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ORIGINAL RESEARCH

Bridging communities and schools in Urban development: community and citizen science

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Abstract

This paper presents the results of two community and citizen science research projects – *Cities at Play* and *Community Drive* – in which young students (aged 11–15) from vulnerable residential areas in Copenhagen, Denmark, collaborated with architects and urban developers to engage in urban development initiatives in their neighborhoods. An educational design was developed over the two research projects in which students underwent phases of discovery, interpretation, ideation, and experimentation. Data were collected from surveys, observations, and interviews to elucidate the ways that three bridges central to community and citizen science projects can function. These include professional (bridges student learning in school and professional communities outside school), citizen (bridges student learning in school and local communities), and student (bridges student learning in school and new student communities) bridges. This research makes both theoretical and practical advancements. Theoretically, it advances our thinking about the diverse roles that participants in multi-sector partnerships can have, as well as how CCS widens the view of cultural asset-based learning by viewing students as experts of their local communities. Practically, we offer four guidelines that were gleaned from the results that can be instructive for the design of future educational community and citizen science projects.

Keywords Community and citizen science · Design-based research · Urban development

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Introduction

Community science and citizen science have traditionally been related to public engagement in scientific research activities, where citizens and members of local communities actively contribute to science through their intellectual efforts, local knowledge, tools, and resources (Ballard et al., 2017). Community and citizen science (CCS) links community science with citizen science, with a methodological focus on the involvement of communities of citizens as collaborators in research and development processes. Citizen science often involves projects in which the public primarily participates in collecting and categorizing large datasets (Shirk et al., 2012), while CCS projects focus heavily on citizen communities as collaborators throughout extended parts of project development and research phases, including co-developing questions, collecting and analyzing data, and disseminating findings (Harris et al., 2020). CCS has the potential to support students in K–12 education who are studying science – particularly by providing them access to practices and values of professional communities (NAS, 2018) – as well as laypeople and residents through authentic problem solving (Ballard et al., 2018).

Previous studies indicate that CCS in education poses key challenges for teachers in integrating authentic community challenges into the curriculum and school more generally (Benichou et al., 2022; Magnussen et al., 2019; Roche et al., 2020; Zoelick et al., 2012). It demands that teachers balance having students engage in authentic professional problems that aim to solve local challenges connected to specific tools, values, and practices, while also meeting the more general learning goals that are defined by the curriculum. This paper contributes to our understanding of how to navigate this balance by presenting the results from the CCS urban development projects *Cities at Play* (2015–2018) and *Community Drive* (2018–2022). To do this, we offer a novel conceptualization that bridges educational CCS and participating professional, student, and local communities; then we show the results gleaned from exploring different aspects of these bridges.

Designing for learning between communities and schools

Learning in CCS projects, which is fundamentally a sociocultural endeavor (Ballard et al., 2018; Lave & Wenger, 1991), involves creating bridges between the values, knowledge, and practices of school communities with those of communities outside school (Harris et al., 2020). We begin the next section by articulating the theoretical grounds used to establish a bridges model that conceptualizes how this process occurs, before moving on to our research questions, methods, and results to elucidate this model.

Connecting schools and professional society

Connectedness between schools and society is central in CCS so that students can be provided with access to professional expertise that can lead to authentic learning experiences (Hod & Sagy, 2019; Tabak et al., 2019). This view is based on a sociocultural understanding of learning, which defines a culture by the authentic activities, tools, and belief systems it recognizes as relevant (Brown et al., 1989) and argues that the process of picking up, or enculturating these practices *is* learning (Rogoff, 2014). This idea was elaborated on by Gee (2005), who described the knowledge domains of professions as sets of activities – special

ways of acting, interacting, and using knowledge – that a good educational design can help students know, do, and be.

In recent decades, approaches such as serious game research have developed formats to simulate professional practice by the users or learners (Cooper, 2014; Magnussen et al., 2013). Shaffer (2007) for example, talks about epistemic games that simulate professions in learning spaces that primarily aim "to create the epistemic frame of a socially valued community by re-creating the process by which individuals develop the skills, knowledge, identities, values, and epistemology of that community" (p. 164). A chief difference, however, between approaches such as epistemic games and CCS is that professions are often simulated in the former, whereas in the latter students generally *collaborate with* real-life professionals and solve authentic problems defined by the professional community. This split has been described as the simulation versus participation (or hybrid) approach to authentic learning (Hod & Sagy, 2019).

When developing CCS projects, it is essential to maintain professionals' practices and goals, while keeping in mind that CCS projects must incorporate educational designs, too. This means gaining an understanding of participants' background knowledge, learning processes, and activities, not to mention the structure of theirlearning environments and the tools afforded to them in their classrooms (Beetham, 2007). When creating educational spaces and bridging professional communities and schools, it is also necessary to define the learning goals and key skills the educational CCS design should aim to develop. The skill sets of professionals are complex and differ from the skills that students need to participate in CCS projects. Student participants also possess unique, authentic knowledge that are often highly valuable (Magnussen & Elming, 2017; Magnussen, 2022).

Connecting schools with local communities

Another aspect of CSS involves connecting between local communities and schools or classrooms. Pandya (2014) points out that making this connection is not the case for all citizen science projects, nor for participation in scientific research. In these disconnected cases, while the public may be invited to participate in data collection and analysis, the research goals are often determined by the scientists. Pandya (2014) describes some common features and premises of community-driven science projects, which we summarize as:

1. It is central that all parts of community-driven science projects collaboratively define community or research questions. This should address the overlap between community priorities and scientific capabilities;
2. Community-driven research should benefit all parties and not just contribute to science;
3. The project should value community learning and seek expertise from all partners;
4. Community-driven projects should involve all parties at all stages, such as data collection and analysis, as well as the presentation of results, which may involve training members in methods;
5. It is central that community-driven processes allow all parties to learn from the collaboration. Scientists or professionals can learn from the local expertise or knowledge of community members, while non-scientists can learn from collaboration with professionals.

