BEAT: Branding and Entrepreneurship of Assistive Technology for Social Good

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***Abstract* - This paper describes the opportunities and challenges found in incorporating both branding and entrepreneurship components into an engineering senior design course (Capstone course). This newly upgraded course is called BEAT: Branding and Entrepreneurship of Assistive Technology. The original joint senior design course on assistive technology has been run for over ten years, serving undergraduate seniors in computer science, computer engineering and electrical engineering at CCNY, working on assistive technology projects to help people in need. The class had informally included entrepreneurial components in the past, but from 2019 on, we formally integrated both branding and entrepreneurship components into the curriculum. This paper describes the motivation of the work, the four key components in the course syllabus, a number of student evaluation mechanisms, course outcomes so far and results of a student survey, and some final discussions of the opportunities we provide to our students and challenges we face in implementing this cross-disciplinary curriculum.**

Index Terms – assistive technology; cross-disciplinary projects; student entrepreneurship; team-based senior design; branding, logo designs

INTRODUCTION

In the past ten years (2010-2021), we have been developing and running a cross-department joint senior design course (Capstone course) for undergraduate seniors majoring in Computer Science (CS), Computer Engineering (CpE) and Electrical Engineering (EE) in the Grove School of Engineering (GSOE) at the City College of New York (CCNY). The program aims to enable students in developing assistive technologies for smart living of all, especially for those who have challenges and/or disabilities. We mainly focus on developing assistive solutions for people with are blind and visually impaired (BVI), and with Autism Spectrum Disorder (ASD), which align with our sponsored research, but the student teams also have the freedom to choose projects assisting people of other groups, such as seniors, people with Alzheimer's, people with hearing or mobility disabilities, OCD, Down syndrome, learning processing deficits, etc. In the past we have informally included entrepreneurial components in the class, which has led to a number of entrepreneurship awards in the college and national levels, such as the first CCNY Kaylie award, a few Zahn Competition awards and a VentureWell grant [1]. To further improve real-world relevance and community engagement, we have had collaborations with the Lighthouse Guild [2], NYS Industries for Disabilities (NYSID) [3] and Goodwill Industries in Greater New York and Northern New Jersey [4] via the NYSID's CREATE (Cultivating Resources for Employment with Assistive Technology) program [5].

In each year, the joint senior design course is a mandatory two-semester sequence for undergraduate seniors in both CS and EE departments. In the first semester, we offer technical lectures on basic technologies in sensors, actuators, robotic navigation, vision algorithms, and assistive technologies. Under the guidance of the faculty mentors and collaborators in selected fields, undergrad seniors form teams to survey the state-of-the-art technologies in several challenging areas (i.e., multimodal sensing approaches, assistive technologies, and mobile apps), conduct marketing analysis, and write project proposals which include design ideas, a reasonable budget, a management plan with milestones, and a business plan. In the second semester, the student teams are expected to implement design ideas, prototype, test, and evaluate different designs, and produce final design prototypes. Students also have the opportunity to perform usability studies with real users, for example with visually impaired users in collaboration with Lighthouse Guild and people with Autism Spectrum Disorder (ASD) in collaborating with Goodwill, therefore better understanding their needs to improve the designs and to create more appropriate business plans. Prominent teams with innovative ideas/technologies and solid business plans are recommended to compete for CCNY's Zahn Innovation Center Entrepreneurship Competitions [6], NYSID CREATE Awards [5] and VentureWell E-TEAM Competition [7].

Based on our experience from 2010-2018, students do not have the necessary skills in communicating with the users, investors, stakeholders and community partners to really make their breakthrough work actionable. Additionally, they lack a more holistic set of entrepreneurship skills that will help them turn their brilliant ideas into reality. Therefore, entering the ninth year of the senior design program, inspired by the Campus Engagement Network (CEN) at CCNY and supported by a course innovation grant [8, 9], we tapped into CCNY's resources (CCNY's M.P.S. in Branding + Integrated Communications, known as BIC, and the Zahn Innovation Center) to teach them the useful and practical branding, storytelling and

entrepreneurship skills they need. The proposed program Branding and Entrepreneurship of Assistive Technology (BEAT) is a collaboration between GSOE, BIC and The Zahn Center. The branding component is closely integrated with the assistive technology and the entrepreneurial components [10]. The common theme for all the four entities (Branding, Entrepreneurship, Assistive Applications, and Technology Innovation) is the pursuit of social good, through helping people with disabilities.

