Developing a Robust Cartography Curriculum to Train the Professional Cartographer

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Abstract

In this paper, we discuss our experiences advancing a professional-oriented graduate program in Cartography & GIScience at the University of Wisconsin-Madison to account for fundamental shifts in conceptual framings, rapidly evolving mapping technologies, and diverse student needs. We focus our attention on considerations for the cartography curriculum given its relevance to (geo)visualization education and map literacy. We reflect on challenges associated with, and lessons learned from, developing a comprehensive and cohesive cartography curriculum across in-person and online learning modalities for a wide range of professional student audiences.

Index Terms: Cartography education, pedagogy, professional graduate programs.

1 Introduction

Cartography and GIS is a 350 billion dollar industry that employed an estimated 625,000 Americans in 2010; today, 5 million U.S. employees rely on geospatial services to perform regular job duties[1]. The Bureau of Labor Statistics estimates five percent employment growth for "cartographers" between 2022 and 2032, which translates to 700 new jobs[2]. The rapid pace at which technological innovation is advancing cartography, geovisualization, and geovisual analytics creates significant challenges for both educators and industry professionals [28]. Cartography educators are forced to grapple with first deciding which technologies are relevant to teach then ensuring the curriculum is kept current as those technologies (and their dependencies) evolve. Professional cartographers, on the other hand, find themselves in situations where they must continually update their skillsets to stay relevant (and employed) in a highly dynamic field.

Professional-oriented graduate programs serve as a primary avenue for individuals seeking to launch or enhance their career trajectories and aim to instill a mantra of life-long learning needed to be successful in a rapidly evolving field [14]. Many of these programs are offered either fully online or blended online/in-person, catering to early to mid-career professionals who need to balance ongoing work commitments with the pursuit of new skills and credentials [18]. The culminating or centering experience for professional graduate programs typically entails a capstone or practicum course, in which students combine the conceptual training and skills developed throughout the program to solve real-world problems [5, 16]. The goal is to facilitate experiential learning via student-led projects completed for clients, in partnership with professional organizations, or as part of a required internship [21]. Thus, the outcome of these programs promotes practical skills rather than research experience.

In the case of Cartography and GIS, there is an entire organization and website called GISDegree.org that is dedicated to aggregating and sharing information on prominent degree and certificate programs across the U.S., most of which are professionally-oriented and include a cartographic component. In this paper, we discuss one such program at the University of Wisconsin-Madison with a focus on considerations for developing a robust cartography curriculum to account for fundamental shifts in conceptual framings, rapidly evolving mapping technologies, and diverse student needs. We offer several key takeaways that aim to inform, rather than prescribe, how to develop a cohesive, comprehensive, and flexible cartography curriculum across in-person and online learning modalities to serve the evolving needs of the professional cartographer.

2 Background

GIS Professional Programs (GISPP) reflect a portfolio of academic programs within the Department of Geography at UW-Madison, encompassing non-thesis design and technology certificates and degrees in Cartography & GIScience. GISPP offers two Master's degrees, one online emphasizing GIS development and web map programming (*subsequently referred to as the Online MS Program or OMP*), and an accelerated, primarily in-person option (*subsequently referred to as the Accelerated MS Program or AMP*), allowing students to complete resident coursework in as little as one year. GISPP also offers two online capstone certificates, one focused on fundamentals (*subsequently referred to as FCC*) and the other dedicated to advanced topics (*subsequently referred to as ACC*). OMP was launched in 2016 in response to rapid growth and change in the geospatial industry and enrolls working professionals who wish to advance (or update) their cartographic design and GIS development skills. FCC and ACC were launched two years later in 2018 to broaden the online student audience and create stackable pathways into OMP. AMP was also launched in 2018 as an evolution of a successful post-graduate resident certificate program, catering to students who wish to take advantage of the on-campus experience and Department resources (e.g. Cartography Lab, Robinson Map Library, State Cartographer's Office, etc.), but are more interested in developing design and technical competencies for professional practice than conducting research. Students across all programs engage with one another and instructors via an organizational slack space; graduates retain access indefinitely, creating an alumni network of practitioners who serve as mentors to current students and share information on career opportunities. The overarching goal of GISPP is to position students for growth and success in a broad range of geospatial career paths.