Further advancing these points, Roth and Lee (2004) contend that science education should be open and seen as a social activity with real participation in a community rather than solely preparing for life after school. They criticize the traditional interpretation of scientific literacy as an isolated endeavor defined by scientists and for failing to recognize the complexity of science as played out in the community. Given this, they propose three ways to advance the understanding of scientific literacy as community participation. First, scientific literacy should be seen as a collective endeavor since society is built on a division of labor, which means that not everyone must be familiar with the same set of basic concepts. Second, scientific knowledge should not be privileged in a democratic society, but rather seen as one resource among many. Third, science education should be reconceptualized to make participation in communities the foundation of lifelong learning in communities that cross the boundaries separating formal schooling from everyday life (Roth & Lee, 2004; Wenger, 1999).

Rogoff (2014) more specifically describes learning and knowledge building processes in local and family communities, which stands in stark contrast to formal or instructional learning that involves adult control of student attention, motivation, and learning (Rogoff, 2014). Based on observations of how children in indigenous communities in the United States, Mexico, and Central America informally learn by observing and contributing to the local community, Rogoff identified *learning by observing and pitching in* as a way of supporting children through active participation and involvement in local and family community activities. This approach involves the following seven components:

- community organization of learning, where learners are incorporated in and contribute to the local community;
- motivation, where individuals are eager to participate and fulfill valued roles;
- collaborative and flexible groups, where fluid leadership is evident;
- goal of learning, where participation is transformed;
- learning with broad but focused attention, i.e., with community expectations providing guidance;
- communication based on shared references in community endeavors;
- assessment of learner proficiency and contributions.

These components are vital to consider when bridging between the knowledge, values, and practices in school and local communities. Still, we add yet another component that is missing in this framework. That is, students can potentially participate as local experts, members of the local neighborhood, *and* as students who are part of the school community. Dual participation is indispensable to understanding and designing for particular contexts and skill building.

A model to bridge schools and local, student, and professional communities

Bringing the aforementioned ideas together, we[1] present a preliminary conceptual model (Fig. 1) that illustrates the various bridges that CCS projects need to attend to support the

[1] "We" refers mainly to the first author of this paper. The second author was added towards the conclusion of the research to support the conceptualization and writing process. For simplicity, we refer to the authors as "we", but make clear that the first author was primarily responsible for this research.

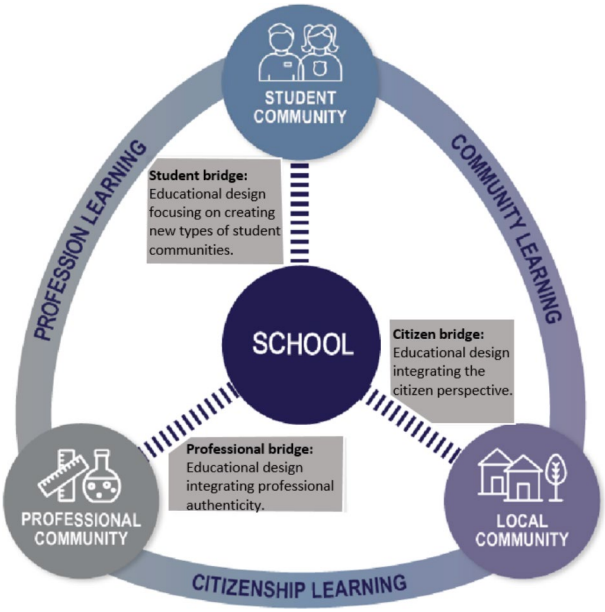

Fig. 1 Preliminary bridges model showing connections between schools and local, student, and professional communities

rich, cross-cutting goals they are purported to achieve. The model is preliminary in that it offers a way to think about the connections between different communities involved in CCS, but requires further empirical work to both explicate and validate it. Three community bridges are defined in this model. The *citizen bridg*e connects citizen communities and schools; the *professional bridge* connects professional communities and schools; and the *student bridge* connects new types of student communities and schools. The model also contains a learning circle that suggests what types of learning take place within the various collaborations that are forged between schools and communities. The learning circle links the bridges based on three connections: citizenship learning, community learning, and profession learning.

Depending on the proximity to the three bridges (visualized in Fig. 1 by the color gradient in the learning cycle around the bridges), the focus on the educational design can more or less be on citizen, professional, or student community learning—understood as a focus on connecting school education to the citizen, professional, or student community perspective. To understand how to create educational designs that bridge school, professional, and local communities and to support the learning of practices, values, and knowledge of community members and students as shown in the bridges model, the first author of this paper led the development, implementation, and upscaling of two iteratively-designed CCS projects. Carried out in close collaboration between Aalborg University and the City of Copenhagen's Social and Technical and Environmental Administration, these projects were launched to define problems in collaboration with students and urban developers and to introduce methodological solutions for developing structural changes in the neighborhoods where the students resided, which also included social and educational objectives.

