User-oriented GIS tools in higher education of urban design and planning

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ABSTRACT: Geographic information systems (GIS) have emerged as indispensable tools for decision-making, planning and problem-solving tasks across various domains in today's evolving world. However, there exists a pressing need to augment the utilisation of GIS tools in higher education of urban design and planning to foster a user-oriented approach. This article explores the imperative of integrating GIS tools more comprehensively into higher education curricula to empower students with the skills necessary to leverage geographic information effectively. Selected cases from the Programmes of Architecture and Spatial Development at Gdańsk University of Technology (Gdańsk Tech), Poland, and Physical Planning at the Norwegian University of Science and Technology (NTNU), Trondheim, Norway, demonstrate students' experience with user-oriented GIS tools. Results reveal there is a growing demand in higher education to integrate GIS tools into service design approaches and participatory practice. Enhancing access to GIS technologies for students and stakeholders will encourage collaboration between education and practice, facilitating real-time adjustments and cross-disciplinary efforts.

INTRODUCTION

In today's dynamic world, digital technologies and shifting societal norms present challenges and opportunities. Higher education increasingly seeks innovative digital tools for urban design and planning to engage diverse stakeholders effectively [1][2]. While geographic information systems (GIS) tools are popular in academia and practice, there is a need to integrate them better in higher education of urban design and planning. This is not only to teach students new tools or assess and integrate emerging apps and plug-ins. The authors argue that there is an emerging need for students in architecture, engineering and planning to develop soft skills while using GIS tools, and a more agile and user-oriented approach to adapt to the rapidly changing landscape.

User-oriented GIS tools (such as geo-surveys or field data collection applications) enhance students' learning, and a user-oriented approach is needed to better cater to the needs and preferences of users, focusing on the ease of use, accessibility and functionality. These tools are often easy to learn in higher education by offering intuitive interfaces, customisable features and comprehensive support to help users efficiently analyse, visualise and interpret spatial data. Moreover, teaching such tools will result in specific user-oriented skills. By putting users at the centre of the design process, user-oriented GIS tools empower individuals across various domains to leverage geographic information effectively for decision-making, planning and problem-solving tasks.

Students not only learn to identify and respond to users' needs but in some cases to co-design with them, to attentively learn to address different perspectives of stakeholders while also acknowledging their expertise and roles [3]. There is a need to facilitate creative thinking for generating innovative ideas among students, while also structuring thought processes around key themes and exploring various alternative possibilities and concepts [4]. Moreover, problems faced by students often occur at the edge of disciplines and as such require an interdisciplinary approach [5].

A user-oriented design approach for urban design and planning where end users are included in the delivery of services/product development, here namely, an urban transformation or development project, should embrace a wide range of collaboration-focused approaches, including: 1) participatory design, which originated from Scandinavian workplace negotiation [6]; 2) co-design, which refers to the formats to include actors and more general stakeholders; and 3) co-creation, which describes methods enabling an exchange of ideas between actors [7]. An operationalised version of these approaches, such as design thinking [8] with accompanying methods to solve problems, has been used in design studios as an informed, human-centred approach based on qualitative values and goals and supporting the design of a liveable urban environment [4]. Focusing on this context, this research aims to investigate the potential of GIS tools within the realms of urban and architectural studies in higher education to promote participatory approaches. Specifically, it seeks to discern whether the utilisation of geospatial data acquisition techniques can foster a culture of engagement among students and practitioners, ultimately facilitating a user-oriented approach to urban design and planning processes.

In this article, the authors employ two primary qualitative research methodologies. The first one is the case study analysis method, which involves a detailed examination of selected examples of GIS tools utilisation by students in the classroom, which allows for the identification of factors influencing the outcomes of the studied phenomenon [9]. In the featured case, best practice, recognition and award are sought, which are pivotal for the education of future designers and planners well prepared for their professional work. Thanks to the use of this method, it was possible to refer to the theoretical concept of the user-oriented approach [10] in urban design and planning in real-world practice [11]. The second method is a survey [12] conducted among students of the Programme of Spatial Development in the Faculty of Architecture at Gdańsk University of Technology (Gdańsk Tech), Poland, in 2022. It was designed to collect students' opinions on the usefulness of GIS tools within the realms of urban studies in higher education to support their readiness for work in planning praxis using participatory approaches.

