VisGuided: A Community-driven Approach for Education in Visualization

Alexandra Diehl[1], Elif E. Firat[2], Thomas Torsney-Weir[3], Alfie Abdul-Rahman[4], Benjamin Bach[5], Robert S. Laramee[2], Renato Pajarola[1], Min Chen[6]

[1]University of Zürich, Switzerland, [2]University of Nottingham, UK, [3]Swansea University, UK, [4]King's College London, UK, [5]University of Edinburgh, UK, [6]University of Oxford, UK

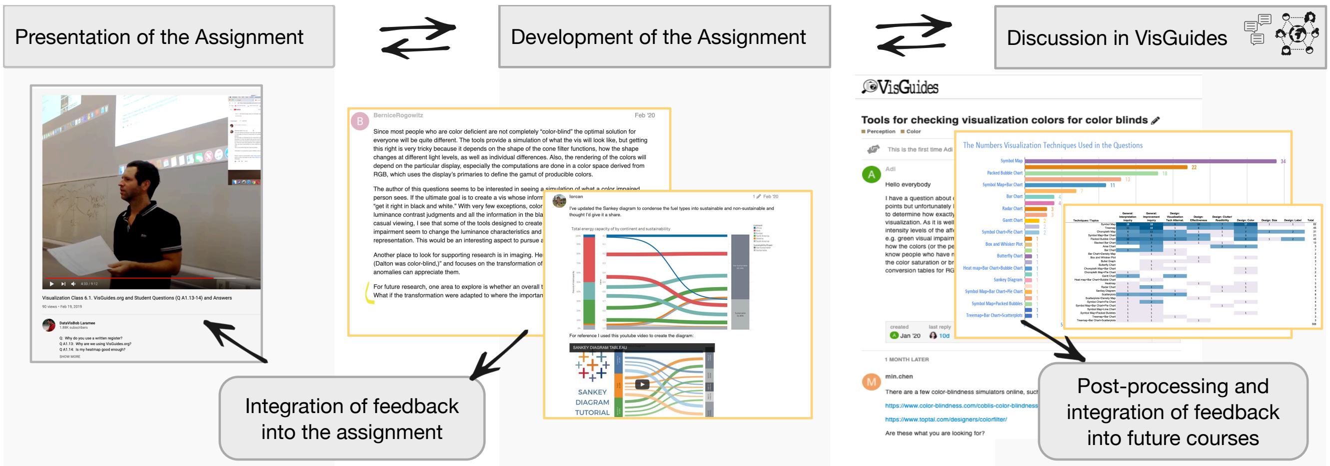

Figure 1: *A five-step process corresponding to our community-assisted education methodology.*

Abstract

We propose a novel educational approach for teaching visualization, using a community-driven and participatory methodology that extends the traditional course boundaries from the classroom to the broader visualization community. We use a visualization community project, VisGuides*, as the main platform to support our educational approach. We evaluate our new methodology by means of three use cases from two different universities. Our contributions include the proposed methodology, the discussion on the outcome of the use cases, the benefits and limitations of our current approach, and a reflection on the open problems and noteworthy gaps to improve the current pedagogical techniques to teach visualization and promote critical thinking. Our findings show extensive benefits from the use of our approach in terms of the number of transferable skills to students, educational resources for educators, and additional feedback for research opportunities to the visualization community.*

1. Introduction and Motivation

The literature on visualization is steadily growing, with a great set of books both from academia and beyond (e.g., [Mun14, KH19, RL19]) and online resources. These books and traditional educational methods have provided visual designs with a wide range of *rules and guidelines*. Example guidelines include Shneiderman's mantra [Shn96], Tufte's data-ink ratio [Tuf85], a critique of the rainbow color map [BT07], etc. While these guidelines are often seen as part of the collected wisdom in visualization, they naturally do not cover all the nuances present in concrete, real-world scenarios, With their exceptions, often undefined scope, and conflicting supporting evidence, applying visualization guidelines in the wild therefore poses major challenges that the next generation of visualization practitioners and researchers must face. Meanwhile, these challenges provide students with opportunities to develop critical thinking as well as the ability to discern the *whys*, *whats*, and *hows* in visualization [DKAR*20].

This paper describes visualization activities [HBH*20] that engage students in the use of visualization guidelines to support teaching, learning, and discussion around visualization guidelines. In our activities, students are asked to post and discuss visualiza-

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tion guidelines in the *VisGuides* forum [DAREA*18]. VisGuides is a discussion platform that facilitates the collection, evaluation, critique, revision, and dissemination of visualization guidelines and knowledge. It targets researchers and practitioners working in the field of visualization, as well as students receiving formal and informal education on the topic of visualization.