The projects involved young people in vulnerable areas bringing in their expertise on their living environments. These students were invited to engage in design thinking and use design tools to foster the development of their local knowledge, ideas, and models of their

future neighborhoods. They worked in collaboration with the professional community of urban developers and architects in the City of Copenhagen. As a professional community, urban planners use specific language when they talk about developing city spaces. Moreover, they have a particular way of looking at the city, just as they have ways of valuing neighborhoods that differ from how members of other professions and laypeople do. Therefore, students had the opportunity to enculturate these practices by being involved in all aspects of CCS development, including problem definition in the local area, collection and mapping of data on those problems, formation of ideas for the future development of their neighborhood, and design and presentation of physical and digital models for the professional community of urban developers.

Within the context of developing and enacting these projects, we defined a research question as a way to further explore the bridges model. Specifically, we asked: *How can CCS projects be designed to bridge collaboration practices between schools, professional, and citizen communities outside of schools?*

Method

The study took a design-based research (DBR) approach (Brown, 1992; Cobb et al., 2003; Kali & Hoadley, 2021). This systematic methodology aims "…to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually sensitive design principles and theories" (Wang & Hannafin, 2005, pp. 6–7). In other words, the collaborative practice and understanding of the design that supports practice must be thoroughly understood to change it. Moreover, practice must be changed simultaneously to understand it (Cobb & Gravemeijer, 2008). DBR, which consists of iterations of design, intervention, analysis, and redesign, has various phases that include context and domain research, defining design hypotheses, developing theory-based prototypes, and analysis with a dual focus on developing new practices and theory (Ejersbo et al., 2008; Cobb & Gravemeijer, 2008).

To carry out this DBR study, we iteratively refined the design of the two iterations of the urban development projects. Therefore, the iterations had similar processes and activities, with students redesigning their disadvantaged neighborhoods in collaboration with urban developers, architects, and local government representatives. The iterations focused on gradually developing the project approach with new insights from the community and on integrating educational and professional objectives. The iterations also focused on applying the educational design to two different age groups (first iteration: 7–9th grade; second iteration: 5–6th grade) and on upscaling the project to involve a larger number of classes and departments in the Copenhagen City Council. However, the research focus and objectives changed based on the results from the first study. The first iteration's overall focus was experimenting with developing educational designs and understanding how the student–professional collaborative process can be integrated into the school curriculum. This was manifested in the design and intervention phases with the development and facilitation of phases and activities that allowed the professionals and students to interact in solving real-world problems. For example, in the discovery phase, the professionals introduced their perspective on the urban area and presented the challenges they needed the students to help

develop, and in the final testing and presentation phase, the students presented their models to a panel of urban developers, architects and other stakeholders.

The results from the data analysis in the first iteration led to a more specific focus in the second iteration on understanding community perspectives and on experimenting with creating educational designs to bridge school, professional, and local communities. The design iterations focused on integrating learning about professional and citizen values and perspectives in the educational design. For example, we emphasized involving urban developers in creating educational materials to experiment with integrating professional skills from the urban developer community into the school curriculum. Integrating the perspectives of professionals and citizens was reflected in the incorporation of methods co-designed with the urban developers and in mixing a stronger design-thinking methodology with the goal to facilitate robust participation of local communities in the neighborhood (Cross, 1982).

Educational design

Three schools were selected to participate in the two projects based on the need to develop the surrounding neighborhoods. In total, this included 12 classes in grades 5–9 across three schools in vulnerable areas in the City of Copenhagen. The Capital Region of Denmark had designated these areas as vulnerable based on socio-economic factors such as the large percentage of low-income families with little or no education, high degree of unemployment, and substantial amount of crime. The city had also allocated resources for the development of these neighborhoods. Focusing on these neighborhoods gave local urban planners and residents needed rationales to find new solutions to existing problems.

Local urban developers set up urban development challenges for students that involved broad cases directly connected to the students' local environments, e.g. establishing green areas to encourage more social life near the school. The urban planners in charge of renewal had selected these cases in advance because they needed the students' help to make the area more attractive and useful citywide, including for the students. Using cases from the local community as the foundation gave students the opportunity to use their lived experiences in the area and to develop solutions based on their local expertise.

To bridge students as residents and members of local communities and as students, a design-thinking process comprising five phases was developed (Brown & Wyatt, 2010; Cross, 1982) that included: discovery, definition, ideation, experimentation and model construction, and testing and presentation (Table 1). The focus of this approach was on students' expertise about the local environments where they lived, as well as strengthening their design-thinking skills and ability to take part in developing solutions to complex, authentic problems derived from their local expertise and learning emanating from collaborating with professional urban developers (Rusmann & Ejsing-Duun, 2021).

Various design-thinking phases were created to connect schools to the communities. In Phase 1 (discovery), the professional urban developers presented the problem, for example, of creating more social life in the city space or generating connections to the rest of the city. Students then participated in a module called "What Is a Place?" (presented in more detail below) to learn about the skilled perspective of urban developers concerning the city space and designed to bridge skills between students in the participating schools and the professional urban development community. Students were then involved in studying their neighborhood from their own perspectives and people living nearby. In this phase, the stu-

Table 1 Five design-thinking phases of the students' urban development process

Phase	Activity
1. Discovery (Empathizing)	Students conducted investigations applying disparate methods, such as interviews with residents and photo documentation of the residential area they were to develop
2. Definition	Students organized data from the discovery phase and listed the issues they had identified
3. Ideation	Students experienced an open idea-generation process using exercises, such as brainstorming and opportunity scenarios
4. Experimentation and model construction	The ideas were developed through a creative visual process involving various analog and digital forms of representation, such as games and animation, and physical tools such as LEGOs; temporary models were also built along the way in the physical urban space
5. Presentation and testing of ideas	Students presented design proposals of their future urban spaces to architects and urban developers from the City of Copenhagen; the professionals provided feedback about how the process would be implemented to develop their ideas in practice

dents conducted interviews with adults from the area and interviews with a project manager and an architect as experts involved in the area's renewal. The students also explored the area and created photo documentation based on three criteria: good places, bad places, and places they wanted to develop.