RELATED WORK

Team-based design courses focused on products for people with disabilities have become relatively common [11, 12, 13, 14, 15], in part because of training grants such as the NSF Research to Aid Persons with Disabilities course grants [16]. A study has been conducted [14] to generate best practices for assistive technology product development courses and how to use these courses to teach students the fundamentals of innovation. A comprehensive list of recommendations is comprised, which includes: identifying a client through a reliable partner [12]; allowing for transparency between the instructors, the clients, and the students; establishing multi-disciplinary teams [13]; using a process-oriented vs. solution-oriented product development model [17]; using a project management software to facilitate and archive communication and outputs; facilitating client interaction through frequent communication; seeking to develop professional role confidence to inspire students' commitment to engineering and (where applicable) rehabilitation field; publishing student designs on repositories; incorporating both formal and informal education opportunities related to design; and encouraging students to submit their designs to local or national entrepreneurship competitions.

Given that Capstone design courses are applied and experiential by nature, they provide an optimal context for integrating entrepreneurship into engineering education. To better understand how and to what degree entrepreneurial elements are integrated into Capstone design classes, 225 Capstone design faculty were surveyed in [18] with an instrument designed using the entrepreneurial Capstone practices described in [19]. The quantitative data illustrate the extent to which faculty incorporate different entrepreneurial practices in their Capstone design courses and how important faculty believe it is to increase different entrepreneurial practices in Capstone design. The qualitative survey data provide additional insight about how faculty incorporates different entrepreneurial practices in their Capstone design courses and the challenges (perceived and actual) to implementing entrepreneurially focused Capstones. However, integrating branding, entrepreneurship and assistive technology is something new in the field.

BEAT COMPONENTS

The BEAT Capstone design course has the following four critical components: Branding, Entrepreneurship, Assistive Applications, and Technology Innovation (B.E.A.T.). They will be briefly discussed below in a backward fashion, from the cores (T.) to the needs (A.) to the means (E.) and finally to the faces (B.) of the program.

I. Technology Innovation

Technology innovation is the core of the course for our CS, CpE and EE students. Based on the expertise of the two founding faculty mentors in robotics and perception [1], we mainly focus on assistive technologies that use mobility and sensing techniques. The projects include: sensor designs, computer vision algorithms, mobile app designs, web service development, assistive apps, game designs, and mobility assistance device designs. For giving students a more concrete idea of what they are expected to learn and to produce, we give highlights of past projects, usually using one slide per project for some exemplar projects, in addition to lectures on robotics, vision and assistive technology.

II. Assistive Applications

To ensure students have a better understanding of users' needs and application requirements, we leverage our resources in the greater NYC area with community engagement. The nature of our community partnership is through collaboration in assistive technology with complementary objectives - CCNY for training our students to work on projects for social good and partners for identifying technologies for serving their customers with disabilities. The engagement of our community partners is through: (1) site visits to our partnership institutions in order to understand the needs of users, and (2) community professionals' visits to our classes for educating our students and providing feedback to our projects. Our two major focused groups are people with visual impairment and people with ASD. For both groups, we leverage our collaboration with Lighthouse Guild, Goodwill and Rutgers through our NSF-sponsored research projects on building assistive navigation for BVI and ASD people [20]. For the latter, we also leverage the support from NYSID via its CREATE program [5], with Goodwill as our industrial partner. Every year we work together for the CREATE awards (up to four each year, $1000 for each team of students), as well as the final CREATE competitions with from $5K to $15K cash awards. In addition, the senior design course is open to any innovative ideas of assistive technologies for any groups of people with special needs.

III. Entrepreneurship Experience

For enhancing the entrepreneurship experience, we align our two-semester course syllabus with the Zahn Center [6] schedule. The Zahn Center staff also gives lectures to our students on entrepreneurial practices at Zahn Innovation Center, including using a Business Model Canvas with nine business model building blocks [21] and encouraging them to participate in Zahn Competitions and other state and national-wide competitions. Students from GSOE will form project teams, each consisting of about three to four students from CS, CpE, and EE. We have about 24 senior design

students each year in our BEAT senior design program, so roughly we have 6-8 teams.