We approach visualization education from a perspective where both the classroom and the community mutually benefit. We address the following high-level research questions through a participatory and co-created experience:

1. **R1:** Can participatory science support teaching? Does it lead to the availability of more resources and the identification of open problems and improvement?
2. **R2:** How do community-driven and participatory education support distance learning? Does it support transferable skills development, promote critical thinking, etc.?
3. **R3:** How can community-driven education contribute to teaching and research?

In the remaining of this paper, we describe two cases where we run activities with VisGuides over the duration of 13 months, involving 259 students with diverse backgrounds in two universities in two countries (Section 4). We report on the lessons learned, the benefits of our approach, including transferable skills, benefits for educators, and opportunities for research (Section 5). Our activities enable lecturers and students to use and reflect on new and diverse educational resources from formal and informal sources before, during, and after class assignments; encourage an open and democratic debate of visualization guidelines; and are organized and moderated by scientists of the visualization community.

2. Related Work

Related work falls into the categories of citizen science, learning resources, and education.

Citizen Science for Education. Recent studies of online distance learning [Lee20] stated that *massive open online courses* (MOOCs) and other open online platforms have a social mission to make education open to a diverse set of participants and unknown beneficiaries. Among the unforeseeable benefits of open platforms that provide a diversity of knowledge, sources is the plurality of opinions [AP14]. Among the disadvantages of using open educational systems and MOOCs are that they are structured using an insider-outsider approach where the boundaries of the classroom are very well delimited.

Our strategy is also based on a community-driven approach where *the classroom* is composed of an extended network of participants, including students, lecturers, universities, and the VisGuides community composed of well-known scientists and researchers, practitioners, educators, students, and anonymous actors that contribute to the creation, curation, and discussion of knowledge. Moreover, our approach can be framed under the umbrella of participatory citizen science [ECSL*17]. Similar participatory approaches and citizen science projects have been successfully applied in other areas [BCD*09]. For example, previous work from Zoellick et al. [ZNS12] highlights the benefits of combining participatory science and education not only in the context of informal science education but also for formal science education, including the availability of new resources such as real data sets, online educational resources, and collaboration between scientists and non-scientists. These co-created new sources of information can unveil new research challenges and transferable educational knowledge.

Visualization Learning Resources. There are many available online learning resources, although they cannot be considered fully participatory. For example, YouTube dedicated channels such as Tamara Munzner's channel [Mun21], educational and scientific communication podcasts such as `https://datastori.es/team/`, and dedicated blogs such as Eagereyes `https://eagereyes.org/` provide very useful resources for students, but they are not structured for debate and discussion and mostly provide one-directional communication. On the contrary, in our community-driven approach, we propose a bi-directional communication, where several actors interact, providing educational resources, discussing predefined ideas concepts, and co-creating new knowledge.

To engage learners in discussing, there are several online and open community platforms. Examples include `vis.social`, the subreddit `r/dataisBeautiful`, and the Data Visualization Society slack channel `DVS Slack`. ManyEyes [VWVH*07] was an open platform where users could upload their datasets, create interactive visualizations, make them publicly available, and engage in discussions with other users. Although all of these platforms are community-driven, they are unstructured in terms of goals, scope, and purposes. Instead, we chose VisGuides [DAREA*18] because it is a semi-structured platform for democratic debate and discussions of knowledge in the visualization field; it also is a participatory science approach that integrates community feedback. However, it is moderated by visualization experts, used for formal learning, as well as informal learning, and the anonymous comments are publicly available for research.

Tools & Methods for Visualization Education. The visualization community has invested great effort to foster formal education and literacy in the visualization field [RVM*14, KSD08, RDDY07, HBH*20]. There is a wealth of literature on visualization tools for education. Firat and Laramee [FL18] survey visualization tools used for education and classify them based on evaluation method. Among them, there are visualization tools for teaching visualization such as VisTrails [SASF11], Visualization Cheatsheets [WSMRB20], storytelling workshops [WDB19], visMOOC [SFCQ15], and methodologies focused on tools [RSDB20], literacy, and understanding of visual design [GTS10, ZOC*12, RHR17].

The closest antecedent to our work is Seyda et al. [SMR*20] that presents a methodology for design studies in the context of visualization education. The authors implemented their methodology in five courses in the context of Service-Learning, where learning classroom objectives are aligned to community goals [BYH*17]. Our approach is bi-directional, serving the community by diverse educational resources, exploiting both formal and informal education via community feedback. To the best of our knowledge, this is the first approach that serves from and to the visualization community for formal and informal educational purposes.

