

Visualization Education Through Social Impact: A Service-Learning Approach for Visualization Pedagogy

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ABSTRACT

Service-Learning is an experiential learning model in which classroom learning objectives are aligned with community service to meet both educational and community goals. In this paper we present a curriculum and methodology for the implementation of Service-Learning in visualization pedagogy. With the use of a novel modified adaptation of the design study methodology we present the results of a case study of the Service-Learning integration into a visualization curriculum through the course's final project requirement. In the course 26 undergraduates worked with 4 community partner organizations to produce 12 new interactive web-based visualizations displaying, for example, the social impact of the organization. This Service-Learning curriculum benefited the students through more effective learning of the visualization material and benefited the community through service to the non-profit organization.

1 INTRODUCTION

Data has become ubiquitous in our society, and the amount of data continues to grow at every level from personal data to corporate databases to large-scale computing. Non-profit community organizations are just one such case with their own collections of data relating to their organization as well as local municipality and community-growing. This data may contain insights into optimization of their operations, trends in current community support, and strategy for how to increase their community impact. However these non-profit organizations typically do not have the budget or resources to manage, analyze, or visualize their growing collection of data in order to discover these valuable insights. But what if there was a way for these organizations to gain insight through analysis and visualization of their data at no cost, and have the ability to communicate more effectively to the public their impact on the community?

In this paper we present a curriculum and methodology for the implementation of the Service-Learning teaching methodology into undergraduate visualization education. Through the integration of Service-Learning with visualization pedagogy, the students are able to more effectively learn the concepts and skills taught in the classroom, develop professional and interpersonal skills unattainable in a classroom setting, and experience first-hand how their visualization skills can lead to a positive impact on their community. In the methodology described in this paper, Service-Learning is implemented through a semester-long final project component to the course in which the students create an interactive web-based visualization for a non-profit community organization. As a result the community partner receives not only an interactive data visualization

product to be used on their internal or external website, but also valuable insight into their data. This insight and final product may be used, for example, for internal decision making and planning for more effective social impact, or communication to the public or funders on their impact on their community.

In the following sections the Service-Learning methodology is introduced, followed by a discussion of a case study implementation of the new curriculum to teach an introductory visualization course. Finally, suggestions for the implementation of the curriculum are provided as well as a summary of the key benefits of Service-Learning for visualization education.

2 SERVICE-LEARNING

Service-Learning is an experiential learning model in which classroom learning objectives are aligned with community service to meet both educational and community goals [5, 6, 10]. There are various methods of Service-Learning including volunteerism, community service, internships, and field education [5]. A key component of Service-Learning is reflection either through written prose or group discussion in order for the student to develop critical thinking skills as well as reflect on how their learning and service relate [4]. Many positive effects of Service-Learning on students have been demonstrated including development of a sense of meaning and purpose to their academic studies [4], interpersonal and communication skills [4], and leadership skills [2]. Service-Learning has also been shown to foster diversity awareness, exposure to other cultures, and an increased sense of community [4]. As will be detailed in Sec. 4, the final project objectives and the community partner objectives were synergistically aligned for mutual benefit.

3 DESIGN STUDY "LITE" METHODOLOGY

Service-Learning was integrated into the case study curriculum (Sec. 4) as part of the final project requirement of the course. The goals of the final project are to expose students to the real-world research and design process of doing an in-depth visualization design and implementation, and demonstrate proficiency of the skills taught in class. These goals lend themselves perfectly for synergy with the goals of community organizations through the creation of an interactive data visualization.

In order to align the final project and community partner goals, a design study methodology [7, 9] was adapted and applied to the final project curriculum. A challenge of implementing a full version of the design study methodology is the limited duration of the course. A typical visualization design study takes many months to years. This long duration is due to the need to become familiar with the domain, possible limited availability of the domain expert(s), and iterative process of data analysis, visualization design, and implementation. In order to expedite the process to fit the duration of a semester (~3 months), the following modifications and specifications to the design study methodology were applied for the course curriculum:

Choose a domain problem that is easy to understand. When most visualization practitioners apply the design study methodology to a project with domain experts, the required prerequisite knowledge and skills necessary for effectively understanding the domain

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may require extensive background reading or training with experts. This level of expertise is unattainable in just a couple weeks. To minimize this information and skill acquisition hurdle, community partners and associated questions were chosen to be as easy to understand to a non-expert as possible. This was relatively easy when recruiting community partners as most non-profit community organizations focus on relatable topics such as education, volunteerism, and neighborhood improvement.