IV. Branding and Logo Designs

Within the framework of the BEAT program, BIC's faculty and students help educate and assist our senior design students in the BEAT senior design course in GSOE in gaining an appreciation of the importance of branding and storytelling. These include: the branded naming of each project, the communication media channels to be used (such as video), the audience-specific storytelling used in communicating with different groups of community partners, and the presentations for competitions, exhibitions, conferences and other venues.

In summary, the expected outcomes/deliverables at the completion of the BEAT course include: (1) Branding: Senior students projects (6-8, with about 24 students) that are more relevant to the needs of users through the branding of their project materials, including project naming, posters, videos and reports. (2) Entrepreneurship: More competitive presentations at the Zahn Center competitions, the state-wide NYSID CREATE competitions, as well as the nation-wide VentureWell competitions, hopefully leading to prizes of these competitions. (3) Assistive Applications: Graduates from our CS/CpE/EE programs and BIC program who have more awareness for social good. (4) Technology Innovation: Students can explore the full potential of what they have learned from their past classes, and meanwhile are motivated to learn new technologies by doing for real applications.

BEAT COURSE SYLLABUS

Here we use the real course syllabus in the inaugural year of the BEAT Capstone program (Fall 2019 - Spring 2020) [22] as an example. The yearlong course included the fall semester for project proposal with 14 weekly meetings and the spring semester for project development with 7 biweekly meetings. The mechanisms include seminars/tutorials, student presentations, wiki logs, external evaluations, and the online class meets. The syllabus integrates entrepreneurial seminars [23, 24], branding tutorials and practices on communication skills such as the ABT formula (details see Table III) [25], community engagement for assistive applications, and the technology lectures, exploration and implementation. When classes were on site, we also offered networking activities such as work lunch and site visits, thanks to the CEN course grant [9]. Both fall and spring class schedules were aligned with the Zahn schedule [6] considering CREATE/VentureWell timelines. In the spring semester, the suggested numbers of interviews to users/partners were for teams that were accepted in the Zahn Center Competition, but CREATE and VentureWell teams could use them as references. After the first class, students met biweekly to update what each team had done in the past two weeks (the other weeks will be used as individual meetings for teams by appointments), but each team still needed to update their wiki logs weekly. We also planned to have BIC students provide monthly feedback (via meetings or postings) to CS/CpE/EE teams for developing their video, demos and materials for the Zahn/CREATE/VentureWell presentations. In both semesters, invited community partners from Goodwill and other institutions, BIC faculty and Zahn Center staff came in class (or joined our Zoom meetings) to act as judges for project presentations; we had two such class meets each semester. Due to the COVID-19 pandemic, CCNY entered distance learning in the middle of March. But since most of the materials and course activities were already online or could be changed to online mode, there was not much disruption except on-site user evaluations and site visits.

COURSE EVALUATION MECHANISMS

The major evaluations of the student teams include: a pre-proposal evaluation using a quad chart modified from the CREATE program requirement with entrepreneurial emphasis, a BIC log design brief worksheet, two rounds of proposal evaluations (Fall), and finally midterm and final project evaluations (in Spring). Each week, student teams update their wiki pages, which can be viewed by all teams as well as commented by instructors and industrial mentors.

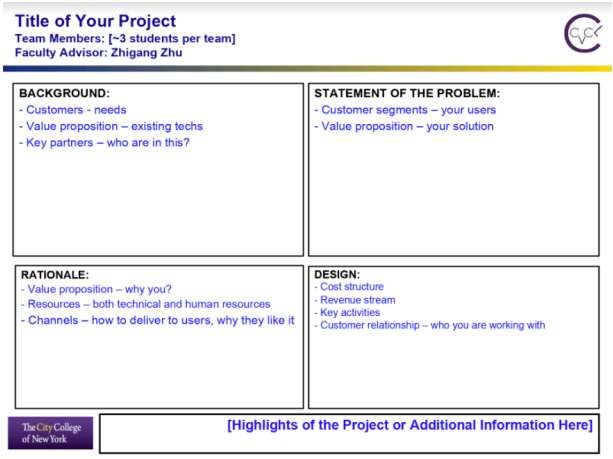


FIGURE I

Quad chart with nine-blocks from business model canvas

I. Quad Chart Evaluation with Entrepreneurial Focus

The pre-proposals of student teams are evaluated by integrating the requirements of CREATE program of NYSID with a quad chart (Background, Problem Statement, Rationale and Design) and the entrepreneurial practices at Zahn Innovation Center using a Business Model Canvas with the nine building blocks [21] (Figure I). Our student teams selected to the CREATE program (each team with a $1000 budget) are involved in the hands-on projects in their collaboration with a NYSID not-for-profit rehabilitation center that is the site of employment for workers with disabilities (in our case Goodwill NYNJ). Together, each student team and the rehabilitation center identify a project that can improve the rate and efficiency of a worker's productivity, with a goal to create more jobs for individuals with disabilities. CREATE also brings awareness to a

younger population on the employment challenges that are faced by this deserving cross-section of NY state's workforce. Each year we can have up to 4 teams participating CREATE, but all the teams are required to submit applications to the CCNY Entrepreneurial Competitions.