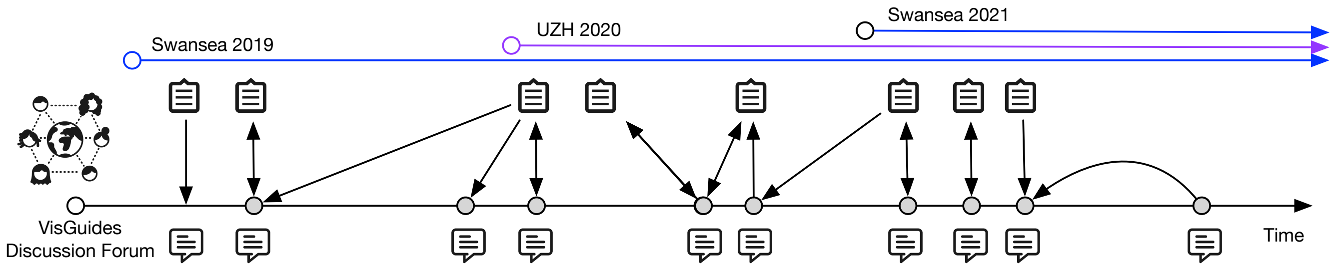

Figure 2: *The exercises begin with the lecture assignment but continue to live in VisGuides. A given post in VisGuides can be answered by one or more experts, students' colleagues, or even students from previous courses.*

3. Methodology

Setup — Our research methodology takes advantage of the currently available technologies to extend the learning process beyond the traditional boundaries of the classroom to the open forum of ideas from the visualization community (Figure 1). Although students are already using external forums, blogs, and other online resources, such as Stack Overflow, Reddit, YouTube as well as dedicated blogs, these tools are not specifically adapted to the classroom. VisGuides [DAREA*18] is the first dedicated discussion forum to exchange views on visualization guidelines and concepts. This platform provides an educational tool that supports community-driven learning and extends education beyond the boundaries of the physical classroom. Its historical content can be used as a database of knowledge that can be reused in the context of other courses.

Course Context — Our approach of integrating VisGuides into the visualization classroom consists of the following five steps, which were repeated three times in two different visualization courses attended by 259 students:

1. **Traditional lectures** presenting the topic and assignments.
2. A set of **assignments** for individual or group development.
3. **Community exchange and feedback via *VisGuides***. We use different strategies to introduce the discussion platform *VisGuides*; *(i)* describe the tool during the lectures, *(ii)* answer questions about its use and the assessments in Q&A sessions, and *(iii)* introduce the platform and select particular examples for elaboration during the course exercises to foster critical thinking. This last strategy turned out to be the most effective in terms of promoting debate and increasing discussion thread diversity (see Section 4).
4. **Integrating feedback** from the VisGuides community into the given **assignments**.
5. **Assimilating feedback** from the VisGuides community **into current and future courses**.

Analysis — We evaluated our proposed methodology based on three different instances, with the following two goals in mind: the use of VisGuides to *validate visual designs* and to *discuss guidelines*. To quantify the benefits of our approach, we focused on three main aspects: (1) benefits for educators, (3) benefits for students, and (3) benefits for researchers.

For the analysis of these three benefits, we performed an open coding of all posts using the following codebook:

1. **Topics** of the posts. We classified the topics as general or related to a specific area, for example, visual design, theory, or evaluation, and sub-classify it according to the intention of the posts: inquiry, advice, or discussion of a guideline. We also indicated the specific aspects, e.g., color, if they are relevant to the topics.
2. **Visualization Techniques** discussed in the topic threads.
3. **Resources** mentioned, with references to educational materials for the students, the lecturers, and the community in general. Examples include books, papers, online sites, and data sets.
4. **Improved Design.** We identified three different types of discussion related to design improvement: *request*, when a student asks for advice to improve their visualization; *suggestion*, when a piece of advice is given by the community for design improvement; and *implementation*, when a student used the forum advice to improve their visualization and share it in the forum.
5. **Research Questions** that could lead to new research challenges, open problems, or new areas of research.

We coded all VisGuides posts associated with the use cases and derived basic statistics for the three coursework runs. The coded data and statistics are provided as supplementary material.