GISPP was founded in part on the Geography Department's cartographic legacy and the role Arthur Robinson played in shaping academic and professional cartography following the end of World War II [20]. The cartography curriculum at UW-Madison dates to 1937 with a long tradition of excellence in the art, science, and

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[1] https://www.esri.com/en-us/what-is-gis/careers

[2] https://www.bls.gov/ooh/architecture-and-engineering/cartographers-and-photogrammetrists.htm

Table 1: Cartography curriculum at UW-Madison, 2024-2025. Applicability to GISPP's online fundamental capstone certificate (FCC), online advanced capstone certificate (ACC), online MS in Cartography & GIS degree (OMP), and accelerated in-person MS in Cartography & GIS degree (AMP) highlighted in blue.

Course	Description	Modality	FCC	ACC	OMP	AMP
Geog 175: *Mapping our Changing World*	first-year special interest group seminar that introduces and explores the role of maps and spatial data in popular culture	In-Person	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Geog 370: *Intro to Cartography*	intermediate-level course on the fundamentals of reference and thematic map design	In-person & Online	Core	Pre-Req	Pre-Req	Core
Geog 570: *Cartographic Production & Project Management*	advanced-level course on applied cartographic print production and project management	In-person	Not Applicable	Future Offering	Future Offering	Elective
Geog 572: *Graphic Design in Cartography*	advanced-level course that integrates conceptual and technical competencies across the full spectrum of contemporary cartography	In-person & Online	Not Applicable	Elective	Core	Elective
Geog 575: *Interactive Cartography & Geovisualization*	advanced-level course on interaction design for web and mobile mapping	In-person & Online	Not Applicable	Elective	Core	Elective
Geog 576: *Geospatial Web & Mobile Programming*	advanced-level course on full-stack interactive web map application development	Online	Not Applicable	Elective	Core	Elective
Geog 970: *Geovisual Analytics*	advanced-level course on analytical reasoning with spatial data via interactive coordinated interfaces, computational methods, and user-centered design strategies	In-person	Not Applicable	Future Offering	Future Offering	Future Offering

technology of mapmaking. The current cartography curriculum is nested within a campus-wide array of 20+ courses covering theoretical and applied topics in geospatial data science, GIS, remote sensing, and spatial statistics. Seven of these courses are fully or partially dedicated to cartography instruction; five have already been integrated into the GISPP curriculum (Table 1). While beyond the scope of this discussion, it is important to note that the cartography curriculum also supports the undergraduate major in Geography, undergraduate major in Cartography & GIS, resident MS in Cartography & GIS, and PhD in Geography.

3 Curriculum Organization & Course Catalog

As a result of a multi-year restructuring effort, Roth [26] aligned the cartography curriculum at UW-Madison to an orthogonal pair of axes to capture both the traditional distinction between mapmaking and map use [24, 6, 17] and an emerging distinction between cartographic representation and interaction that was gaining traction in the fields of Cartography, Information Visualization, and Visual Analytics [19, 36, 2, 25] (Figure 1). The conceptual framework sought to harmonize fundamental components of the Robinson era communication model with newer perspectives on the dynamic interplay between spatial data representation techniques and the digitally-mediated dialogue between the map and its user(s). The utility of this framework is its ability to (a) quickly summarize the extent to which the cartography curriculum aligns with a range of conceptual and technical competencies and (b) inform the development of new courses or enhancement of existing curriculum in response to a rapidly changing field and technological innovation. This framework further reinforces the importance of 'fostering core skills around visual representation and interaction,' which Bach et al. [1] identified as a prominent methods challenge for data visualization education.

Figure 1 organizes each of the seven UW–Madison cartography courses within this conceptual framework based on learning objectives. Six of the seven cartography courses cover the pairwise antipodes of these orthogonal axes (i.e., the corners in Figure 1) with greater emphasis placed on the left side of the figure (i.e., the intersections of cartographic representation, mapmaking, and interaction). The seventh course, Geography 572, is positioned at the intersection of these axes to integrate influences and technologies across cartography. The following subsections summarize these course offerings and contextualize their applicability to the GISPP curriculum.

