerns that must be addressed include a reluctance to accept virtual environments as an effective educational tool [9, 25], potential technical and information technology issues [9, 25], privacy and distraction issues, intellectual property and legal issues, and not least, concerns that virtual environments will not be accessible to all students with disabilities without considerable knowledge and effort by developers and instructors [9, 25].

All of these factors play a role in the implementation of BreakThru, since the project focuses on digitally mediated e-mentoring and STEM learning support. The Second Life Mentoring Islands provide the backbone of project intervention with students, with other digital tools (SMS, Skype, audio calls, etc.) used to supplement the virtual world interactions, as needed. Of particular concern has been the provision of full accessibility to students with a broad range of disability issues. BreakThru has emphasized the need for advance planning and development, use of Universal Design for Learning principles [27] in all project tools, and training for all users to address the specific access needs of each student, mentor and instructor.

4 Theory of Change

The GSAA BreakThru Theory of Change guides the project's efforts to improve student success in STEM. The Change model demonstrates the project's core efforts to recruit students into the program and deliver e-mentoring and STEM learning/support activities that lead to changes in students' internal characteristics pertinent to STEM. These changes are intended to increase the students' intention to persist in STEM and increase participation in relevant activities. Finally, the model posits program effects and concrete steps taken by students to persist in STEM that lead to actual persistence and completion of undergraduate and graduate degree programs (see Fig. 1, below).

As expressed in the Figure, BreakThru relies upon multiple points of information to assess progress toward goals, including survey instruments, evaluation constructs, and enrollment and graduation records.

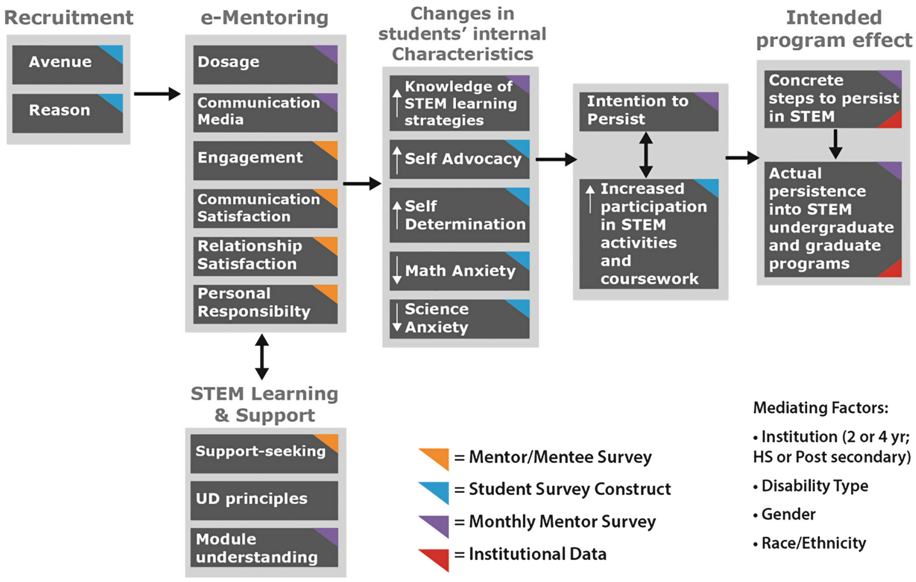

Fig. 1. Theory of change for GSAA BreakThru, with data input sources and core measures for determining efficacy of project activities and progress toward objectives. Color tabs indicate instruments and data sources for each measure.

5 Project Goals

The GSAA BreakThru program seeks to put students with disabilities on the path to post-secondary STEM education that otherwise would not have entered or persisted in STEM education programs. It serves three cohorts of students over a five year period from 2010 to 2015: 105 unduplicated high school students; 65 unduplicated 2-year students; and 55 unduplicated 4-year students. Its primary goals include:

1. **Retain Students in Virtual Mentoring and STEM Majors**: Retain high school, 2-year, and 4-year students with disabilities participating in the GSAA Virtual Mentoring Program at a year-to-year persistence rate of at least 50 %.
2. **Enroll to Virtual Mentoring:**

   – Enroll (assign to a mentor) 105 unduplicated high school students with disabilities to the GSAA STEM Virtual Mentoring Program by the end of the project award period.
   – Enroll (assign to a mentor) 65 unduplicated two-year students with disabilities to the GSAA STEM Virtual Mentoring Program in STEM majors at one 2-year college partner institution (Georgia Perimeter College) by the end of the project award period.
   – Enroll (assign to a mentor) 55 unduplicated four-year students with disabilities to the GSAA STEM Virtual Mentoring Program in STEM majors at two alliance universities (UGA and GT) by the end of the project award period.