II. BIC Logo Design Brief Worksheet

The branding and logo design component of the BEAT program aims to improve the present ability of the engineering projects of our CS/CpE/EE students to engage different audiences - partners, users and funding agencies, especially in the context of entrepreneurial competition. After a branding seminar, each student team is asked to work on a two-part logo design brief worksheet: Brand Analysis and Executional Considerations (Tables I and II).

TABLE I
LOGO DESIGN BRIEF WORKSHEET: BRAND ANALYSIS

1	What does your company do? (This is your Value Proposition)
2	What BHAG (Big Hairy Audacious Goal) is your startup seeking to achieve?
3	Who are you catering to? (Think of the REAL audience. You might, i.e., be selling a service for kids, but the real decision makers would be mom and dad).
4	What are you offering them (those you're catering to) that they will definitely benefit from?
5	If your startup were a person, who would it be? A serious scientist? Gandhi? Lady Gaga? Han Solo? James Bond? Ren? Conjure up the most representative character and write it down. Then define their tone of voice (i.e., formal, casual but respectful, youthful, classic, bold, funny yet compassionate) and indicate it, too.
6	In one sentence, what do you want your clients to think about you? (don't make it sound like marketing talk; say it like you'd tell it to a friend, "you gotta check out this stuff because….").

TABLE II
LOGO DESIGN BRIEF WORKSHEET: EXECUTIONAL CONSIDERATIONS

A	Pick three existing logos that you love (from any type of company) that evoke the same vibe and share the same look and feel you envision for your startup's visual identity. In one sentence, please describe why you love them.
B	Pick three existing logos (from any type of company) that have nothing to do with how you envision your startup's visual identity. In one sentence, please describe why they wouldn't work for you.
C	Pick three existing logos from competitive companies that do what you do (competitors), to make sure you don't look just like them. If, however, there's an aspect of those logos you'd like to emulate, clearly state so.
D	Are there any mandatory elements that you absolutely need, or that you do not want as part of your logo? Is this non-negotiable?

III. BEAT Proposal Evaluation

The following is the actual Capstone Proposal Presentation Suggestions (and Grading Rubrics) to our student teams, which reflect the integration of four components of the BEAT program. Even though not all the teams will get into CREATE or Zahn, all of the teams are required to address all the four aspects of the BEAT program as an all-around training. While some teams will be formally involved in either or both, some other teams which are more research oriented are encouraged to publish papers in conferences or journals. Tables III and IV are the suggestions to align students' team proposals (& quad charts) with the ABT formula [25], with considerations of B.E.A.T., for both the written reports and oral presentations.

TABLE III
PROPOSAL WRITING SUGGESTIONS AND GRADING RUBRICS

Background	Talk about the needs, existing technologies and solutions (the "And" part). [10 pts]
Problem Statement	What is the pain point and problem you have identified, and what you propose to do to address the problem (the "But" part). [10 pts]
Rationale	Why do you think your solution will solve the problems, in terms of technical readiness, users acceptance, business model (cost & market), etc. (Why question of "Therefore" part). [10 pts]
Design	How you are going to do it, including technical tools, user studies, partnership, evaluation (the How question of the "Therefore" part).[10 pts]
Schedule	Timeline from now to the end of Spring 2021. [10 pts]
Summary	Simplify your quad chart as a slide, with bullet points in each quad. [10 pts]

TABLE IV
PROPOSAL PRESENTATION SUGGESTIONS AND GRADING RUBRICS

Branding	Including a logo, the use of colors and fonts in your presentation, and your overall communication effectiveness with the audience [10 pts]
Entrepre-neurship	The business canvas we put in the quad chart, like customers, cost, revenue, partners and value proposition [10 pts]
Assistive Applications	The needs, the problems, the societal and economical importance [10 pts]
Technology Soundness	Your solutions in terms of concrete, solid technical means, including platforms, tools, systems you will develop your project on [10 pts]

IV. BEAT Final Project Evaluation

The BEAT Capstone Project Final Project Report and Presentation requirements were tailored from the NYSID CREATE final reporting requirements, but with some more highlights on our four unique features: branding, entrepreneurship, assistive application, and technology innovation.