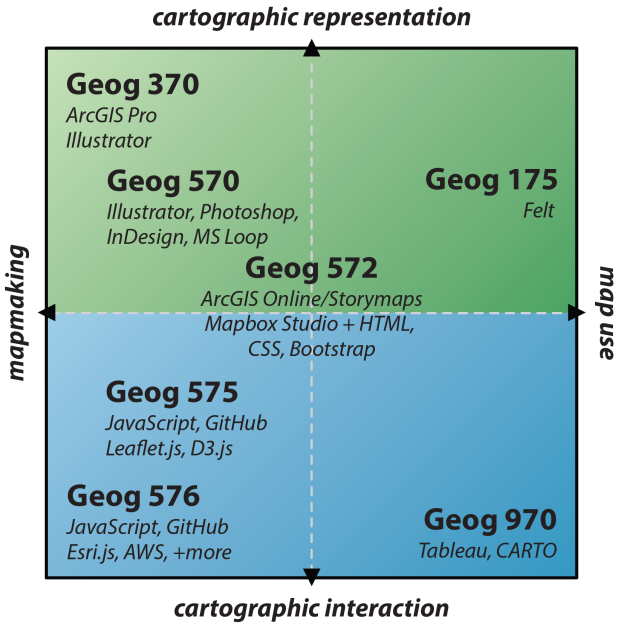

Figure 1: Cartography curriculum at UW-Madison, 2024-2025, organized within the mapmaking v. map use & cartographic representation v. interaction conceptual framework [26].

3.1 Map Use + Cartographic Representation

3.1.1 Geog 175: Mapping Our Changing World

Geography 175 is a three-credit introductory first-year undergraduate seminar that introduces students to the expansive role of maps and geospatial data in popular culture and society. Developed in 2023, this course serves as both an introduction to cartographic ethics and spatial thinking and as a survey of the dynamic and ever-evolving societal role of maps. The course further serves to cultivate a broad critical understanding of how maps function as a powerful tool for communication, while also revealing their underlying power structures and dynamics. Throughout the course, maps are critically explored through transdisciplinary perspectives that span geography, psychology, history, sociology, and philosophy. Students are encouraged to consider and reflect on how personal and societal beliefs and views influence how we capture and represent our world through maps and spatial data products. The course explores how maps serve as tools for change—enabling both positive and negative impacts. This exploration occurs through three major lenses of critical cartography: understanding what maps are, recognizing why maps matter and exploring who creates, uses and benefits from maps. Throughout the semester, students develop map literacy skills and learn about the role of maps within society directly from established guest cartographers from various sectors spanning government, media, industry and research. By the end of the semester, students can appreciate and articulate the power, potential, and importance of maps in our modern complex society. Geography 175 is specifically designed for first-year undergraduates so is not currently available to GISPP students.

3.2 Mapmaking + Representation

3.2.1 Geog 370: Introduction to Cartography

Geography 370 is a four-credit intermediate course on cartographic design and representation. This course covers the theories and best practices needed for thinking critically about map design and transforming design concepts into finished map products. Lecture ma-

terials detail map projections and coordinate systems; map design concepts (e.g., scale & generalization, semiotics, typography, etc.); and thematic map types (e.g., choropleth, proportional symbol, flow maps, etc.). Discussion activities aim to promote active student learning via critique of recent map examples and at least one case study on map design ethics. Laboratory assignments prompt students to apply lecture concepts to a set of four map design assignments and a final project. These assignments are framed as 'design challenges' and require students to find their own datasets in the creation of unique, personalized cartographic design solutions. Laboratory assignment scaffolding introduces the cartographic production workflow using Esri ArcGIS Pro and Adobe Illustrator, with all lab assignments requiring use of both software applications. The goal is for students to develop an understanding of the cartographic design tasks best completed in GIS software versus graphic design software. Geography 370 is a prerequisite course for GISPP ACC and OMP students and part of the core curriculum for FCC and AMP students.