Every year, within the Geographic Information Systems II course at Gdańsk Tech, an annual assessment survey concerning the curriculum and instructional methods is conducted. In 2022, a fraction of the students enrolled for the course participated in the anonymous survey, providing responses to four qualitative inquiries, resulting in a cumulative total of 26 responses.

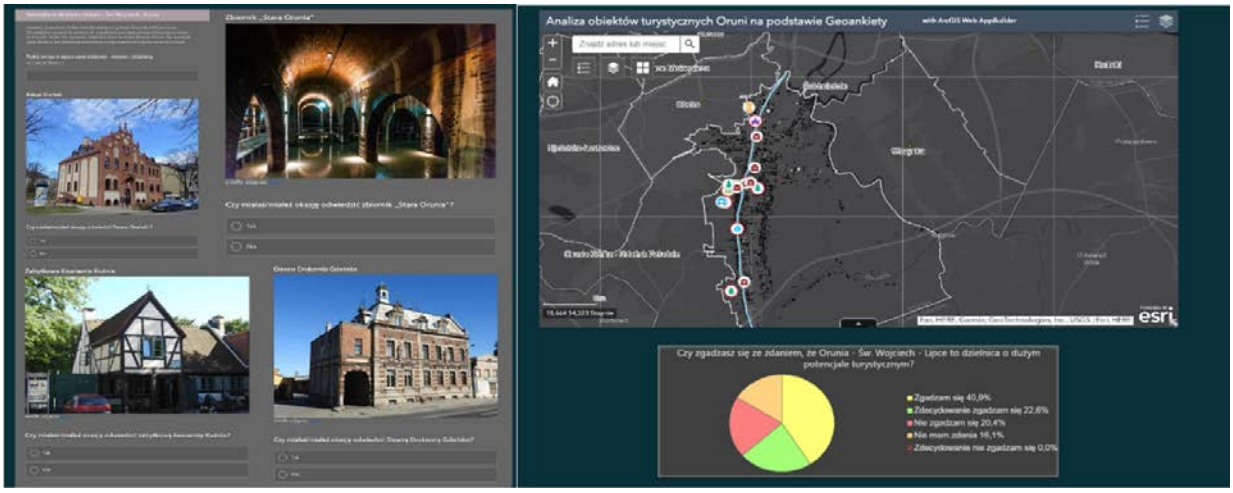
This article embarks on an evaluation of selected cases wherein students are involved in the application of GIS tools, serving as a foundation for integrating user-oriented design and planning methodologies. The study examines experiences from the Programmes of Architecture and Spatial Development at Gdańsk Tech, as well as the Programme of Physical Planning at the Norwegian University of Science and Technology (NTNU) Trondheim, Norway.

USER-ORIENTED GIS TOOLS SUPPORTING PARTICIPATION IN URBAN DESIGN AND PLANNING PROCESSES AT GDAŃSK TECH

Today, user-oriented tools, notably GIS software, are prominent in architecture and urban planning, aiding data analysis. GIS tools introduced to students early in their education enable them to identify patterns, assess relationships and make informed decisions, fostering collaborative creation. In this section, geospatial tools used at Gdańsk Tech across diverse academic disciplines in the Faculty of Architecture (fields: architecture and spatial development) are exemplified and assessed.

In the 4th semester of the Spatial Development Programme, a year-long course focused on multi-criteria analysis and spatial problem-solving methodologies introduces QGIS software together with essential analytical tools. Subsequently, the following 5th semester uses ArcGIS Pro software for more intricate analyses, comprising theoretical assignments and an analytical project situated within an urban area designated by the municipality for prospective modifications. During this latter semester, students are structured into paired teams to formulate interactive analytical frameworks, granting them autonomy in tool selection and data presentation methodologies.