An overview of the results of **Goal 1: Retain Students in Virtual Mentoring and STEM Majors** for 2011–2014 for all three cadres of students follows (Figs. 2, 3, 4 and 5):

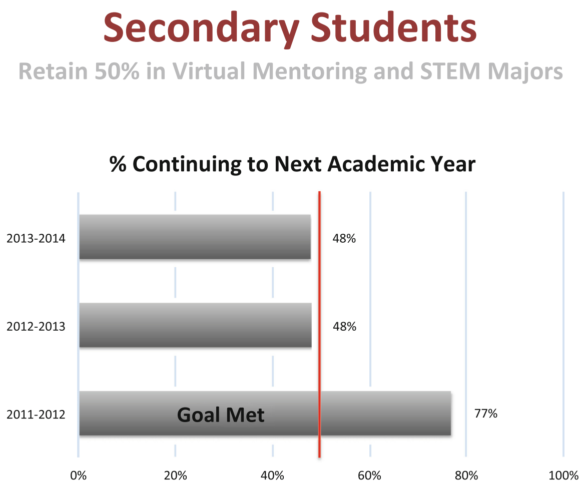

Fig. 2. Retention of Secondary Students

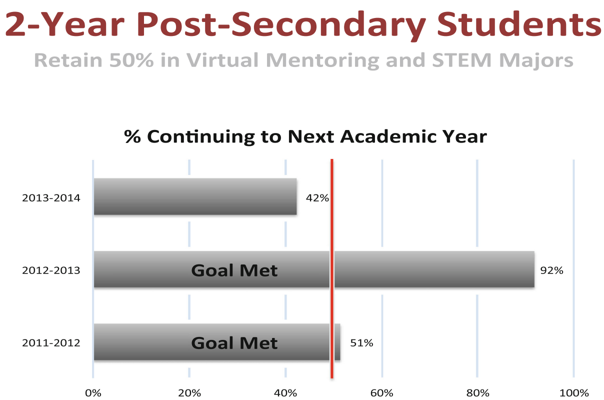

Fig. 3. Retention of 2-Year Post-Secondary Students

Retention results varied by academic year and by student cadre. In each year, the target was exceeded in one or two of the cadres, with other student cadres close to goal percentages.

The results of **Goal 2: Enroll to Virtual Mentoring**, are summarized in the figure following (Fig. 6):