Data Privacy and Data Ethics—The data privacy policy is specified in the VisGuides policy. The privacy policy was designed under the supervision of the Data Privacy support office of the University of Zürich and follows Swiss laws for data privacy. Regarding the data ethics, we followed two different procedures depending on the university involved. The case study performed at the Department of Informatics, University of Zurich, requires the formal approval of the Human Subject Committee at the Faculty of Business Economics and Informatics. For the two case studies performed at the University of Swansea, the ethics guidelines classify the project as low risk, and therefore they do not need committee approval.

4. Use Cases

We present two different use cases: (1) a use case of community-driven learning of visual design executed in two different instances, and (2) a use case of critical thinking and community-driven learning of visualization guidelines.

4.1. Community-driven Guidance of Visual Design

One assignment was run at Swansea University as part of the Data Visualization course from the Department of Computer Science. The course is cross-listed for third-year Bachelor (final year) and Master students. There are no formal prerequisites to this course. As an upper-level computer science course, however, students are

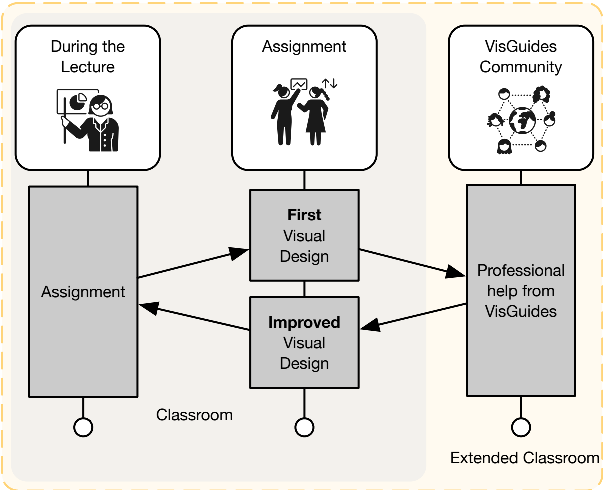

Figure 3: *Community-driven education model. The lecturer presents the assignment to the students. Students elaborate their work in the context of the classroom and then ask for external help from the VisGuides Community. The community feedback is integrated into the assignment, and it is used to improve the students' work.*

expected to be familiar with general programming techniques, problem-solving, and analysis.

Learning Model Lectures mostly focus on theoretical aspects of visualization, selecting visual encoding and example solutions. The coursework is intended to provide students with skills to design visualizations. The assignment dynamics are illustrated in Figure 3. The assignment is presented during the lecture. Then students work individually on their visualization project. Finally, the students seek advice for their assessed visualization project by uploading work-in-progress screenshots of their coursework to VisGuides.

Pilot Coursework Use Case During the first pilot, Swansea's students were given a visualization design challenge related to a well-known data set recording health conditions in different geographic regions: Global Power Plant Planning Production (GPPPP). A total of 64 students participated in the assignment, resulting in 134 posts and discussion exchanges at VisGuides, posted between February 4 and March 13, 2019. Replies to posts came partly from the course instructors, partly from authors of this paper, partly from external users, including researchers from the visualization community, and also sometimes from other students.

As part of the assignment, students request external help from VisGuides. Their task is to choose an image they produced and to upload the image as well as its description to VisGuides. They then pose one or more questions on the site with the goal of improving their initial design. Their description also contains the DOI(s) of the data file(s) they used to generate the image. The DOIs allow other VisGuides users to know exactly which data file(s) were used to create the image(s) and supports reproducibility.

Findings from the Pilot During the pilot run of Swansea course 2019, we have identified several useful indicators of transferable knowledge and points to improve in our curricula. We did an open coding of the students' posts and identified the top visualization techniques selected by the students. Figure 4a shows the distribution of visualization techniques that appeared in the posts. The top visualization techniques selected by students are treemaps and maps (choropleth and symbol maps). While doing a close reading, we observed that there were many questions about how to add temporal data to *geospatial visualizations*. This trend indicates that students could benefit from learning and discussing guidelines on geospatial visualization. We also observed similar discussions on the topics of hierarchical visualizations, treemap layout algorithms, and colors. Another recurring theme was the treemap layout. Our close-reading revealed that students generally struggled with the node placement strategy of treemap layout algorithms. Students could benefit from guidelines on using treemap layout algorithms.