In Phase 2 (definition), the students gained an overview of their data to identify and concretize what they defined as problems in the area. This phase focused on connecting student experiences in the schools with the experiences of members of the local community, as well as student experiences as residents and members of the local community by developing their problem scoping skills and ability to empathize with members of the local community.

In Phase 3 (ideation), the students brainstormed ideas based on the problems they had defined and from the input they gleaned from the interviews. In this phase, the students devised as many ideas as possible so they could ultimately choose what to focus on.

In Phase 4 (experimentation and model construction), they experimented with building models out of LEGO, making miniature models indoors, and building large models outside to represent the urban space. They also made digital models in Minecraft and other tools.

In Phase 5 (testing and presentation), the students presented their processes and models for area renewal and received constructive feedback from the participating urban developers and architects to further develop and refine their models. This process took two weeks. One week was for the discovery and define phase, the first model development, and finally feedback on their work. The second week focused on a continuation of the modeling phase based on feedback followed by the experimentation phase, and a culminating presentation of their renewal models for creating meeting places for city residents. The panel of renewal experts comprising urban developers, architects, and other stakeholders examined these to determine how they could be realized.

Participants and data sources

We used a mixed-methods approach to observe and evaluate interaction and collaboration processes in and with the educational design that had been developed (Creswell, 2018). This included quantitative surveys, qualitative interviews with students and teachers, and observations of interventions.

Quantitative surveys collected digitally were administered to create an overview of the students' participation. The data provided an indication of student motivation, the knowledge they perceived to have, and experience regarding solving real-life problems. This was augmented by qualitative date that we analyzed thematically (Braun & Clarke, 2006) to understand the background and lifeworld of the students behind the survey results. Table 2 provides an overview of the methods used across the two research projects.

Since the schools were selected according to geographic location and whether they were an area designated as vulnerable by the City of Copenhagen based on socioeconomic factors, the students came from a variety of backgrounds. There were more students from vulnerable families than at an average public school in the city, but there were also students from more socioeconomically advantaged families. The teachers who participated did so voluntarily, which was an important factor in their motivation, and taught math, natural sciences, crafts and design, and social sciences. Given the challenges in the area, the teachers were experienced in managing the social issues that some students and families dealt with, but they were not experienced in teaching real-life problem solving or design thinking with external partners. As a result, workshops were held in the second iteration to facilitate design thinking and collaboration with outside partners. The next section describes the procedures, data preparation, and specific analysis methods for each of the data sources.

Surveys

Surveys were conducted before and after the two iterations and focused on grasping student understanding of their citizen and community participation in five specific ways: (1) student motivation for taking part in the projects; (2) student experiences of possessing local knowledge about their area and urban planning; (3) students' perceived understanding of whether the project program supported 21st century learning skills (Dede, 2010) concerning real-world problem solving and collaboration compared with what was defined as everyday school; (4) what the students viewed as making the program different from everyday school, and (5) student understandings of their ability to structurally change their living conditions. The teachers gave their classes the surveys the day before the CCS urban development course started and on the day it ended. All students in the participating classes were given the opportunity to participate in the program and answer the survey. The surveys contained closed questions or statements in which respondents were asked to choose from predefined responses, as well as open-ended questions with blank fields for students to type their answers. An example of a closed question in the first iteration was, "Did you think that you worked to solve problems for people outside the school?" The following predefined responses were designed to capture the degree to which students felt they had worked with real-life problem solving and to understand how much had been defined by the teacher and how much by the students:

Table 2 Overview of methods and number of participants in the first and second iteration

Methods and data collection setup	First iteration No. of participants	Second iteration No. of participants	
Surveys	School 1	School 2	School 3
Pre- and post-surveys conducted before and after interventions with educational designs with a focus on student perception of their own knowledge about neighborhood and motivation	7th grade:	5th grade:	5th grade
	Pre-survey: N = 45	Pre-survey: N = 32	Pre-survey: N = 34
	Post-survey: N = 31	Post-survey: N = 28	Post-survey: N = 33
	9th grade:	6th grade	6th grade
	Pre-survey: N = 36	Pre-survey: N = 27	Pre-survey: N = 25
	Post-survey: N = 35	Post-survey: N = 27	Post-survey: N = 22
Qualitative data collection	School 1	School 2 (two weeks)	
Video observations with contextual interviews	7th grade (two weeks): N = 45	5th grade: N = 32 (two weeks)	
		6th grade: N = 27 (one week due to COVID-19 lockdown)	
	9th grade (two weeks): N = 36	Teachers: N = 2	
	8th grade (one week, pilot study no survey): N = 22	School 3 (one week due to COVID-19 lockdown)	
Focus group interview with entire class of students	Teachers: N = 3	5th grade: N = 34	
		6th grade: N = 25	
Separate interviews of teachers		Teachers: N = 3	
Qualitative semi-structured interviews			

- We didn't work with solving problems for people in the real world outside school;
- We worked with solving problems for people in the real world outside school;
- We followed instructions containing steps on how to scope the problem;
- The problems we had to solve required us to come up with our own new ideas.