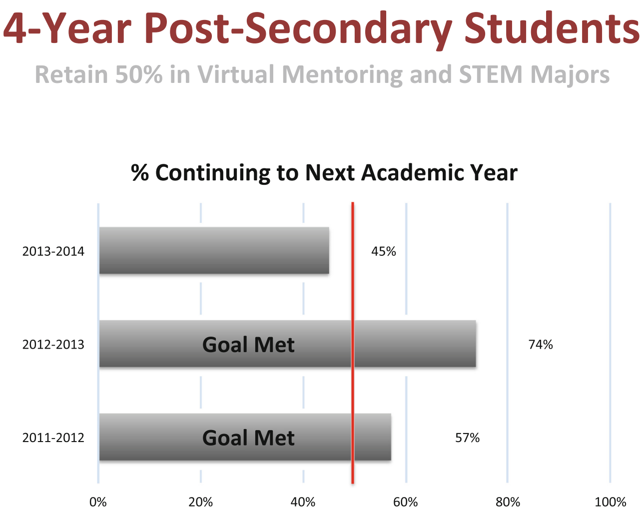

Fig. 4. Retention of 4-Year Post-Secondary Students

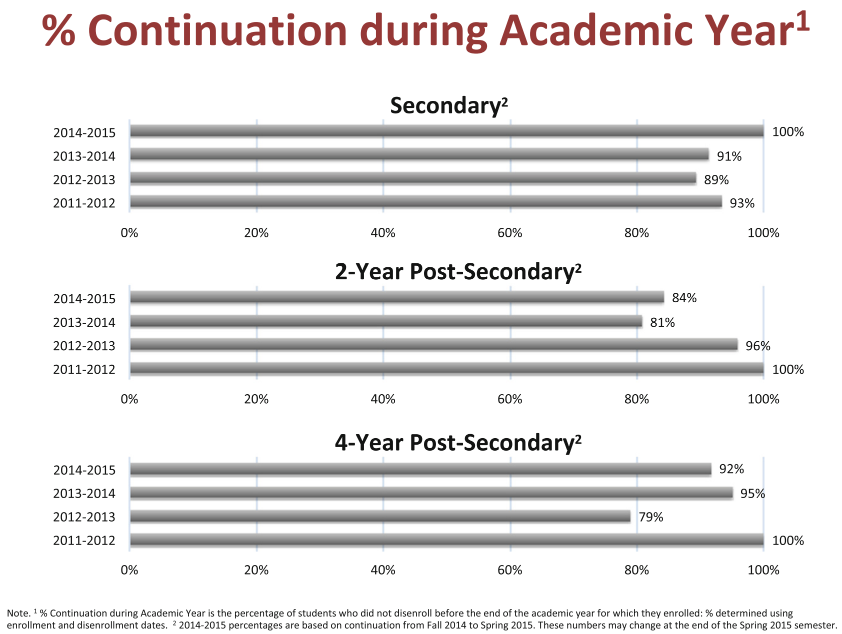

Fig. 5. Summary of Retention/Continuation Data

In academic years 2011–2014, targets for Goal 2, as measured by number of students enrolled, were not met, but in each student cadre approached the goal by 78 % to 87 %.

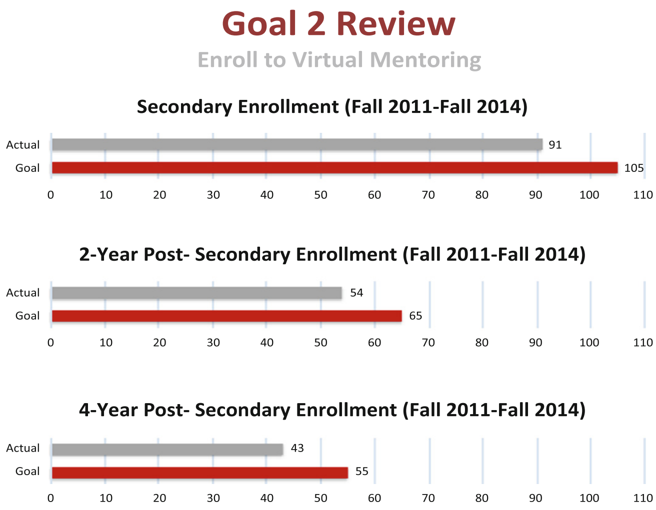

Fig. 6. Goal 2 - Enroll to Virtual Mentoring

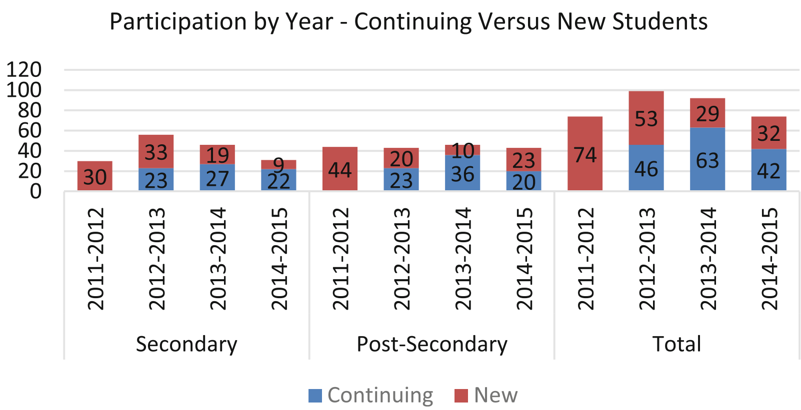

Fig. 7. Continuing Versus New Students

As noted in Goal 2, it is important for project staff to distinguish between students continuing in the program and those newly enrolled in each year. The following figure summarizes that information (Fig. 7):