Final Report should be a discussion of the work completed on the assistive technology aid, device or rehabilitation technology service that the student teams produced. The suggested order of headings: Background, Statement of the Problem, Rationale of Solutions, Design and Development of Systems, Evaluation with Users and Partners, Discussion of Potential Markets and Future Work, Branding (the evolution of the names, logos and topics of the team project), References Cited, and Acknowledgements (to Instructors, Partners, and Others).

Videos should be 3-6 minutes in length and include a demonstration of the device. Student teams should consider their branding and entrepreneurship aspects as much as possible, including logos, names, user studies, and potential markets etc. Videos must be uploaded to YouTube as private, and the link provided in their wiki page. The link to the video should also be referenced in the report in a separate document.

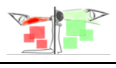
Prototype must be a working prototype, exemplifying high quality, accuracy, functionality and safety, tested and evaluated on productivity, and if for CREATE, delivered to the NYSID member agency at the end of the school year.

Presentation must consider all the four aspects of the BEAT features as detailed in the grading rubrics in Table V.

TABLE V
MID-TERM AND FINAL PROJECT EVALUATION - GRADING RUBRICS

A. Characterizing the need (**Assistive Applications**)	Did the team clearly define the problem? Do they understand the problem they are trying to solve—who would use the design? Did they consider "real life" use scenarios?
B. Coordination with communities and users (**Entrepreneurship**)	Did the team communicate well with the people who may benefit from their invention and the communities serving those people? Did the team understand the market and users?
C. Ease of use and acceptance (**Branding**)	Is the invention intuitive for their users? If instructions are required, are they easy to understand? Are the name and logo of the invention inviting and fitting?
D. Design solution (**Technology Innovation**)	How useful is the invention to the community and users and to the people they serve? Does the invention do what it is supposed to do? Does the technology sound and cutting edge?

TABLE VI
2019-2020 PROJECT TEAMS, NAME AND LOGO DESIGNS, AND OUTCOMES

Final Designs	Initial Designs	Project Topics	Outcomes
Undaunted 	SE.VR: 	Virtual Reality application for people with ASD to deal with stress in workplace	CREATE
ParaShop 	ASPAR: 	Assistive Shopping Application for ASD with AR and AI	MIT & CSUN papers
Share&Care 	Share&Care: 	Family Communication Platform with senior friendly interfaces	MIT & CSUN papers
VPP 	VPP 	Voice Powered Platformer for people with physical disabilities	Zahn
Worktual Reality 	VRRB: 	Virtual Reality application to target social difficulties with ASD in conversation and communication	CREATE
BERA 	Bera 	A Practical Employment Analyst for people with ASD	CREATE, Zahn
Goodplan 	IAPR 	Interactive Activity Planning and Recommendation for individuals with ASD	Goodwill supported and deployed
GazeIntoView 	GazeIntoView 	Training Eye Contact in Interviews (including people with ASD)	Zahn

COURSE OUTCOMES AND STUDENT SURVEY

I. Project Teams and Outcomes

In the 2019-2020 cohort, the first year of the BEAT Capstone program, we have 8 team projects of 23 students; YouTube videos of the projects can be found at [26]. Table VI lists the topics, name and logo designs and BEAT outcomes of the teams. The projects need students to use a wide range of knowledge and tools in mobile computing, cloud services, web development, human computer interaction, AI and machine learning. All teams (except one) went through a number of design cycles of their branding and logo designs (Table VI listed the first and last ones). At the end, student teams received 3 CREATE awards (for their employment apps in Assistive Applications), 1 Goodwill award (for their Assistive Applications), and 3 Zahn selections (for their entrepreneurial strengths). Two student teams published their results (for their Technology Innovations and/or Assistive Applications) at IEEE MIT Undergraduate Research Technology Conference (URTC) [27, 28] and their extended versions were developed into 2 CSUN Assistive Technology journal papers [29, 30]. An article in Harlem View reported the BEAT program and student projects [31].