An example of an open-ended question in the first iteration was, "Were the problems you had to solve in City at Play different from the problems you normally work on at school? How?" Students could then write their answer in an empty field. The same types of questions were also posed in a pre-survey asking if students had experience working with solving problems for partners outside school. Table 2 shows how many students participated from each class. Students were also asked questions to their perception of collaboration in the projects compared to everyday schooling. They were asked whether more than two people worked together when they collaborated, if they made important decisions collaboratively, and if the result of group work reflected a collaborative process. The post-survey included the same questions on collaboration and real-world problem solving but covered their participation instead.

After analyzing data in the first iteration, it became clear that real-life problem solving was central in the students' understanding and was experienced as something new in the educational design compared to everyday schooling. It also became clear, however, that the order of questions created unclear results when posed in connection with questions regarding whether students or teachers defined the level of collaboration. Moreover, the closed questions with a defined number of answers were not sufficiently specified according to the literature on 21st century learning skills. Consequently, the two types of questions were asked in separate sections, and questions about the level of student independence in choosing their focus in the real-world problem solving process were specified according to the literature on 21st century learning (Dede, 2010). For example, "When we solve the tasks, we have to find a way to do it ourselves" and "The tasks we solve require us to come up with our own, new ideas". For these questions, students had the option of selecting a response from predefined categories ranging from strongly disagree to strongly agree. Preparing the qualitative data involved grouping individual answers into semantically defined themes (Braun & Clarke, 2006) to understand what mattered to the participants. The themes were defined and analyzed to understand what motivated students, how students experienced the project as being different from everyday school, what knowledge they felt they were able to contribute, and how they experienced their possibilities for participating and taking action.

Observations and interviews

The qualitative data collection included video observations designed to examine the influence of the CCS educational design and to understand which processes and reflections the CCS design supported for the students. The observations centered on documenting the students' dialogue in the design process to understand what reflections and knowledge the various urban models were based on (Onwuegbuzie & Leech, 2006). The project interventions lasted one to two weeks in each class at the three schools (Table 2). Video observations and audio recordings of student's collaboration in groups took place during the design-thinking phases (Cross, 1982), which lasted one to two school days each. The interventions and observations involved all students in fifth and sixth grade in the three schools. This sample was selected due to interest in how the educational design that was created would develop the students' knowledge and perspective on their local area and possibilities for action in collaboration with the professional urban developers. For this reason, we chose students who had a close connection to the area. This was the case for all participants since most of them lived in close vicinity to the school and spent their everyday lives in the area. Students

11–15 years of age were selected based on the hypothesis that they focus more on the surrounding local area since they are gradually allowed to move around on their own.

Observations were specifically conducted during the initiation of a new phase to document its introduction and initial developments, but also at the end of each phase when students presented their models. Following this pattern allowed us to see how the ideas and designs developed. The research team also did brief contextual interviews with students comprising two to three questions while they were in the design process and focused on allowing students to explain the background for their design. This gave the research team the opportunity to understand the focus of the various designs, how students reflected on their learning, and the underlying knowledge that provided the foundation for the assorted aspects of their designs. For example, the team asked, "Could you tell me what you are working on here?", "What is this part for?" and "Why did you choose to change/design this part?". These questions allowed students to explain their design during the actual process, instead of waiting for later when their underlying reasoning would have become tacit.

The research team also conducted full-length, semi-structured qualitative interviews with teachers, students, and the professional partners in an attempt to further understand the project's possible outcomes and challenges (Kvale, 1996). One-hour qualitative interviews with teachers addressed specific aspects of the educational design and the teachers' view of students' class work, dialogues, and perception of the educational activities, as well as the challenges and potential learning outcomes. Thirty-minute focus group interviews were conducted with all of the participating classes immediately after the urban development courses ended. Similar to the teacher interviews, they focused on understanding the various aspects of the educational design from the student perspective, their perception of the course, and if and how it was different from everyday school. The interviews also focused on the challenges and potential of the course design and possible redesigns. The interviews were audio recorded and transcribed verbatim before data from the various design phases was analyzed in the first iteration by applying thematic analysis, and in the second iteration with a more specific focus on community elements. We defined themes based on participant-generated concepts in perceived knowledge and learning practices (Braun & Clarke, 2006).

Results

The following sections present the results that answer our research question. The first subsection presents findings that relate to bridging professional communities and schools, whereas the second subsection focuses on the remaining two bridges, local and student communities with schools. Following these sections, we discuss their meaning and contribution to the learning sciences.

Results regarding bridging professional communities and schools

We begin this section by presenting illustrative examples of our results before moving on to presenting the findings collected from all participants. Illustrative examples provide a way to understand perspectives taken at a high resolution within a rich context, adding meaning to the wider, but more decontextualized results collected through surveys.

The first introductory module, "What Is a Place?", served to develop the students' ability to understand the urban space by applying key skills used by professional urban developers. The goal was for students to work with professional perspectives in analyzing what influences people in urban spaces, which is a central aspect of modern urban development and the education of architects and urban developers (Gehl & Rogers, 2010). An urban development researcher at Aalborg University in Copenhagen and a Danish learning platform developer worked jointly to produce the module. The aim of the material was to have students apply the perspectives of urban developers in analyzing various urban spaces using these three questions:

1. What can be measured and sensed in the space?
2. What can be felt and valued?
3. What can be explained?

The module comprised an introduction by the teacher or urban planning researcher and a five-minute video of Tivoli, a 180-year-old amusement park located in the heart of Copenhagen. Many Danish children visit the park at least once a year, hence it is a familiar place to most of the students. Students were asked to pay attention to how Tivoli affected their senses, feelings, and mood and how their senses and feelings could be explained. The students recorded their responses to the three questions, noting what they became aware of, sensed, and felt, including what influenced the mood and tone of the space. The aforementioned urban development researcher (UDR) participated as a co-teacher throughout the module and led the discussion. The excerpt below is from a fifth-grade class. While introducing the module, the researcher pointed to the whiteboard, which listed the three categories the students had to keep in mind while watching the video: (1) Senses – what can we see and hear? (2) What kind of feelings, atmosphere, and mood can we sense? and (3) What is the purpose or identity of the place? After watching the video, this dialog emerged during their analysis:

UDR: So, taking these three categories into account, what would you write for the first one about senses? Based on what you just saw? Yes, Student (S) 1?
S1: That's how you see the rides, how you see the various cafes and restaurants, and all sorts of things. The places are like that.
UDR: So, there are lots of different buildings like these … cafes, eateries and ….
S1: [interrupts] Rides.
UDR: Rides, yes. Yes, S2?
S2: It smells a lot of popcorn and stuff like that.
UDR: Yes, because it does [writes on whiteboard]. There's the smell of popcorn, and maybe food in general. What else do we see? Yes, S3?
S3: You can hear when they, when they, when people talked. (…)
UDR: How does your body feel when you're together with so many people, and when you can smell it, and maybe see it? So, what kind of person is it? How does your body feel? (…)
S1: You can be both annoyed by the fact that there are many people.
UDR: [interrupts] Yes [writes on whiteboard].
S1: But, also happy because there are many people. (…)

UDR: Can anyone else think of something about the bottom one (points to whiteboard)? As is the case with what, the place is there for a purpose. It has certain features, hmm?
S5: I think maybe it has the purpose that you can go there and then you can do that.
S6: (interrupts) Have fun, have fun. It's like that. It's one of those times of year when you're just together and don't really think about anything.
(Transcript from What Is a Place? module, introductory phase, fifth grade class, school 3, second iteration)

After the introductory What Is a Place? session and as part of the discovery phase (Table 1), the students were assigned to work with areas and challenges that architects from the City of Copenhagen had identified as needing student input. The students produced photo documentation of the area they were to develop by focusing on photographing and registering good and bad places in the area. They also discussed why the neighborhoods evoked specific moods, feelings, and sensations. Students then defined problems in design-thinking Phases 2 and 3, and they experimented and developed models of their ideas for future developments in their local area (Phase 4).

The following excerpt illustrates the discovery phase and is a discussion between a student (S) and a project research assistant (RA) about the challenges involved in redesigning the green area between the lanes of a boulevard:

S: Well, I think, kind of, even if you made this road into something really cool, I kind of think that I would not really go there because it's out in the middle between the two lanes.
RA: Hmm.
S: Kind of. It's something different—a different place to be than if you're over at the playground.
RA: Hmm.
S: Where there's only a road on one side, and it goes further in, and stuff like that.
RA: So, this, the feeling of being trapped between two roads, this is what you think is kind of ….
S: [interrupts] No, I probably wouldn't hang out there.
(Transcript from What Is a Place? module, introductory phase, fifth grade class, school 3, second iteration)

Later in the fourth, model phase of the design-thinking process, the same urban development researcher discussed the students' urban development idea of putting a Japanese garden in the green area between the lanes of the boulevard:

UDR: And why did you want to make a Japanese garden on the boulevard?
S2: Because it's very cozy.
UDR: I see. And what makes it cozy, do you think, compared with the way it is now?
S2: Because there are also benches and things like that. Then it becomes more enclosed.
UDR: I see. And why should it be enclosed?
S2: Because then there's not so much traffic noise, and then it is also nicer.

UDR: So, you are actually using nature to make these enclosed spaces?
S2: Yes.
(Transcript from What Is a Place? module, design phase, fifth grade class, school 3, second iteration)

These above excerpts illustrate the implementation of educational design as a bridge between the professional community and the school. In the excerpts, the researcher applied the three perspectives of urban developers to analyze the spaces with the students. In the various phases, the students defined and explained why their physical designs were based on the senses and feelings of users in these spaces. The excerpts also illustrate how the urban development researcher's perspective, practice of the educational design, and understanding of how physical urban spaces shape residents' feelings and moods became a part of the students' argumentation for supporting their designs and influencing their development.

The focus of the educational designs on supporting professional authenticity (Dolin, 2003) was particularly aimed at the CCS approach and supported the idea that students can participate not only in collaboration with professionals outside the school, but also develop skills in relation to the professionals' practices and skills. A general weakness of CS in a teaching context is that it is predominantly researcher-led. Hence, it does not focus on the development of skills, but rather solely on participation (Magnussen et al., 2014). In the Community Drive and Cities at Play projects, which involved the collaboration of urban development researchers at Aalborg University and a textbook publisher, the objective was to develop courses to support students in entering into practices that coincided with those of the urban developers and in developing skills in understanding how the city's spaces affected residents' perceptions and emotions, which providing key input for architects and urban developers. In conclusion, it was possible to develop educational designs bridging school and professional communities based on skill development rather than research processes, content, or results, which is the traditional focus of CS projects (Harris et al., 2020).

To deepen these points, our findings also include a description of the students' perception of their own knowledge in the collaboration process with architects and urban developers. To gauge if and what type of knowledge students perceived that they contributed, both iterations included a student survey with questions asking if students experienced that they had knowledge that they could contribute as part of the collaboration with professional partners. Thus, the pre-survey in City at Play asked students questions such as: "Do you possess knowledge about (name of neighborhood) that the architects redeveloping (name of neighborhood) do not have?" (Fig. 2).

In their basline responses, 9% answered either "Yes, I know a lot that they don't know" or "Yes, I know a bit more." This percentage changed to 45% in the endline. Correspondingly, student perception of whether they had knowledge about their neighborhood that the professional urban planners did not possess changed due to their participation in City at Play.