The assumption of the assignment was that students would figure out how to construct a data hierarchy by introducing data categories. However, not all students knew how to do this. This is evident by looking at the questions posed on VisGuides in the treemaps category. Again, treemaps are an exceptional design, generally, in the visual design categories on this aspect. All other visual designs incorporate an intuitive placement strategy and usually have clear 1- or 2-dimensional axis mappings for placement. Treemap layout algorithms is a topic we cover in the data visualization class. However, even with the current level of topic coverage, this aspect still remains challenging for a significant number of students. These findings helped us to reflect on topics that we need to reinforce during the lectures, improve the syllabus and the teaching methodology when teaching hierarchical visualization. We recorded these efforts, performed further research, and published the results in Firat et al. [FDL20].

From the coding, we could observe that most of the students (95%, 61 out of 64) have been satisfied by the replies and did not need to discuss and iterate, and about 20% of the students received at least two different replies. For example, one student mentioned that *"Personally the question I myself asked did not improve much directly for my assignment, however, this may be [because] I had already learnt a great deal from reading all the questions and replies made by other students. I also learnt quite a bit about visualisation techniques I did not even consider for my own assignment through VisGuides."* In general, that same student continued highlighting the overall benefit of VisGuides for the course work: *"At first, I did not think this part would contain much substance as I guessed all questions would be very similar, however, I now think [VisGuides] was probably the most valuable aspect of the coursework."* These findings are potential indicators of indirect collaborative learning during the lifetime of the course. Our hypothesis is that students can leverage and calibrate their work based on other students' posts from the course or previous courses. The coded data sets are available as supplementary material.

Second Iteration In 2020, the second iteration of the course assignment was performed. In this case, two assignments were used with two different data sources, focusing on different types of data common in visualization: abstract data and 3-dimensional volume data. The abstract data was a publicly available data set on power-plant construction dates around the world. This data included geo-

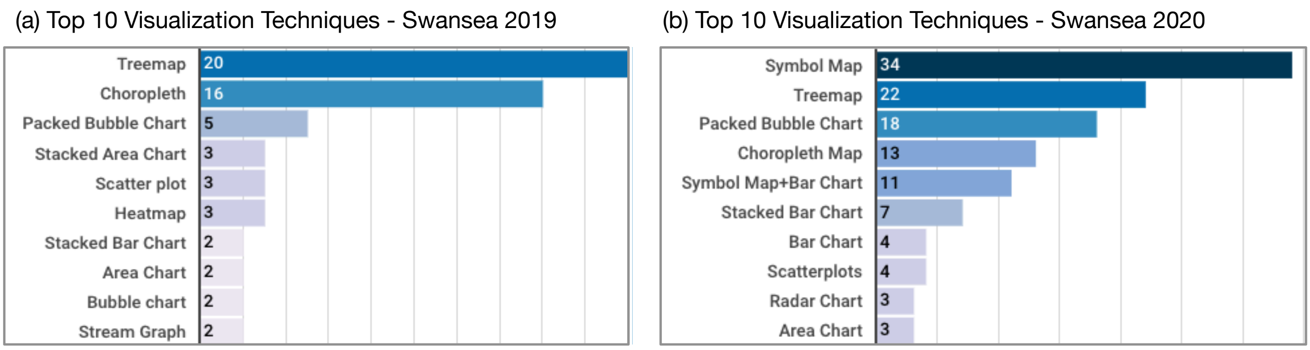

Figure 4: *Top 10 distribution of visualization techniques on the Swansea's coursework, in (a) 2019 and (b) 2020.*

graphic information, categorical information, and scalar data. The other data sets were publicly available 3D medical scan images.

Instructions from the Lecturers Students were instructed to produce five different designs for each data source. They were also required to explain how they mapped data attributes to visual encoding. Students were also required to explain, in their own words, a 'unique observation' one could derive from the visualization. Then, students were asked to submit a screenshot of one of their designs to VisGuides and ask for feedback.

Findings from the Second Coursework VisGuides provides excellent feedback for the lecturer in terms of identifying areas where the lecture can be improved. It enables the lecturer to find topics that need to be reinforced and techniques that need to be explained better, as also shown by the pilot use case. Figure 4b shows the top 10 visualization techniques selected by students. Most of them are maps and treemaps (98/139), although the data sets used were different. There is more diversity than in the pilot in terms of visualization techniques, including bar charts, Gantt charts, area charts, etc. We consider these results as an improvement on the coursework results because students could apply more diversified tools to perform their visual design. In particular, a number of students used a packed bubble chart, but those overwhelmingly resulted in design improvement suggestions (9/12, see Figure 5). The discussion format of VisGuides also makes it easy to identify which techniques are adopted by the students from the lectures. For example, a number of lectures are dedicated to data transformation techniques. However, only 14 out of the 59 that mentioned data transformation techniques used them in their actual designs. A number of post replies mentioned more "advanced" techniques that students could use to improve their visualization. Again, these responses give an idea of how to improve the lectures.