3.2.2 Geog 570: Cartographic Production & Project Management

Geography 570 is a three-credit advanced course on cartographic production and project management. Developed in 2023, this course combines two essential aspects of modern production cartography: advanced cartographic design skills and project management. This project-based course is modeled after the workflow of a professional cartographic design studio. Student team members are "onboarded" and taught the cartographic design workflow spanning ArcGIS Pro, Tableau, Adobe Illustrator, Photoshop and InDesign. Students collaboratively contribute to a print atlas project. Each student serves as a topic lead responsible for pitching and managing an atlas topic from start to finish. The course covers a comprehensive design pipeline, spanning from basic spatial data preparation and page layout design to the comparison of vector and raster design, as well as the development of advanced design templates. Additionally, students learn how to effectively use collaborative and project management tools that are gaining popularity in the industry (e.g. Microsoft Loop and Project/Planner). Accordingly, the course is structured around the four stages of project management: initiation, planning, execution, and closure. Students are taught how to plan, track, manage, and monitor project tasks using project management principles such as the iron triangle (balancing scope, time, cost/resources) and Gantt charts. This course prepares students for a more seamless transition into professional roles where cartography and project management expertise are not only expected but intertwined. Geography 570 is currently an elective for GISPP AMP students with future course development efforts planned to translate the course into an online offering that will serve as an elective for GISPP students enrolled in OMP or ACC.

3.3 Mapmaking + Interaction

3.3.1 Geog 575: Interactive Cartography & Geovisualization

Geography 575 is a four-credit advanced course on interactive web map development. The course examines cartographic interaction design, drawing on relevant concepts from human-computer interaction (HCI), Information Visualization, Usability Engineering, and Visual Analytics. Discussion activities prompt students to tactfully critique the current status of interactive mapping and reflect on where it is headed as technologies advance. Laboratory assignments introduce the technical competencies needed to design and develop interactive maps for web and mobile mediums. In response to shifts in mapping technology and professional practice, Roth et al. [28] conducted a three-stage research study to inform a significant curriculum transition away from reliance on proprietary plugins (e.g., Adobe Flash and ActionScript) and towards integration with open web standards and libraries (e.g., HTML, CSS, JavaScript, Leaflet.js and D3.js). Leaflet and D3 are introduced as two separate labs that are integrated into a broader 10-week linear sequence of modularized technical lessons designed to provide the necessary scaffolding for additional competencies needed for contemporary web development (e.g., the DOM, AJAX, GeoJSON/TopoJSON formats, browser debugging tools, Github, etc.). Students also complete a multi-week, intensive group final project, resulting in a substantive online portfolio piece. Geography 575 is a required course for GISPP OMP students and an elective for ACC and AMP students.

3.3.2 Geog 576: Geospatial Web & Mobile Programming

Geography 576 is a four-credit advanced course on full stack interactive web map development for mobile applications. Redesigned in 2022-23, this course aims to bridge the gap between the front-end development skills introduced in Geography 575 and the additional back-end development skills needed for deploying a complete web application. Lecture materials are framed as 'technical documentation' that details the process of building responsive, mobile-first web applications that are connected to geospatial databases and provide analytical functionality. Students learn how to use various web technologies/frameworks (e.g., HTML, CSS, JavaScript, Node.js, Express, AWS, Leaflet.js, Esri.js, APIs, GitHub, etc.) to create dynamic maps, geovisualizations, and spatial queries. The course includes a series of hands-on laboratory assignments that serve as the scaffolding for two major self-directed projects — *one focused on 'pure' JavaScript stacks and one dedicated to 'cloud-based' full stacks* — that require students to apply their skills to real-world geospatial problems. Geography 576 is currently only offered online and is a required course for GISPP OMP students and an elective for ACC students.

3.4 Map Use + Interaction

3.4.1 Geog 970: Geovisual Analytics

Geography 970 is a three-credit graduate seminar that rotates between topics in cartography and GIS. The most recent course offering (Spring 2024) focused on exploring the state-of-the-art in geovisual analytics through the survey of seminal and current literature, covering both theoretical concepts and applied use cases across a variety of domains. In this seminar, students undertake a literature review on a narrowly focused topic of interest directly related to geovisual analytics; complete three lab assignments to gain hands-on experience using and evaluating industry standard geovisual analytics platforms (e.g., CARTO, Tableau, etc.); and develop a team term project that (a) identifies a problem that could be solved leveraging geovisual analytics, (b) prototypes a geovisual analytics application to solve that problem, and (c) presents a proposal for how to systematically evaluate the design solution. Geography 970 is currently only available to students in our resident MS and PhD programs; however, future course development efforts plan to formalize an advanced online course offering of "Geovisual Analytics" that will serve as an elective for GISPP students enrolled in either ACC or OMP.