In the practice of spatial planning in Poland, the boundaries between urban programming and design are blurring, emphasising the need for designers with interdisciplinary knowledge, who can assess areas through a comprehensive lens to identify crucial spatial conditions. The focal role of higher education lies in the integration of these GIS tools, which provide the opportunity for autonomous spatial data analysis, enabling rapid adaptation to changing conditions - a pivotal need in today's dynamic environment. Teaching students to gather and utilise societal data is crucial, as users, such as residents, tourists, entrepreneurs and officials play a pivotal role in decision-making regarding space. Therefore, educating students to harness GIS tools and understand the significance of societal input is essential for effective spatial planning in contemporary Poland. Figure 1 shows the results of Gdańsk Tech students using GIS tools.



a) b)

Figure 1: a) geo-survey on tourism in the Orunia - Św. Wojciech - Lipce district of Gdańsk (l) (source: https://s1884346.wixsite.com/kinga-i-zuzia/blank-2); and b) results of analysis of tourist facilities in the Orunia district of Gdańsk based on survey research (r) (source: https://storymaps.arcgis.com/stories/7d344e925b744703b75ff259096ef1e8) (co-authors: K. Długińska and Z. Zdrojewska, students, 5th semester of the Spatial Development Programme).

An important tool utilised in Gdańsk Tech courses (like the first semester of the Architectural and Urban Design course in the Master's Programme) is Survey123 (ArcGIS application for creating geo-surveys), which is an excellent tool for collecting data due to its ability to gather information in the context of geolocation. Moreover, geo-surveys can be used to monitor changes over time and space, enabling a better understanding of cultural, social and economic differences between different regions. They can serve as effective research tools for analysing phenomena related to geolocation (Figure 1).

In the Architecture Programme, different courses offer learning GIS tools geared towards user-centric applications. In the first semester of the Master's Programme, students engage in competitive projects aimed at addressing specific spatial requirements of the analysed urban environment. They have a chance to learn to conduct analyses aimed at facilitating practical exploration and engagement with the local population. Students opt to conduct geo-surveys (Figure 2) to gain insights into the perceptions of space held by users. These surveys provide valuable qualitative data that enriches traditional urban analysis. These endeavours yield a multitude of discoveries, primarily offering valuable insights into the requirements of urban space users.

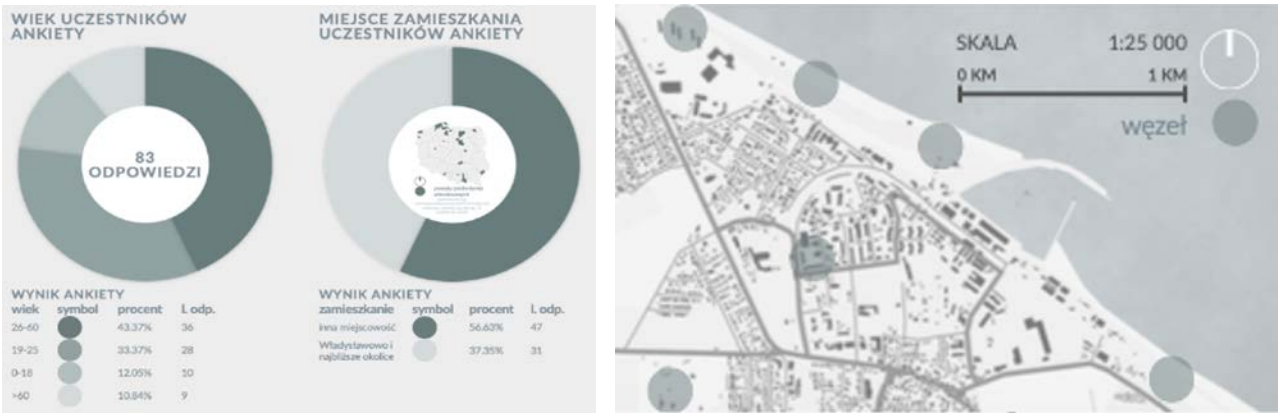


Figure 2: Results of the geo-surveys: age of participants and place of residence (l); places where residents, etc spend time - nodes (r) (authors of the geospatial surveys: K. Dawert, B. Kaznowski, K. Kiersztejna, K. Kozieł, K. Kąkol and U. Maczuga, students of Architecture, 1st semester of the Master's Programme).