We also observed that when students requested feedback on VisGuides, many posted an image of their solution and asked very general questions like *"Does the visual design make sense?"*, *"Could I get any feedback on the visualization?"* or *"How can I improve it?"* These general questions might not solicit feedback that helps the students improve. Specific questions are usually better for attracting feedback, such as *"Are there too many or too few data points?"* or *"Do you think this design helps achieve the task of showing the relationship between the number of plants and electricity generation?"* VisGuides shows the lecturer how certain types of challenges are received by the community and what types of questions lead to better recommendations. Figure 6 provides an example of an improved design after receiving feedback from VisGuides.

4.2. Discussing Guidelines

The third assignment was run at the University of Zürich (UZH) as part of the course *Data Visualization Concepts* that takes place every year at the Department of Informatics.

Audience The students in this course are bachelor and master students advanced in their studies and enrolled in a major or minor program in Informatics at UZH, with many being in a data science track. Thus students may come from a diverse range of programs, such as biology, mathematics, business, economics, or computer science, just to mention a few common examples. The prerequisites of the course are successful completion of introductory computer science, programming, and math courses.

Learning Model Given the audience's characteristics and the main focus of the course on visualization concepts, we changed the format of the assignment, introducing a two-step exercise as illustrated in Figure 7. First, a lecture was given with a focus on visualization guidelines, then a first exercise was introduced. Students were instructed to select a guideline discussed in reference books, in VisGuides, or other online resources. The goal of this first exercise was to guide and prepare students for the critique, challenge, and debate of visualization guidelines. Students were asked to write an essay of approximately 500 words elaborating on the context, applicability of a guideline, providing evidence of its usefulness gathered from papers, books, or other online resources. This first exercise was corrected and graded by the lecturer. In a second exercise, students were instructed to apply the skills learned during the essay in a challenging discussion. They were asked to post a question, *optionally and voluntarily*, at VisGuides about a timely topic or open problem, or to discuss a controversial guideline, or critically answer a previous post at VisGuides.

Findings A total of 79 students presented their essays on discussing visualization guidelines, and a total of 29 students participated in 40 posts uploaded to VisGuides. Questions and answers were posted between December 19, 2019 (launch of the assignment) and February 22, 2020. Although the sample of posts and participants from the UZH's coursework is smaller than the

(a) General Inquiry									
Techniques/Topics	Interpretation	Improvement	Technique Alternative	Effectiveness	Readibility	Color	Size	Label	Total
Symbol Map	19	18	9	10	7	17	1	1	82
Packed Bubble Chart	12	11	9	2		8	1	2	45
Treemap	11	19	1	4	3	7			45
Symbol Map+Bar Chart	5	6	3	3	1	3			21
Choropleth Map	4	11	3	1	1	7	2	2	31
Stacked Bar Chart	3	7	1	1	1				13
Bar Chart	3	3	1						7
Scatterplots	2	3	3						8
Gantt Chart	2		2						4
Radar Chart	1	2			1	1			5
Symbol Chart+Pie Chart	1	2				1			4
Sankey Diagram	1	1	1		1	1			4
Treemap+Bar Chart	1	1	1						3
Scatterplots+Density Map	1	1		1					3
Treemap+Bar Chart+Scatterplots	1	1		1					3
Symbol Map+Bar Chart+Pie Chart	1	1			1				3
Symbol Map+Packed Bubbles	1	1				1			3
Symbol Map+Line Chart	1	1							2
Heatmap	1			1		1			3
Choropleth Map+Pie Chart	1					1			2
Area Chart		3			2	2			3
Bullet Graph		1	1	1					3
Choropleth Map+Bar Chart		1	1			1			3
Bar Chart+Density Map		1	1						2
Butterfly Chart		1							1
Heat map+Bar Chart+Bubble Chart		1							1
Box and Whisker Plot				1		1			2
									306

(b) Replies				
Visualizations/Answer Topics	Improvement Advice	Alternative	Educational Source	Total
Symbol Map	32	6	1	39
Treemap	18	1	2	21
Packed Bubble Chart	12	9	2	23
Choropleth Map	11			11
Radar Chart	10			10
Stacked Bar Chart	8			8
Symbol Map+Bar Chart	6		1	7
Scatterplots	3			3
Bar Chart	2	1		3
Gantt Chart	2	1		3
Area Chart	2		1	3
Bar Chart+Density Map	1	1		2
Box and Whisker Plot	1			1
Choropleth Map+Bar Chart	1			1
Heat map+Bar Chart+Bubble Chart	1			1
Heatmap	1			1
Sankey Diagram	1			1
Scatterplots+Density Map	1			1
Symbol Map+Bar Chart+Pie Chart	1			1
Symbol Map+Line Chart	1			1
Treemap+Bar Chart+Scatterplots		1		1
				142