3.5 Integration

3.5.1 Geog 572: Graphic Design in Cartography

Geography 572 is a four-credit advanced course that integrates a wide range of conceptual and technical competencies needed to excel as a professional cartographer. The overarching theme of the course is ethical visual storytelling with lecture materials set up as three-act narratives, introducing the origins, evolution, and design insights for prominent theoretical frameworks used in cartography. Students develop a critical understanding of "how maps work" [19] from the perspectives of visual perception (i.e., *how maps are seen*), visual cognition (i.e., *how maps are understood*), and visual culture

(i.e., *how maps are imbued with meaning*). These theoretical framings enable students to trace the etiology of the mapmaking and map use canon in cartography and reflect on how these principles require rethinking for both cartographic representation and interaction as mapping technology evolves. The course consists of four laboratory assignments, three of which are framed as 'design challenges' that prompt students to create novel longform storymaps, interactive mapping guided tours, and custom-styled map tilesets. The final assignment involves walking students through the process of creating an online web portfolio using GitHub. The course purposely does not introduce JavaScript programming, instead focusing on GUI-based tools and the fundamentals of HTML and CSS. Geography 572 is a required course for GISPP OMP students and an elective for ACC and AMP students.

4 Discussion

In this section, we reflect on the process of developing the UW–Madison cartography curriculum and integrating it into the GISPP certificate and degree offerings. We detail several key takeaways for designing and implementing a cartography curriculum that meets the needs of a wide range of learners and positions them for success as professional cartographers. These takeaways are neither exhaustive nor prescriptive; rather, they aim to serve as adaptable recommendations for informing the design of cartography curricula at other universities, recognizing that course volume and resources for cartography at UW–Madison may be greater than other institutions.

4.1 Takeaway 1: Employ a 'Mixed-Methods' Student-Centered Approach to Pedagogical Design

We ground the design of the cartography curriculum in a pedagogical philosophy and approach that integrates active learning [31, 32], collaborative learning [23, 15], project-based learning [34, 11], scaffolding [22, 30], and experiential learning [10, 33]. Most of our cartography courses are 4-credit offerings split between lecture material, delivered synchronously in-person or asynchronously online, and a hands-on "laboratory" component. Lecture materials are designed to facilitate active discussion and tactful critique of real-world map examples. Laboratory materials are designed to complement and reinforce the lecture materials, prompting students to complete a set of self-directed map design assignments and final projects. Assignments are typically framed as client requests or guiding scenarios, in which students are tasked with finding and preparing their own datasets and developing a cartographic design solution informed by elements of their professional or personal interests. Instructor support is scaffolded such that demonstration and intervention decrease as the course progresses and students' skills and confidence increase. This project-based learning approach promotes design thinking and problem-solving workflows rather than prescriptive step-by-step tutorials and empowers students at different levels of learning to tailor their active learning experience to their unique interests [13].

With respect to GISPP specifically, students in the accelerated in-person MS and online MS programs also complete a practicum course in their final semester of study. A practicum is a form of experiential learning, in which students apply knowledge, skills, and tools to real-world contexts in preparation for the transition from academia to a professional environment [4]. In our practicum, students draw upon cartographic concepts and geospatial skills obtained throughout their time in the program to conceive, design, and implement map-based projects that inform place-based challenges. As part of the project development process, students connect with academic and professional mentors, draft detailed project plans, record an elevator pitch, create digital mockups, and conduct user testing exercises. Final deliverables include the cartographic design solution or product, a demonstration video, executive report, and a comprehensive digital portfolio showcasing the students' unique map projects completed throughout their time in the program. Digital portfolios foster professional networking opportunities, promote self-reflection and critique, and thus are particularly important in design-oriented fields such as cartography and visualization [12, 3].