TABLE VII
2019-2020 COHORT END OF THE COURSE SURVEY QUESTIONS

Course Organization:	
O1	One class meet per week is adequate in the first semester.
O2	One class meet every other week (i.e., biweekly class meet) is adequate in the second semester.
O3	Maintaining a wiki page for your team and keeping weekly logs are very useful for communications between team members and with the instructors, and keeping track of progress of the project.
O4	Two external evaluations per semester are very helpful for your team to get feedback from a diverse body of external experts to improve project.
O5	Online class meets are actually better than on-site class meets.
Branding:	
B1	The branding component helps your team in project development, e.g., by making your proposed solution stand out.
B2	The branding component helps your team in communicating with users, partners and evaluators.
B3	The branding seminar on ABT (And...But...Therefore) and logo designs are helpful throughout the project.
Entrepreneurship:	
E1	The overall course schedule followed the Zahn Innovation Center timeline is adequate.
E2	The required Zahn Competition participation helps your team turn ideas into reality.
E3	The entrepreneurial seminar on logical gateways helps your team turn ideas into reality.
Assistive Application:	
A1	The site visits (to partner institutions or other agencies) and user interviews helps your team understand the problems
A2	Using the templates of CREATE program in proposal, reporting and YouTube video helps your team develop our assistive project (regardless whether your team get the CREATE award or not)
A3	You have learned the most through self-learning, e.g. by searching the internet for assistive applications.
Technology Solutions:	
T1	This capstone design section using learning by doing helps you learn important new tools and skills that you haven't learned from all the other courses.
T2	What you have learned from previous courses is very useful in your capstone project.
T3	The technical seminars on machine vision and human vision are useful for you to understand the use of related technologies to help people with challenges in cognition and perception.
Open-end Question.	
C1	Any comments and suggestions?

II. End of the Course Survey

At the end of Spring 2020, we did an online survey to all the students who attended the final presentation (23 in total). Table VII lists the questions, including 17 Likert-scale questions (Scales 1-5, from strongly disagree to strongly agree): 5 for course organization, 3 for each of the 4 aspects of B.E.A.T, and 1 open question for comments and suggestions. Table VIII and Table IX reported the statistical results (with numbers of students for each of the 5 scales, and then mean scales for each question), and the comments and suggestions for some of the students.

TABLE VIII

STATISTICS OF THE 17 LIKERT-SCALE QUESTIONS (1-5, FROM STRONGLY DISAGREE TO STRONGLY AGREE) IN TABLE VII

	O1	**O2**	**O3**	**O4**	**O5**	**B1**	**B2**	**B3**	**E1**	**E2**	**E3**	**A1**	**A2**	**A3**	**T1**	**T2**	**T3**
1	2	1	0	0	0	0	0	0	0	0	0	0	1	0	2	2	1
2	0	0	2	2	1	5	3	3	2	4	4	2	2	1	1	1	4
3	0	0	3	4	10	8	8	9	7	10	9	2	3	4	1	6	6
4	1	1	3	7	5	5	8	8	8	6	6	3	8	7	6	7	4
5	20	21	15	10	7	5	4	3	6	3	4	16	9	11	13	7	8
M	*4.6*	*4.8*	*4.3*	*4.1*	*3.8*	*3.4*	*3.6*	*3.5*	*3.8*	*3.3*	*3.4*	*4.4*	*4.0*	*4.2*	*4.2*	*3.7*	*3.6*

CONCLUSIONS, DISCUSSIONS AND ONGOING WORK

I. Conclusions and Discussions

Here are some more "objective" conclusions from the outcomes of the 2019-2020 CREATE practice (Table VI).

1. All the student teams had clear awareness of their designs in names and logos through the logo design seminar and feedback from partners and users. Table VI listed the initial (2nd column) and final (1st column) of their names and logos. All teams except one had changed their logos, 4 teams even changed the names of their "products".

2. All the teams went through the entrepreneurial training in terms of market analysis, value proposition, user interviews, and system evaluation. At the end of the first semester, three out of eight teams were selected by the Zahn Center, which was the best outcome in the last ten years.

3. The students are benefited from our partnerships with Goodwill in reaching out users with ASD and other partners for other groups of users. The application selection preferences were further boosted up by the support of the CREATE program who advocate employment. Among the eight teams, 6 teams developed apps for people ASD, one for seniors and one for people with mobility impairment. Three teams were chosen by the CREATE program, and the Goodplan team was funded directly by Goodwill for their practical usefulness even though NYSID felt it was not directly employment related (thus not with a CREATE award).