Figure 5: *Heatmaps showing the correlation between topics and subjects for Swansea 2020. (a) Top 20 topics and visualization techniques posted by students. (b) Top 20 topics and visualization techniques in the replies posted by the community. Additional data for the other use cases can be found as supplementary material.*

Swansea coursework, it shows more diversity in terms of the selected subjects, guidelines, and participation strategies. Our hypothesis is that the dedicated lecture to visualization guidelines and the first essay assignment paved the road for prompting more general and engaging discussions. There was no specific template provided to the students to formulate their posts. Some students decided to post a new question, others discussed a guideline or visualization concept providing their viewpoint, and others answered and discussed previous posts. For example, one student followed-up a question from previous coursework posted one year before,

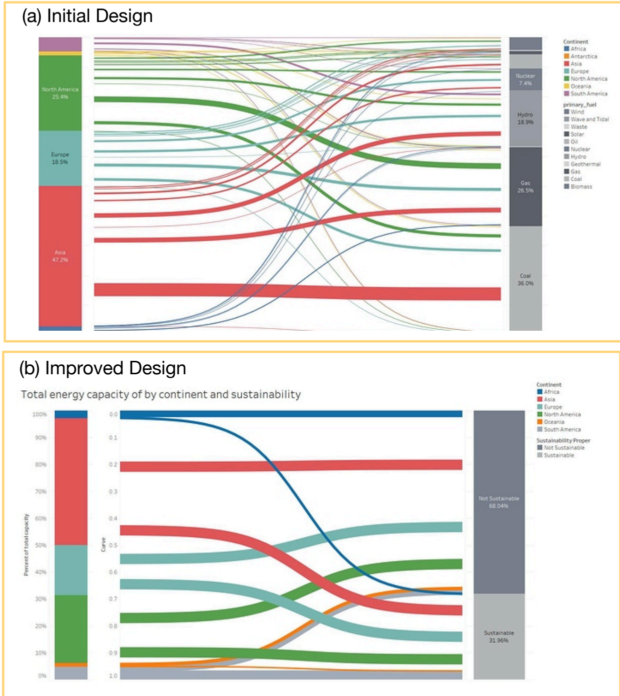

Figure 6: *Comparison of a student's visual design before and after incorporating VisGuides community advice.*

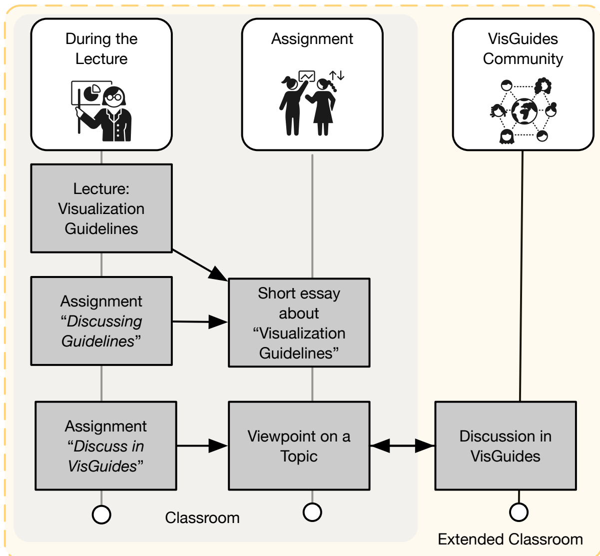

Figure 7: *Two-step exercise: First, an introduction to visualization guidelines, then an individual reflection on the topic, finally, a public and open discussion of a chosen guideline at VisGuides.*

giving his opinion of the selected visual design of another student [swa20c].