Work with pre-curated and “clean” data. A pervasive component of the visualization research process is cleaning, analyzing, and mining data. Although the latter two concepts are important to a visualization-focused data science course and enable students to gain experience with exploratory visualizations, data cleaning can be an arduous long iterative process. In order to minimize the time spent on data clean-up, pre-curated relatively clean data sets were solicited from partner organizations. Note that even with “clean” data, the students still had to clean the data and apply data standardization strategies - a valuable learning experience without distracting the student from the main visualization focus of the assignment.

Structure and limit the amount of iteration. A valuable part of the design study methodology is the iterative process. However this cyclical process can take a very long time. In order to provide iteration, but limit its duration, a pre-defined number of feedback sessions with the domain experts was set at the beginning of the project. Although this certainly may hamper the full potential of the final product, the compromise is an expedited timeframe.

For the course (Sec. 4) the primary text utilized was Munzner’s “Visualization Analysis and Design” [8]. This book, in addition to covering much of the visualization theory and concepts in the course curriculum, is naturally structured to be complementary to teaching the design methodology to students.

4 CASE STUDY: DATA SCIENCE 4200

The Service-Learning model was applied to the instruction of the inaugural offering of CCIS’ new undergraduate data visualization course Data Science (DS) 4200¹ in Spring 2017, taught and developed by the first author. The course partnered with four non-profit organizations for its Service-Learning component: Boston Cares (the largest New England volunteer agency), the Massachusetts Promise Fellowship Program (an AmeriCorps organization which organizes out-of-school time programming), Mothers for Justice and Equality (organization whose mission is to end neighborhood violence), and the Northeastern Center of Community Service (facilitates diverse service opportunities for students, staff and faculty). These non-profit organizations were recruited for partnership through Northeastern’s Service-Learning Program.

The 26 students in the course worked in small groups, each assigned to a particular data set and problem provided by an organization. The motivation for this structure was to maximize the number of datasets analyzed per organization. The motivating questions from the community partners for each project were brainstormed and curated by the instructor in meetings with partners prior to the start of the semester. Questions were chosen based on both their importance and impact to the organization, but also availability of clean curated data to support exploring the questions. With each student group assigned an community partner, contact, and motivating question(s), the students executed the design study “lite” methodology over the duration of the semester. In order to keep projects on schedule for completion, each step of the methodology was broken down into small pieces and incorporated into the students’ weekly homework assignments. The phases of the project included:

1. Abstract the key tasks and questions to be answered of the data by the visualization through observation of those users tackling the domain problem. As part of this portion of the final project,

students had to conduct an interview with a contact person at their organization, volunteer at the organization, and synthesize their experiences into a task taxonomy.

A key part of the design study methodology is understanding your domain users and tasks through, e.g., field study, and a key part of the Service-Learning methodology is volunteer service with reflection - a perfect synergy. As part of this Abstract phase, each of the students in the course volunteered at their partner organization, and conducted a semi-structured interview with their organization’s contact. This assignment taught the students how to conduct an interview and code their interview notes through a qualitative analysis methodology.

The students were also required to volunteer a minimum of 3 hours at their partner organization. After their completed community service each student wrote a reflection essay on their experience, and discussed how it gave them insight and perspective on their final project. This journaling/reflection exercise not only helped the students with their task analysis, but more importantly as part of the Service-Learning model helped the students observe the connections between their classroom-acquired skills and their community impact. The interview in conjunction with the volunteer experience enabled the students to produce a detailed task taxonomy for their project. The students primarily applied the task typology of Brehmer & Munzner [3], supplemented with the analytic task taxonomy of Amar, et al. 2005 [1] as needed for finer grain description of low-level tasks. The students also shared and presented their experiences in class in the form of short presentations and full-class discussion.

2. Design through an iterative design process with the real users a data representation optimized for the domain tasks. The students first cleaned and mined the data provided by their partner organization. Part of this phase included exploratory visualization with Tableau to both start gaining insight into their data as well as determine the best visual encodings for their final product. The students were required to create multiple hand-drawn sketches and storyboards of their interactive visualization, create a clean final static version with a drawing tool (e.g., Illustrator, PowerPoint, etc.), and then implement their final sketch. During this design process each student group was required to meet with the instructor and TAs for feedback, as well as solicit feedback from their partner organization.