The first iteration of the study examined this change and student perceptions of their knowledge or local expertise more closely by asking the students to qualitatively specify what knowledge they felt they had that the urban planners did not. The qualitative part of the pre-survey conducted before participating in City at Play provided a picture of the local knowledge students believed they had. Most responses to the open-ended qualitative question, "What, for instance, do you know more about?" contained reasons for why students

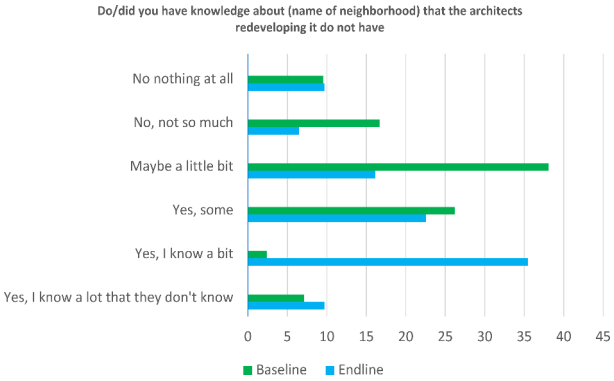

Fig. 2 Baseline and endline results of student surveys

Table 3 Areas of student knowledge based on qualitative survey data from post-surveys after interventions involving 7–9th grade classes in the City at Play project

Types of knowledge areas	Examples from qualitative data*
1. Physical buildings or facilities in the area	"I know a little about (name of neighborhood) and the buildings." "Supermarkets and lighting."
2. Experiences or feelings	"What the atmosphere is like, what's good and what's bad, what it's like in general to be here." "I can find my way around (name of neighborhood) with my eyes closed. I'm part of it."
3. Experiences or feelings concerning locations or facilities in the neighborhood	"That it's boring to be here/live here. They couldn't know that there isn't much light in the evening, which makes it scary." "Where it's safe and unsafe." "Safe and unsafe places. What needs to be changed."
4. Social aspects of the community in the neighborhood	"I know more about the things that some people need." "I know, for instance, what it's like to live here and what most people want/don't want."

** Students responded to the following two open-ended qualitative questions: "Think about the City at Play course: Did you possess knowledge about (name of neighborhood) that the architects redeveloping it did not have?" and "What, for instance, did you know more about?"*

thought they knew more than the urban planners. For example, "I know (name of neighborhood) very well because I grew up here, so I'm sure I can work out something with some of my friends or alone" and "I grew up in (name of neighborhood) and know almost everyone. I think my friends and I can find something good to build here in (name of neighborhood)." Based on a thematic analysis, we grouped student knowledge into four types based on their responses (Table 3).

In conclusion, these findings indicate that students became more aware of their knowledge about their local city space and that collaboration with professionals influenced their perspective of the physical environment in the city. This resulted in a stronger focus on bridging the professional community and school in the development of the educational design in the second iteration (Community Drive) of the CCS project.

Results regarding bridging citizen and student communities with schools

A central goal of this study was to understand if, how, and in which ways students were motivated to get involved in changing their neighborhood. With a theoretical focus on authenticity (Hod & Sagy, 2019), another vital aspect of the educational design experiment was for students to perceive their participation in developing their neighborhood as relevant and meaningful (Dolin, 2003).

In City at Play, there was a 90% positive response rate (Yes, a little −14%, Yes −31%, Yes, a lot −45%) for the pre-survey question: "Do you want to help decide what (name of neighborhood) should look and be like?" Survey questions also asked about student perception of the area. To the question, "How much do you agree with the statement: (Name of neighborhood) is fine as it is and does not need to be changed?" Students slightly disagreed (42%), disagreed (21%), or strongly disagreed (2%). The percentage increased to 84% in the post-survey, which presented the students with the same question. Regarding why the residential area was good or bad, most qualitative answers mentioned criminal activity or feeling unsafe, as indicated by the following statements: "Too much violence," "There are many rumors about drugs and stabbings; it is a bit unsafe at the moment," and "There are lots of criminals." However, answers also addressed the more positive and social aspects of living in their neighborhood. For example, "It depends on your personality or who you are with" and "Because I have some nice people around me." Overall, the results indicated that, from the beginning of the project, the students were strongly motivated to participate in changing their area and that their personal authenticity was linked to solving the problems they experienced, such as feeling unsafe and anxious due to crime, in their residential areas in everyday life.

A key step was central to creating an educational design to support the integration of the local citizen perspective in the students' design as part of the effort to bridge local communities and schools. The approach involved developing the educational design based on the design-thinking methodology. In the ideation and modeling phases, the objective was to bridge school learning and local community learning by aiming to develop student skills in modeling future neighborhoods. In addition, the modeling was grounded in the first phage(Table 1), where the focus was on discovery and empathizing with users to be able to develop models that met user needs (Cross, 1982). In this phase, activities such as student interviews with residents and student presentations revealed the need for whiteboards that listed members of neighborhood communities.

The aim of including the needs of students and also for the needs of other citizen groups was an integral part of the teachers' and researchers' introduction to both the discovery and empathy phases, as well when introducing and evaluating the designs. This is illustrated in the excerpt below. In this dialogue, a fifth grade student during the second iteration presents the group's design, which encompasses their own needs and the needs of local residents. The students' idea involved developing a dog park in the green area between the two lanes of the boulevard:

> *S*: Yes, it's a dog playground, where dogs can run loose in a fenced area like this, and then there might be obstacle courses for the dogs, where they can play. There are quite a few dog owners who use this place, so you won't just do everything, so the residents can't use it like they usually do.