The second important user-oriented tool introduced to students in the Architectural and Urban Design course in the Master's Programme is QuickCapture - invaluable for collecting data in the field due to its user-friendly interface and efficient workflow. Overall, QuickCapture streamlines the data collection process, enhances data accuracy and improves efficiency. Students learn very quickly making it an essential tool for field-based research and data collection activities.

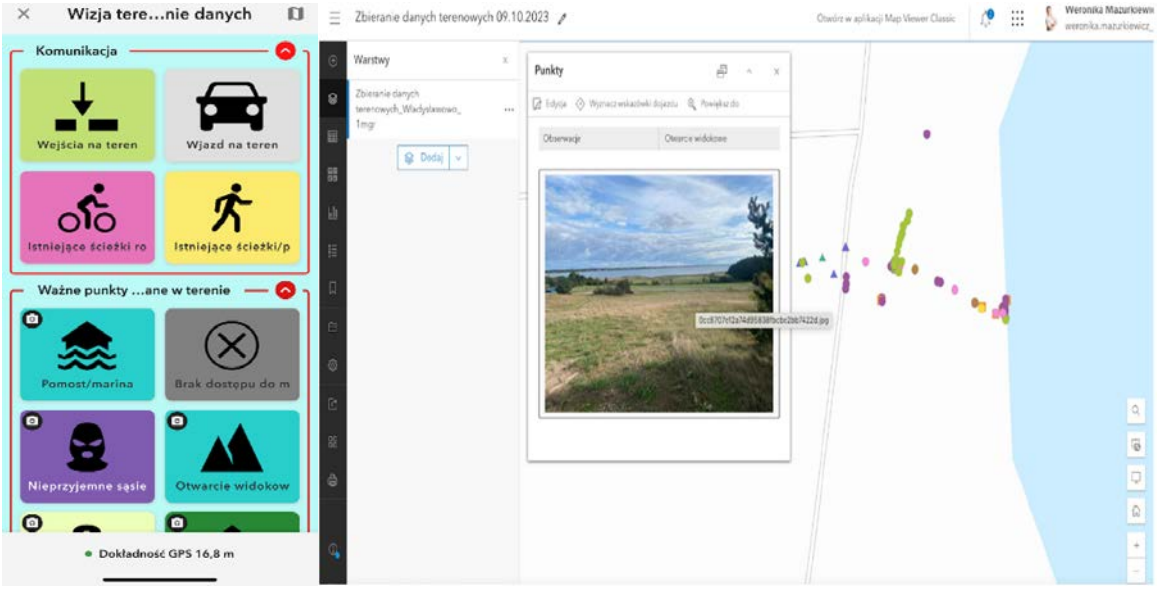


Figure 3: A QuickCapture (ArcGIS application) interface, crafted by the first author of this article, for gathering field data for plot analysis in Władysławowo, Poland. Predefined data categories streamline the process, and the interface operates seamlessly with or without an Internet connection, ideal for fieldwork (l); a story map featuring content derived from field data collection in Władysławowo. Each piece of information is georeferenced, with some accompanied by corresponding photos (r). Architecture, first semester of the Master's Programme.

It has been acknowledged in both the Architecture and Spatial Development Programmes that using geospatial tools, such as StoryMaps and ArcGIS applications in an on-line mode with accessibility for the entire group exploring a given topic,

enables students to better organise and share knowledge. They conduct analyses encompassing a wide array of categories. To carry out these analyses, students utilise a diverse set of analytical techniques, ranging from 3D analyses employing digital terrain models to network analyses, space syntax analysis, cluster analyses, heat maps, demographic analyses, raster analysis, and beyond. For effective communication of the results, students utilise various visualisation methods, such as on-line maps, Web applications or story maps. Figure 4 and Figure 5 depict some of the analyses conducted and presented as interactive maps/on-line applications/story maps on the Web sites maintained by theirs authors.

Figure 4: On-line map showing space syntax analysis demonstrating integration analysis for car traffic in the Orunia district of Gdańsk (source: https://infrastrukturagdansk.wixsite.com/mojastrona\) (authors: A. Dziatko, J. Płoski and T. Sitkowski, students, 5th semester of the Spatial Development Programme).