3. Build the new solution into a usable tool or pipeline for the domain workers. The students were required to create their final interactive visualization using D3, a javascript based visualization library. The choice to use D3 was based on the Data Science program’s curricular requirement that students need to learn D3 in the introductory visualization course. As part of the homework assignments prior to implementation in the project, students were introduced to and taught D3. In order to ensure that the students demonstrated through the final project mastery of key concepts taught in the course, each final project visualization was required to include the following: a minimum of two different visual encoding techniques, effective and appropriate use of the color channel for encoding data, brushing and linking interactivity, and details-on-demand interactivity.

4. Evaluate the new solution through user studies to understand its utility and effectiveness for its designed purpose. A full scale evaluation study was not feasible to complete within the timeframe of the semester, so a qualitative usability study was performed by each team to improve their visualization as well as evaluate its effectiveness. Each student group was required to have a completed nearly-final project a couple of weeks prior to the final project due date to use for a usability study session performed in-class in lieu of lecture. Each project group, which typically consisted of three people, rotated roles between the person conducting the usability study, the note taker observing the experiment, and study participant for another group. The session was conducted in a round-robin fashion with students rotating roles every 10 minutes.

5. Disseminate the final product and share study results. Each project group was required to prepare a final project report in the

¹The course syllabus, schedule, and supporting materials are available at: <http://www.ccs.neu.edu/home/borkin/courses/2017Spring/DS4200/>

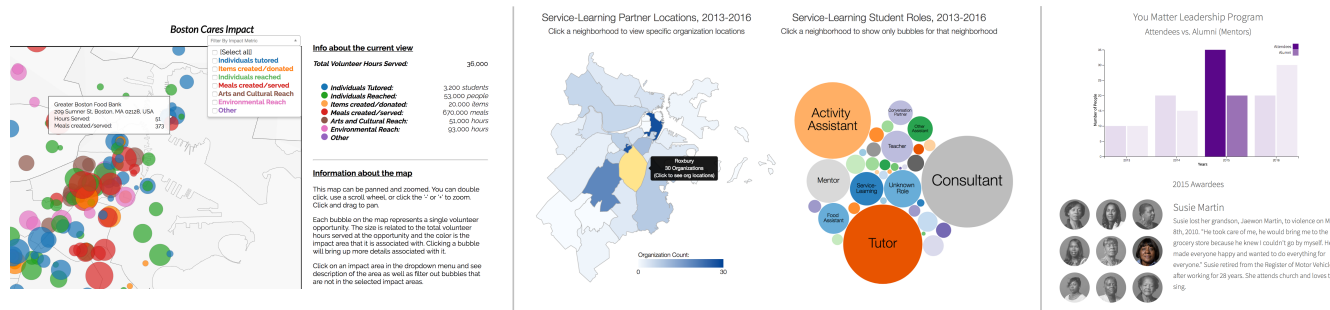


Figure 1: Screenshots of select interactive visualizations produced as part of the final projects for DS4200, an undergraduate introductory visualization course with Service-Learning. From left to right: social impact of Boston Cares, social impact of Northeastern's Center of Community Service, and a storytelling visualization of Mothers for Justice & Equality providing human stories behind the bar chart.

form of a website, including an embedded version of the final interactive D3 visualization, and present their final project in the last class of the semester in lieu of lecture. Their presentation and website were graded, and incorporated into their final project grade. All of the community partner organizations were invited to attend the presentations. The students were also awarded bonus points towards their final project grade for electing to participate in the Service-Learning Expo, a student poster and demofest organized by the Service-Learning Program each semester.

The final interactive visualizations included maps of social impact and volunteer opportunities, graphs of survey results to understand tutoring and mentoring impact, and storytelling visualizations to demonstrate the impact of an organization (Fig. 1). The 26 students collectively put in approximately 1,404 service hours (~54 hours / student). Total service hours committed by the teaching staff include the instructor (~100 hours), TA (~124 hours), and S-LTA (~109 hours). Thus a collective sum of ~1,737 service hours contributed in total by the course to the community partners. The students' commitment is similar to their commitment in a non-Service-Learning visualization course. Aside from their one required volunteer experience at the organization, these hours were composed of the time the student spent on their final project assignment over the duration of the semester. The primary commitments for the teaching staff outside of normal teaching duties were preparing the Service-Learning partnerships as well as additional training, optional meetings, and visits with the partner organization by the S-LTA.