Many students expressed the need for guidelines in the area of big data and data pre-processing, color, and high dimensional visualization. Some of the students' threads developed into lively debates and prompted timely and important research questions. For example, one student posted a question asking advice for tools for color impaired people [col20]. This post was answered by highly recognized visualization experts, specialists in color and perception, and the discussion thread is still active. Providing an ever bigger base of knowledge on the topic. For example, Prof. Bernice Rogowitz replied the student's post, and as part of her answer, she wrote: *"For future research, one area to explore is whether an overall transformation is the best way to go. What if the transformation were adapted to where the important information is?"* Another highlighted example is the post of a student regarding data ethics in Visualization [dat20]. In this case, Prof. Min Chen replied that, *"Further research on this topic will be necessary ... In general, any black-box algorithms for making decisions for the users in the name of "this is best for you" has potentially an ethical question. In most of such cases, interactive visualization can enable users to explore different options and alleviate the biases of the algorithms..."*

5. Lessons Learned

Results of our community-driven approach evidenced a wide list of benefits to the educators, students, and for research.

Benefits for Students—The first immediate benefit of our approach was the response from the VisGuides community, composed of recognized scientists, practitioners, and anonymous enthusiasts of the visualization field that provided generous and useful feedback to the students. Through VisGuides, students have access to different perspectives by participating in live discussions and by reading replies to posts of other fellows. In Swansea 2019, for example, all posts received at least one answer. That means that each student out of the 64 could learn from the other 63 students' post replies, containing experts' advice and additional educational resources. There is also evidence of conversations among students helping each other [swa20b, swa20a], which can be associated to collaborative learning. More subtle but yet very importantly, the students must learn how to publicly present their coursework in an open and democratic platform. These are soft skills that are very valuable in collaborative and cooperative work environments.

Benefits for Educators—Educators benefit in a number of ways. Firstly, they also receive valuable perspectives on important visualization topics from other researchers and experts in the field. In this way, educators receive the same benefits as students in that they learn new material. Secondly, VisGuides serves as a platform to inform best practices in teaching. It clearly highlights the difficult subjects from a student's perspective. Lecturers may then use this feedback and improve their visualization course. Thirdly, the experience informs new directions in both teaching and research. For example, the platform has inspired visualization literacy studies on the topics of treemaps and parallel coordinates. It highlights areas that require future work, e.g., context-sensitive color mapping and personal visualization. Fourthly, educators benefit from the historical content of the postings. Lecturers also witness what took place in previous years and can build upon that. For the very first time, teachers can compare their current and forthcoming assignments with previous years or with courses from other universities. It is also very interesting to compare student posts from different years, universities, and coursework.

Benefits for Researchers—From a scientific standpoint, the availability of a public corpus of discussions around guidelines is a clear benefit. An anonymous version of the corpus data set with time stamps and statistics is accessible for research via a formal request to the VisGuides team, under the Privacy Policies of VisGuides. The possibilities for research are potentially unlimited, using methods for text analytics, behavioral research, theoretical research, and education research. Examples of this are the work of Diehl et al. [DKAR*20] on the theoretical study of visualization guidelines or the study of treemap literacy by Firat et al. [FDL20]. Other research benefits are new research opportunities, new challenges, and open problems that arise and are mentioned in the conversations threads, i.e., discussions about color [col20] or gamification [gam20].

Limitations and Future Work—One of the challenges in this work is to build and maintain a solid community over time, especially with expert users that can act as moderators of the forum. Moderators invest a lot of effort in coordination, a task that is currently performed only by a few users at VisGuides. There is a need for more involvement and commitment from volunteers that are willing to take a stake in this open, public, and democratic forum. One open question is how this engagement can be made sustainable. So far, we remain optimistic since our community has shown openness and generosity with respect to sharing ideas. We will keep using (and refining) our method in our courses. We hope this paper will encourage other educators to do so. Research into the learning effects of discussing guidelines online will hopefully foster additional support. Eventually, we aim to be an inclusive platform not limited to academics alone but actively reaching out to practitioners.

Another challenge is coursework coordination and time investment for marking. For example, the Swansea 2020 coursework counted 126 participants (64 in 2019), leading to some posts that could not be answered on time. For UZH 2020, 29 participants created 40 posts on different ongoing threads. The results from the intervention indicate that the workload of correcting the assignments may require extra or double effort than when the assignment is done only in the classroom. Educators need to consider these efforts when implementing the assignment. We are evaluating different strategies to optimize the course workload for the students, the educators, and the VisGuides community. For example, creating group assignments, reusing existing threads, and encouraging students to participate in other students' posts. In any case, educators need to divide their time between (1) marking, (2) optionally evaluating the discussion threads generated in VisGuides by students, and (3) optionally evaluating the design improvements after incorporating the feedback from the forum into the assignment.

Future work will require more extensive evaluations comparing the acquired learning skills by the students, trade-offs and spent time of both students and educators when using traditional tools such as books and papers vs. using *VisGuides* and other online resources such as YouTube and MOOCS.

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