6 Students by Disability Type

The GSAA BreakThru initiative welcomes students of all abilities. The following chart summarizes the distribution of students by disability type. Note that students with learning disabilities comprise a high percentage of the total enrolled, but this reflects, to a large extent, the percentage of students with disabilities as a whole across institutions (Fig. 8).

		2011-2012		2012-2013		2013-2014		2014-2015		Total (across all years)	
		n	%	n	%	n	%	n	%	n	%
Secondary	LD	14	47%	30	54%	23	50%	18	58%	54	59%
	ADD/ADHD	8	27%	8	14%	8	17%	5	16%	15	17%
	ASD	4	13%	10	18%	9	20%	4	13%	12	13%
	HEALTH	1	3%	1	2%	1	2%	0	0%	1	1%
	EBD	1	3%	3	5%	2	4%	2	6%	4	4%
	VI	0	0%	1	2%	2	4%	1	3%	2	2%
	MOBILITY	1	3%	1	2%	0	0%	0	0%	1	1%
	SPEECH	1	3%	2	4%	1	2%	1	3%	2	2%
	Total	30	100%	56	100%	46	100%	31	100%	91	100%
Post-secondary	LD	12	27%	14	33%	13	28%	13	30%	25	26%
	ADD/ADHD	8	18%	10	23%	9	20%	11	26%	26	27%
	ASD	1	2%	1	2%	1	2%	2	5%	4	4%
	HEALTH	5	11%	4	9%	5	11%	4	9%	8	8%
	PSYCH	10	23%	6	14%	10	22%	7	16%	20	21%
	HEARING	2	5%	3	7%	2	4%	1	2%	3	3%
	VI	2	5%	2	5%	3	7%	3	7%	5	5%
	MOBILITY	2	5%	1	2%	1	2%	1	2%	3	3%
	DIS	0	0%	1	2%	1	2%	1	2%	1	1%
	NONE	2	5%	1	2%	1	2%	0	0%	2	2%
	Total	44	100%	43	100%	46	100%	43	100%	97	100%

Fig. 8. Students by Disability Type

7 Discussion

This paper can only provide a broad outline of the GSAA BreakThru activities and results. Examination of the literature to date has strongly indicated a need for more data to determine the place of virtual worlds and related e-mentoring tools in the education of students with disabilities in STEM fields. While most institutes of higher education and government agencies in the United States agree that broader participation in STEM fields is a desirable goal, consensus of opinion on the efficacy of virtual world platforms to address this goal will remain unattainable until sufficient data has been evaluated. In its efforts to provide a scalable model for virtual e-mentoring, its focus on Universal Design for Learning principles, accessibility for all students and enrollment of students with diverse abilities, the GSAA BreakThru project seeks to provide data to move researchers closer to answering these questions.

8 Conclusions

The GSAA BreakThru data from 2011-2014 indicate trends of interest to the field at large. Points of note include:

– Creation and implementation of a scalable model and theory of change to guide the replication of the project across institutions internationally.
– Potential viability of a virtual e-mentoring program through data that indicate a high percentage of "continuing" students across academic years as well as relatively high retention rates of students with disabilities in STEM programs.
– The ability of a virtual world environment to accommodate students with a wide range of disabilities through careful development and education.

While GSAA BreakThru data contribute to the overall field of knowledge, it must be admitted that the project results to date raise many questions. For example: Precisely why do some students continue with the project across academic years while others do not? Are the low rates of participation of students with visual disabilities simply a reflection of institution demographics, or do these students "opt out" for specific reasons? While retention of students in STEM programs may appear to be relatively high, does this reflect on completion of educational programs and entry into STEM-related careers?

Data from the current academic year will contribute to the knowledge base, but it must be state that the GSAA BreakThru project will provide perhaps its most important information when it is applied to create and scale a program in replication.

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