In addition to the final interactive visualization and data insight provided to the partner organization, the Service-Learning component had a strong impact on the student's learning, ability to work with real clients, and sense of community. In the end-of-term evaluation administered by the Service-Learning program, the majority of students "Strongly Agreed" or "Agreed" with the following statements: "My service experience helped me to learn and remember important course concepts" (73%), and "I understand how my college education can benefit my community" (95%).

5 IMPLEMENTATION ADVICE

In the paragraphs below advice and words-of-wisdom are provided based on the DS4200 case study implementation of the Service-Learning curriculum. These helpful suggestions were originally derived from advice provided by the Service-Learning program staff as well as other faculty who have successfully implemented Service-Learning curriculum at Northeastern University. This advice helps avoid potential pitfalls including unrealistic student or partner organization expectations, ambiguity of responsibility and intellectual property (IP), and ineffective communication which may lead to unsuccessful projects or community relations.

Service-Learning facilities: A primary contributing factor to

the success of the Service-Learning implementation in DS4200 was the facilities and infrastructure support from the Service-Learning Program at Northeastern University. The program provides online resources and curriculum design help, recruits partner organizations and helps match partners with relevant courses, trains and provides a Service-Learning TA (S-LTA), runs an orientation for faculty and staff teaching Service-Learning courses as the beginning of the semester, administers formal assessment and evaluation throughout the semester of the course, instructor, and S-LTA, and conducts the end-of-term Service-Learning Expo. Of particular assistance is the S-LTA who is trained by and has regular meetings at the Service-Learning Program. The S-LTA is provided at no additional cost to the instructor/department, and is in addition to the designated departmental-assigned TA(s).

Service-Learning programs reside within different departments at different universities, and potentially in unexpected places. These departments may include student affairs, faculty affairs, or community affairs to name a few. If your university does not provide these facilities, make sure to plan ahead of the semester to allow sufficient time to implement the Service-Learning curriculum and recruit partner organizations. Even if a university does not offer a Service-Learning program, other relevant organizations including community service centers and centers for faculty teaching and development may be able to provide connections and resources.

Set realistic expectations: Setting realistic expectations is key for both the students and partner organizations. For the partner, it is important for them to understand that although the students are committed to creating a final visualization, there is no guarantee that they will complete the project or complete it to the level of sophistication drafted in the prototype sketch. Similarly for the students, it is important for them to understand that there are real stakeholders and they need to have a quality deliverable by the end of the semester. As part of the mid-semester feedback sessions and associated homework assignment, the student groups were required to rank all the features of their prototype sketch as "essential", "nice-to-have", and "bonus". In this manner the students had clear implementation priorities as well as clarity about how their project would be graded. Finally, in order to mediate the possible situation of a final project failing, the instructor assigned at least two project groups to each organization. Even though the groups worked on different motivating questions, this set-up increased the probability that at least one team would produce a quality product.

Define clear IP and data use guidelines: Part of setting realistic expectations for the projects is to define clear rules and guidelines on IP and data privacy. Each partner organization was instructed to prepare necessary privacy and/or data use consent forms for their final project student groups. The student groups were also required, if it was not explicitly stated in the organization-provided consent form, to clarify with the organization whether it was acceptable

to host their final interactive visualization on a publicly accessible Github page or whether the students needed to have it on a private not-public page. Finally, the instructor in collaboration with CCIS and legal experts assembled an IP contract that each organization and student group needed to sign and date at the beginning of the semester. The contract states that the students own the IP, but provides the partner organization with a non-exclusive license for the reuse and modification of their code. In other words, the students maintain the IP to their final project visualization but give a copy of the final project to the organization. The organization can then use, including modify, the visualization. Having a clear IP agreement of this nature ensures fair use and indemnity of the student.