4.2 Takeaway 2: Implement a Strategy for Keeping Cartography Curriculum Current, Relevant & Synchronized Across Learning Modalities

In the Geography Department at UW-Madison, tenure-track faculty within the Cartography/GIS subgroup are responsible for leading the development of the cartography and GIS curriculum. These faculty members also teach most of the in-person course offerings, which can enroll a mix of undergraduate students, resident research-oriented graduate students, and GISPP accelerated non-thesis graduate students. When the online GISPP offerings (OMP, FCC, ACC) launched in 2016-2018, the in-person curriculum was translated into an asynchronous online learning experience with support from instructional designers. These online GISPP course offerings are primarily instructed by two full-time teaching faculty and five part-time lecturers who also work in industry. Thus, professional-oriented students in our online programs benefit from a combination of faculty-developed theoretical content and practical insights from an instructional team possessing relevant industry experience.

The challenge, however, is that while resident course offerings tend to be continuously updated by faculty, we did not initially have a plan in place to update the online course equivalents. As a result, online course offerings eventually became outdated and a primary recommendation coming out of an internal five-year self-study was to devise a plan to synchronize course content across in-person and online learning modalities. This plan, now in-progress, includes three integrated components:

1. **Collaborative Curriculum Development**: We employ a collaborative, working group model – *consisting of faculty members, GISPP online instructors, students, and the GISPP director* – to scope and implement the maintenance and expansion of conceptual and technical lessons. Faculty members are charged with leading the development of new theoretical content; GISPP online instructors ensure the cohesive integration of the new course content into the online learning experience, oftentimes refining course discussions, critique activities, and rubrics to support the new content; students participate in the creation or updating of technical laboratory content; and the GISPP director serves as the project manager to help coordinate the effort and ensure timelines and deliverables are met. Course updates are prioritized based on student evaluations and range from minor enhancements to complete redesigns.

   With respect to the online cartography curriculum, the collaborative working group model has been used to update Geography 572 (Graphic Design in Cartography) and completely redesign Geography 576 (Geospatial Web & Mobile Programming). Geography 572 was revised to incorporate conceptual advances in cartographic storytelling, spatial narratives, and data journalism [27] and integrate the latest technologies (e.g., ArcGIS Storymaps) to enable students to create their own interactive place-based stories. Geography 576 advanced from a Java-oriented, mobile GIS applications course to a full stack interactive web mapping application development course that exposes students to a variety of JavaScript APIs, cloud technologies, and mobile software development kits. Geography 370 (Intro to Cartography) is currently under revision and will launch in Fall 2024.

2. **Conceptual Grounding with Technological Diversity**: Supporting the professional cartographer in staying current and

well-rounded in a rapidly-evolving field requires a cartography curriculum that is both conceptually grounded and exposes students to a wide variety of mapping technologies. Proficiency in programming, using scripting languages such as JavaScript, has become an essential job requirement for cartographers working with interactive, web mediums. GISPP does not require any previous coursework in computer science or engineering; however, a key outcome of our programs is to equip students with the programming skills needed to be successful as interactive web map developers. Students entering GISPP's certificate and degree programs possess a wide range of skill level and comfortability with programming, from being completely new to scripting to working as software developers or GIS engineers.

Supporting the needs of a highly variable student profile with respect to technical competency is challenging. We approach this challenge through careful organization of curriculum based on fundamental concepts that remain relatively consistent over time (e.g., mapmaking, map use, representation, interaction) and an iterative approach to updating the supporting technologies in response to industry trends. Moreover, laboratory assignments are typically framed as client requests or 'design challenges' opposed to technology-based tutorials, thus can not only remain consistent over time while the underlying technology stack evolves, but also empower students possessing different skill levels to develop unique projects that reflect their personal interests and capabilities. This strategy also aims to avoid path dependencies or the use of a single cartographic or geovisualization technology beyond its functional life due to expertise or comfortability with it [9]. On one hand, this approach limits the depth of skill or mastery students can achieve in a single technology. On the other, centering a course on a single technology makes the course prone to needing ongoing major revisions or eventually becoming obsolete due to larger shifts in the technological landscape. Striving for breadth over depth in teaching technological competencies further instills that mantra of "lifelong learning" needed to be successful in rapidly changing fields [14].