4. The student teams went through a lot of emerging technologies, most of them learned by doing the projects, such as mobile app development, real-world web-based designs, AR/VR, game designs, computer vision, speech recognition and synthesis, machine learning, cloud computing, etc. Two teams published papers [27-30] for their technology innovation in assistive applications.

TABLE IX

COMMENTS & SUGGESTIONS FOR THE OPEN-END QUESTION IN TABLE VII

Great semester, thank you professor for the work you put in.
Professor Zhigang Zhu was very helpful to your team, as he always responded to our emails and helped to solve with us our problems. I am really glad that I took senior design class with him.
First semester felt too repetitive with us giving the same presentation(s) multiple times throughout the semester. Instead, it may have been helpful to spend that time on getting constructive feedback on the focus of the idea/proposal to let students create a more concrete plan for development.
Online meetings were great for the second semester. Saves time on commute. I'm not sure if listening to/watching every group's weekly updates was the best use of time. The first few weeks were good to allow us to get used to it and to help us gain inspiration. After the first few weeks, presentations felt too repetitive. Groups could have saved some time to meet up and discuss next week's plans, or work on the project instead.
Might be better to convince some judges not to be too picky. ABT part is good to have but I personally think we do not have to stress on it.
In my opinion, the mandatory participation in the competitions earlier in the first half (perhaps also the second had it not been for the current state of events) of the year made it more difficult to focus on our projects.
I think this class targeting assistive applications is a great idea. I'm also happy with learning a lot of new technical skills related to mobile application development and AR.
I believe the user interviews and feedback from most of the judges are very helpful to the design and development of the application. This process turned our application into the reality that helps others. It is necessary to know what users really need so I think it is helpful to have external experts. If all judges have a technical background or understand the application, then it would be great.
I think this class targeting assistive applications is a great idea. I'm also happy with learning a lot of new technical skills related to mobile application development and AR.
Overall experience is great! Would be better if there is more tech support.
I really like the degree of independence that we are given though, so thank you for that.
Overall, I really enjoyed this course. I appreciate that assistive technology is a big part of this course. Most of the academic projects I worked on in the past are solely to exercise the knowledge I gained in the course. There was not really a purpose for most of the work I have done in the past. This course takes a step further by implementing an assistive application that can make an impact in the real world. The most important thing I learned in this course is to seek those that are in need and try to help them with my skills. Secondly, I learned a lot about people with Autism Spectrum Disorder; not just by researching, but also by visiting Goodwill Center and talking to staff trainers and participants.
I would suggest making Entrepreneurship optional for the future. Perhaps, survey the class before the course begins and see how many students are interested in startups. ABT is a good format to deliver presentations. However, I found our presentations repetitive by constantly following that format.
It will be great if we have a mixed-major team, since the project is not only focused on technical solutions to the problem, but also consider the branding and entrepreneurship, which will be hard for the team will only technical majors to handle everything well. External support on the branding and entrepreneurship from other majors (perspective) will be extremely helpful if these are still the requirements. For example, if a student from the communication major that could spend certain times with each team a few times over the semester, could better help the team to organize the idea and receive more valuable feedback from the on-site visits.
I would have liked it if the course/project was more related to career goals as a Computer Science major, but unfortunately it became more about video games instead. Though I guess it was our fault since we chose this project, we just didn't know that it didn't really translate to career-relatable skills and we just needed a topic by a deadline. But I really like the degree of independence that we are given though, so thank you for that.

Based on the survey of opinions from the whole class of 23 students (Tables 9-11), somewhat more "subjective"

feedback has been observed (from 1 to 5, strongly disagree to strongly agree). The mean scores (M) for all the 17 categories are listed in the last row of Table VIII, with a minimum of 3.3 and maximum of 4.8 (3 is neutral). Some students provided valuable suggestions and comments; these are all listed in Table IX. Since the open question was optional, some students scaled their experience more positively didn't provide writing comments, but more positive comments can be found in [31], especially out of those teams of students who excelled in the class.