Figure 5: On-line map showing flood risk in the Orunia - Św. Wojciech - Lipce district of Gdańsk (source: https://s188548.wixsite.com/masterplan-rozwoju-d) (authors: M. Plenikowski, and W. Szczucki, students, 5th semester of the Spatial Development Programme).

In the Spatial Development Programme, the GIS educational material is provided in the form of tutorials available on the e-learning platform. The tutorials include content that may be useful in the process of spatial planning, landscape analyses, preparation for investment implementation, urban mobility, spatial monitoring and studies on the quality of urban environment. What is useful in professional work is taken into account. The programme concludes with a research project that students jointly prepare and conduct.

The outcome of the student's project is a Web site that compiles the data sources utilised, presents the results of all analyses conducted in the aforementioned formats and highlights the most significant conclusions. Notably, students learn from a common platform, fostering collaboration and knowledge sharing. By dividing students into thematic groups, a comprehensive picture of the studied district is obtained. The Web site is shared with the personnel of local government units operating within the project's designated area.

GIS TOOLS IN PHYSICAL PLANNING AT THE NTNU

A two-year Master's degree programme in Physical Planning has been tailored for students aspiring to specialise in physical planning aligned with the Planning and Building Act in Norway. This programme enables participation in community planning and the moulding of the physical environment, impacting the future and shaping people's daily experiences. The programme underscores these crucial elements with a focus on sustainability, utilising digital and GIS-based tools. Additionally, students have to take an obligatory course in GIS and learn the ArcGIS program.

In physical planning, GIS tools used by students to incorporate stakeholders' perspectives are diverse, and students have the freedom to choose from many cost-free options available on-line. They include:

- ArcGIS Online (this program's licence is also available for the NTNU students): this platform allows students to create interactive maps and share them with stakeholders. It facilitates collaboration and engagement by providing easy access to spatial data and analysis tools.
- QGIS (Quantum GIS): QGIS is an open-source GIS software that students can use to create maps, analyse spatial data and incorporate stakeholder input. Its flexibility and customisation options make it suitable for various planning projects.

Other tools including CommunityViz or GeoPlanner are less popular but are promoted at university for more advanced work with stakeholders involved in higher education:

- CommunityViz: this ArcGIS-based software focuses on community planning and allows students to visualise different scenarios and their impacts on stakeholders. It enables participatory planning by integrating feedback from community members into the planning process (source: https://communityviz.com/).

- GeoPlanner: GeoPlanner, often integrated with ArcGIS, enables students to design and evaluate different land use scenarios collaboratively. It facilitates stakeholder engagement through scenario-building workshops and interactive planning sessions (source: https://www.geoplaner.com/).

At NTNU courses, such as Site Planning or Regional and Municipal Planning, students are introduced to the application known as FOCUS Arealplan. This software is utilised for creating plans following standardised regulations for plan design set by national guidelines in Norway. These regulations encompass aspects, such as the use of symbols (colour, line types, thicknesses, hatching), plan geometry (topology) and information storage. FOCUS aids in ensuring compliance with these regulations. It functions as a plug-in for the designing/drawing tool AutoCAD, and it is not a typical GIS tool that captures, stores, analyses and presents spatial information visually. FOCUS requires a separate licence available for students and provided by the university for download and usage. The FOCUS application is used in municipalities to draw plans and is eagerly learnt by students who plan to work in urban planning in Norwegian municipalities. This implies that the use of digital tools by practitioners serves as the best stimulus for students to learn and test in their university work.

STUDENTS' EVALUATION OF THEIR EXPERIENCE WITH USER-ORIENTED GIS TOOLS AT GDAŃSK TECH

Ex-post student evaluation conducted in January 2022 allowed gaining valuable insights into students' perspectives on learning and teaching methodology with related reflections on the use of GIS tools. The questionnaire included general inquiries, such as: What are the areas for improvement or what did not meet your preferences? What components did you find unnecessary, and What aspects did you find particularly useful? It granted the opportunity to gain insight not only into the positive aspects but also into the deficiencies students identified in their learning experiences. Students' answers focused on the following issues: technical, thematic, practical.