3. **Open Educational Resources**: It is not practical for a single cartography (or visualization) curriculum to maintain up-to-date educational resources that cover all possible conceptual and technical competencies. Open educational resources (OER) aim to make lessons, assignments, tutorials, and other learning materials freely accessible to educators, students, and self-learners for (re-)use in educational and research contexts. A key characteristic of formal OER projects is ongoing active development and community engagement [7]. Thus, OER initiatives not only enable cartography educators to share the workload of creating and maintaining curriculum, but also help to build a network of professional cartographers, seeking to enhance their skillsets as technology changes.

   In the case of GISPP, we integrate OER, such as the *Geographic Information Science & Technology Body of Knowledge* [8, 35], into the cartography curriculum to expose students to diverse perspectives on good cartographic practices. We also actively contribute to OER, most notably through our development of an online interactive cartography and geovisualization workbook hosted on GitHub [29]. The workbook titled *Web Mapping* resulted from a series of pedagogical research projects [28, 30] conducted in UW-Madison's Cartography Lab. These projects derived new insights into how to more effectively teach design-oriented students how to code and approach the map creation process through the perspective of a computer scientist. The workbook reflects an 11-chapter, spiral curriculum of interconnected lessons that incrementally build proficiency in interactive cartography and visualization. Key concepts are purposely repeated throughout the workbook while the complexity of the design and coding tasks increases. This OER serves as both the basis for Geography 575's laboratory component across in-person/online learning modalities and as a stand-alone resource for anyone wishing to develop practical skills in interactive web map development.

Together, this integrated strategy of collaborative curriculum development, conceptual grounding with technological diversity, and OER enables us as cartography educators to be more agile [1] and responsive to shifts in student needs and industry trends.

4.3 Takeaway 3: Support Degree Flexibility through Course Bracketing & Credential Stacking

As is clear from above, the development and expansion of a cartography curriculum requires careful consideration of a diverse student audience and a myriad of evolving mapping technologies. In the case of GISPP, the cartography curriculum must also fit neatly within four different academic programs that serve students in different career stages, learning modalities, and geographic locations. To address this challenge, we *bracket* the cartography curriculum such that learning objectives are constrained to the course level, limiting prescribed course sequencing [9]. For example, Geography 175 and 370 assume no existing knowledge in cartography and can be taken as standalone general electives; Geography 572, 575, and 970 can be taken flexibly in any order; and Geography 570 and 576 serve as natural progressions of 370 and 575, respectively. To ensure cohesion across non-prescribed course sequences, we assign a core set of redundant lessons in multiple courses to reorient students to fundamental cartographic concepts but in the context of different learning objectives and problem-spaces.

This bracketing approach aims to promote greater flexibility in how students put together their course plans and creates a framework for credential stacking, in which GISPP's two certificate programs can serve as gateways into its MS programs. For example, a student seeking introductory-level skills may first embark in the Fundamentals Capstone Certificate program, completing Geography 370 (Intro to Cartography) as part of their course sequence. Upon completion of the certificate, that student could then pursue a custom-tailored Advanced Capstone Certificate, consisting solely of advanced-level cartography courses (e.g., Geography 572, 575, and 576). Finally, that same student who has now completed FCC and ACC could then enroll in an accelerated or online MS, in which case they would only need to complete a limited amount of additional advanced-level coursework in both cartography and GIS to earn the credential.

5 Conclusion

Cartography — *as an academic field and profession* — is ever-evolving. As educators, we have a responsibility to our students and the discipline to embrace change and act agilely to meet the challenges of the cartographic profession [1]. To support the professional cartographer, we employ a mixed-methods, student-centered approach to pedagogical design that combines active, collaborative, project-based, and experiential learning techniques. Our curriculum is collaboratively developed, conceptually-grounded, technologically diverse, and integrated with open educational resources to ensure it remains current, relevant, and synchronized across in-person/online learning modalities. Finally, we use course bracketing and credential stacking to foster greater autonomy and flexibility in how students craft their individual learning experiences and course plans. Developing and maintaining a robust cartography curriculum is challenging yet essential for meeting the needs of the professional cartographer.

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