1. In terms of Class Organization, the majority (93.5%) of the students strongly agreed or agreed with the overall class schedules (O1 and O2), most (76%) of the students strongly agreed or agreed with the ways interactions and feedback were provided (O3 - wiki pages and O4 - external evaluators), and over half (52%) of the class actually preferred online class experience (O5, with non-commuting as a major reason). A few students did point out some concerns, e.g. they had to listen to other groups' updates repetitively. We meant to use this as a way for them to learn from each other, but it seems that there should be a good balance of small groups and whole-class meetings.

2. In terms of Branding, about half of the class (49%) either strongly agreed or agreed that the branding component helped in critical thinking (B3), design (B1) and communication (B2) . But since we asked our CS/CpE students to reach out to BIC students for help, and many of them didn't feel this was their major focus so they actually didn't do it. But we will run this for multiple years with improvement, e.g., to put students in communication in place to help them out, and make it clear that the ABT formula is just one way they formulate their presentation - even though they need to consider those elements instead of just proposing a solution or solve a problem as they have used to do in the past.

3. In terms of Entrepreneurship, most (91%) of the students were good with the Zahn schedule (E1), but again only 41% of the students appreciated the entrepreneurship components, strongly agree or agree with items (E2 and E3). This is also understandable since the E-component is more challenging, and we did realize most of our students were more technical focused so we were already pleased with the final survey feedback since there were quite some more concerns from the students in the beginning of the year. Indeed communication and entrepreneurship were two challenging areas for our students to have more opportunities for and awareness of. Some students didn't like the mandatory participation in the competitions therefore in the 2020-2021 cohort this will be optional in terms of their grading.

4. In terms of Assistive Applications, students overwhelmingly welcomed the assistive application focus, with above 78% of them strongly agreed or agreed with our mechanisms in understanding the needs of users (A1, A2 and A3). As a matter of fact, user analysis, need study and partnerships are a big part of both branding and entrepreneurship, but because applications are more tangible and easy to grasp than those two vehicles to make useful and successful products, students appreciated this more. Looking into the comments with regard to the integration of B.E.A.T., students obviously had stereotypes and fears about branding and entrepreneurship even though they appreciate the applications and technologies. This is actually one lesson we have learned to better engage our students on branding and entrepreneurship.

5. In terms of Technology Solutions, more than 65% of the students strongly agreed or agreed they learned new things by doing projects (T1), used what they learned in previous courses (T2), and got inspiration from very general materials about perception and cognition (T3). This was not a surprise since this was their comfort zone, even though a few students did bring up the requests to teach them how to do the work rather than just motivating them to find a solution or even find the problem by understanding the needs of users, as highly appreciated by some other students [31]. We don't expect all the students to appreciate this approach, especially those who are under-prepared, but we believe this is the way to go for a project-oriented class.

II. 2020-2021 Cohort: the Ongoing Work

We just finished the first semester of the second cohort of the BEAT program (2020-2021) with student teaming and project proposals [32]. Based on the feedback from our students as well collaborators, and considering the full year online class format, and the on-hold of the CREATE program for this year due to COVID-19, we have made or have seen the following major changes to the class:

1. The branding part is improved to have more interaction with the BIC instructor (Blumenkrantz) and we have planned to have BIC students in place to help our CS/CpE students for their branding and communication.

2. Participating in Zahn entrepreneurship competitions is not mandatory in terms of their grading even though students will still go through the basic training and submit an application as one of their assignments. This year's E-seminars by co-author Olives and her colleague Hudson were more interactive and students showed stronger interests and responses. Student teams will earn bonus points if invited to the Zahn implementation; two of the teams were invited.

3. Even though all the class meets are online, we have asked students to use every possible way to contact users of assistive technology. Due to the hold-on of the CREATE program which in the past focused us on employment for people with ASD and visual impairment, this year's user groups are much more diverse: from ASD to OCD, from Alzheimer's to DTD, from blind to color-blindness, from memory loss to Down syndrome. We have also started a new funding support model by attracting personal gifts to student teams; this year the PALM team obtained a personal gift of $1000 for their educational app design for children with Down syndrome.

4. While we still use wiki pages for weekly updates and hold weekly zoom meetings, including whole-class

meetings so that students can learn from each other's pitfalls, we have used more breakout rooms for individual team discussions and even for proposal evaluations. In this way, students and evaluators can use their time more flexibly.

At the end of the course in Spring 2021, we will carry out the same survey for a comparison with last year's survey. We also plan to do a longer-term study for carrying out this BEAT course for the next few years, as well as doing follow-on studies of our graduates.

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