Students stressed that *learning ArcGIS tools acquiring proficiency in a versatile system applicable beyond academia* (8% of the answers). They appreciated learning about various tools for obtaining spatial data and the methods of processing them, especially in the context of social attributes, and they valued the possibility of learning the ability to implement their ideas for their projects (16% of the answers). Learning GIS user-oriented tools broadened the horizons of thinking about space in various contexts, especially allowing to answer societal needs, which is why students suggested that GIS classes should appear at earlier stages of studies and be further integrated with other courses (8% of the answers).

DISCUSSION AND CONCLUSIONS

GIS has been regarded as one of the greatest revolutions in planning education [13]. For the past 30 years, it has transformed the landscape of teaching in sociology, geography, economy and urban studies. Teaching geospatial tools, when tailored for end-users, facilitates a shift towards service-oriented, agile, and user-experience-driven approaches needed and appreciated in the professions of city planning and design. These tools, utilised by students, provide opportunities to address urban design and planning challenges through a user-centred lens. By integrating urban design, planning and GIS skills, students gain insights into both present conditions and future projections in a dynamic environment. Incorporating GIS tools into courses related to spatial management provides the opportunity to collect data, analyse processes and visualise changes across various scales [14].

This study argues for better and more comprehensive integration of GIS tools into higher education curricula to empower students with the skills necessary to leverage geographic information effectively in a user-centred manner. Additionally, it emphasises the importance of students practising the incorporation of qualitative data into GIS studies.

Findings indicate that GIS tools supporting user-oriented design approaches in urban planning, where end-users actively contribute to service/product development [4], are widely known by students at Gdańsk Tech and the NTNU. Still, more attention is needed to integrate these tools into courses. The presented student projects from Gdańsk Tech show that much attention has been paid to addressing the gaps raised in the urban planning practice in Poland, where the boundaries between urban programming and design are blurring. This effort is important as urban conditions of urban areas analysed by students, require often more comprehensive studies including gathering and utilising societal qualitative data with the great help of GIS tools.

The evaluation of geospatial tools at Gdańsk Tech, based on a student survey and authors' observations of student work, reveals numerous strengths across various applications: geo-surveys, field data collection and on-line collaboration. Students benefit from these tools by gaining multi-dimensional perspectives, real-time data visualisation, and understanding spatial dynamics and stakeholder involvement. Limitations include the need for paid licences or Internet access, time-intensive data preparation and limited stakeholder access to digital technology. The student survey highlights the emphasis on real-world problem-solving and a user-centric approach to learning GIS tools.

The contemporary role of academia serves as a facilitator of emerging modes of learning, preparing future generations of designers to take responsibility for shaping high-quality built environments [15]. Study shows that students willingly engage in learning processes focused on applying user-oriented tools to gather information and generate knowledge about various spatial contexts, aiming at the high quality of urban spaces. This involves understanding the specific

needs and perspectives of different user groups, such as residents, tourists, entrepreneurs and officials, within particular geographic areas. Students appreciate the opportunity to collect spatial data and learn and gain insights about the town, city or region from their own and stakeholders' perspectives. They enable learning aspects of social values and participatory planning through collaborative efforts involving various stakeholders, such as scientists, local governments, community residents, NGOs and others. Work in teams allows them to strengthen their ability to collaboratively solve specific research problems. Facilitated by lecturers who use GIS tools both in research and in practice, students delve into topics pertinent to contemporary architecture, urban design and planning.

Digitalisation plays an important role in producing, transferring and communicating knowledge in the built environment [15]. Since most of the knowledge regarding built environment and construction is tacit or implicit, the special role of the university involves the necessity to take an active position in disseminating this knowledge embedded in people, organisations, societies and cultures and coming from experience, thinking and competence (tacit) and best practices and application (implicit). This knowledge needs to be actively shared in formal, semi-formal and non-formal activities like consultations with societal actors and practitioners.

This study confirms that using GIS tools greatly benefits communication among various participants, including academics and practitioners, involved in designing and planning student projects at both Gdańsk Tech and the NTNU. This emphasis on user-oriented methodologies not only enhances students' technical skills but also fosters a deeper understanding of the complex interplay between human activities and the built environment. Ultimately, students are equipped with the capacity to contribute meaningfully to spatial planning, decision-making and problem-solving processes in diverse professional contexts. Making GIS tools accessible via Web applications and Web sites encourages broader participation.

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