Maintain effective communication: Of utmost importance is clear and consistent communication between the instructor, S-LTA, students, and partner organizations. Communication is key to ensuring that the projects stay on track and meet the educational and community organization's goals. Each project team was also required to have a single student designated as "Communications Director" (CD) for the duration of the semester. The CD was the only group member allowed to email with the partner organization, S-LTA, and instructor on all final project related matters. This helped ensure streamlined communication overall, as well as communication within each project group. In DS4200, the students were required to send updates to their partners at a minimum when required/noted in homework assignments determined by the instructor. The CD was required to copy the S-LTA on all email correspondence with the partner organization. In this way the S-LTA could ensure that the students were staying on-track with their final projects, and intervene with the partner and/or instructor if there was any issue.

6 SUMMARY OF ADVANTAGES OF SERVICE-LEARNING FOR VISUALIZATION EDUCATION

Provides real world data science experience. The experiential learning exposes students to "dirty" data and teaches them how to clean, manage, and mine data. This requires the students to learn as part of the course these skills at a basic level, or apply these skills from other data science courses. The experience thus takes these concepts out of the sterile classroom environment and makes the students apply their skills to real problems.

Visualization for exploration and communication. As part of the data clean-up and analysis, students learn the importance of visualization for data exploration. Even though the end-goal is to have a final clean visual product to communicate the final insights or stories in the data, as part of the process students learn to analyze and visually explore their data. This component teaches students the importance of rapid prototyping, use of different visual encodings, data annotation, and use of visualizations to help clean data.

Provides more realistic experience for creating visualizations. For the design of visualizations based on a domain problem (i.e., design study methodology), it is important to not only have a domain problem but real clients (domain experts) to interact with. Instead of students being provided with data and design criteria, possibly very generic and not domain specific, the students experience the full visualization research and design experience. The experience also helps students develop interdisciplinary research skills in which they need to apply general knowledge from the classroom, as well as knowledge from other domain examples presented in class.

Teaches visualization design and implementation skills unreplicable in the classroom. By working with real case studies and experts, the students learn skills that cannot be taught in the classroom. These skills are in support of successful visualization research and design and include learning how to communicate with a domain expert, interview domain experts, and request and implement feedback from an expert. The students also learn team communication, leadership, organization, and management skills.

"Guaranteed" deliverable. In a conventional final project set-

up, the student or student groups are the only stakeholders in the final project. If they receive a poor grade, or even do not complete the final project, the only people impacted are themselves. However, in the Service-Learning methodology there are multiple real stakeholders. Failure to complete or successfully execute the final project will negatively impact not only the student's grade but also the partner organization. This high-stakes set-up ensures a higher probability of students successfully executing their final project.

Professional development and future opportunities. By working with real "clients", the students gain valuable professional development experience. As previously mentioned, the students through a Service-Learning curriculum develop professional communication and leadership skills. For many students this is their first experience working with an organization or company, setting goals, managing a large project, and working with a client. The new skills and workplace maturity gives them an advantage for future employment. Many of the students may also be given the opportunity to volunteer at, or be employed with, their partner organization. Thus the students complete the course more prepared for the workforce in addition to future avenues of visualization scholarship.

Students make a positive impact on the community. Students learn how their visualization skills, and computer science more broadly, can be applied to make the world a better place. Their final product provides a positive impact through helping the partner organization either understand their data more effectively to make community-impacting decisions, or communicate their impact to the public or funding sources. The students receive positive reinforcement through the experience of how a seemingly simple course project can make an impact. The students also learn how to be better citizens and members of the community, and instill in them a sense of ownership and responsibility.

7 CONCLUSION

In this paper we present a new methodology for the incorporation of Service-Learning into visualization pedagogy with visualization education goals aligned with community service goals. The methodology was successfully applied to an undergraduate introductory visualization course in which 26 undergraduates worked in small groups with 4 non-profit community organizations. The students' final projects produced new interactive visualizations for the community partners which included visualizations of social impact on the greater community as well as insight into data for decision-making.

Both students and partner organizations provided positive feedback on the experience, and the instructor as well as some of the students are currently volunteering their time to ensure the final visualizations are incorporated into the organizations internal or external websites. These non-profits are unable to afford a professional data scientist or visualization expert for hire, thus this course provided a high impact service free-of-charge to the organization. Many of the organizations are also using the visualizations as part of their annual impact reports to funders to demonstrate their community impact. The students in the course were more dedicated and committed to their final projects, as compared to the instructor's previous teaching experiences, as their project had a real stakeholder and had real potential to make an impact on the community. Data visualization has the powerful potential to produce social impact and positive change, and we hope the visualization community continues to develop similar research and education models.

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