UDR: Yes, so you're actually doing something for those who already use the boulevard.
S: Yes, and I also really like dogs.
UDR: And you really like dogs, so there's also something for the others to look at.
S: Yes.

The City of Copenhagen urban developer who came up with the urban challenges for the students and collaborated with them during the entire process described the types of knowledge the students contributed with and their skills in empathizing with the needs of other residents. When asked whether the students contributed knowledge that the professionals did not have, she replied: There is no doubt about that at all. And they are actually also really good at knowing what kinds of concerns other locals have. As an example, they have been really interested in a place with a roof where they can be, and here, they are aware that if it is completely closed, then people will feel unsafe when they pass by, so you should be able to look in and stuff like that. And at one point, they also talked a lot about light, stating that, "It helps to create safety as well, and when my younger siblings go to sports, it is so dark." So, they really have this … so they see things from a different perspective, which we have not always thought about as adults.

The research focus in the two iterations of the DBR study was to understand how it is possible to create educational designs that bridge school and local communities and to understand how students experience the community environments that have been bridged. Consequently, the study centered on understanding whether students perceived that they were working with, and applying 21st century learning skills in terms of collaboration and real-world problem solving (Dede, 2010) and whether we could detect a difference compared to what students defined as everyday school. The baseline survey contained questions on whether the students experienced collaborating and solving real-world problems at a variety of levels in everyday school. In both iterations, the findings showed that no significant distinction existed between group work and collaborative practices in everyday schoolwork versus the CCS project, which may be due to how much group work and collaboration are integrated into most subjects in primary school in Denmark. Dealing with real-world problems in everyday school education, however, differed significantly from the practices in both iterations in the CCS project.

This section thus presents findings based on how students perceived that the CCS design approach differed from what they defined as everyday school. The results showed that most students (71–83%) experienced working more with solving real-world problems outside school in CCS projects compared with everyday school teaching (33–44%). However, in the project it was central to understand at what level students perceived the collaborative process of working with professionals outside school. Before and after the urban development courses and interventions in the CCS iterations, students were asked whether they, "… had to invent their own ways of solving the tasks," if "the tasks they had to solve required that they had to develop their own ideas," and questions about whether the teacher had a "recipe" for solving tasks or already knew the answer. When the increase in students positively answering questions on inventing their own ways of solving the problem was only minor, there was a marked increase in students agreeing that the tasks they had to solve in the CCS project required inventing their own ideas (Fig. 3).

These data indicate that students thought that the real-world problem solving in the CCS project was on the level at which they were able to independently develop their own ideas

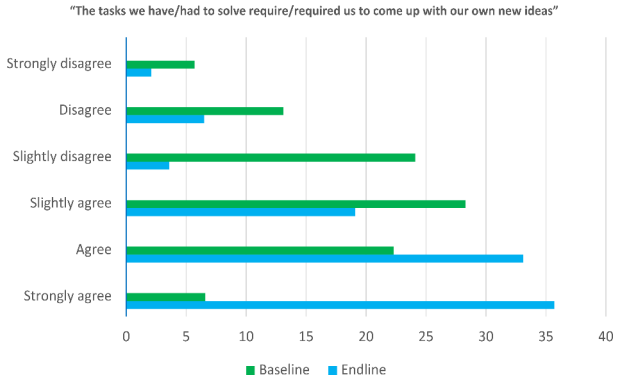

Fig. 3 Average results from participating students in School 1 and 2 agreeing or disagreeing to the statement: "The tasks we have to solve require us to come up with our own new ideas" before and after interventions

and that this was different from what they normally did in school. A central distinction was also that students in the CCS project felt that professionals outside school gave them the tasks to develop and that the teachers did not already know the answer to the tasks they had to solve in the CCS project (52.2%) compared to everyday school (8%). In conclusion, these findings indicate overall that students experienced a high level of independence and that the tasks they were given were authentic and not ones that the teacher already knew the answer to. In both DBR iterations, student experiences with practices was further examined based on the qualitative post-survey questions: "Were the problems you worked with in City at Play different from the problems you normally work with at school?" and "What was different in City at Play compared to everyday teaching?" Based on the qualitative survey data from the first iteration, the thematic analysis of the qualitative responses identified several themes related to collaboration with local communities and problem solving in relation to solving problems for people in the neighborhood (Table 4).

Some of the key elements for students included working with solving real-world problems, especially ones highly relevant to the students and other local residents, such as a lack of lighting, safety issues, and a lack of social or community activities for various groups. Other themes addressed how the design-thinking process in the project's educational design supported a more open and creative process compared to what students defined as everyday schooling. These data indicate that the CCS educational design contributed two-fold by creating learning situations in which students worked by empathizing with other members of the local community and devising a more open, innovative process compared to everyday schooling. A former student also described how the CCS project identified new student experts and communities (as published in the Master's thesis of Hemme and Thorø, 2021):

> Former student (FS): There was a group of marginalized boys, I would say, even now, when I look back. There was one boy who was quite a big drug addict, and there was one who could hardly speak Danish, but they were actually the ones who stayed in school until late and were most motivated, and you know, they stayed and continued building, and it was almost like you couldn't get them to leave. It was actually really nice. (…) They were the ones who were a bit more imaginative and played computer games, and they just had crazier ideas. (…) So, I think it created unity in a different way, and some of them lived in the neighborhood, and I lived, for example, on the

Table 4 Themes that emerged in the thematic analysis were based on responses to two post-survey questions

Themes	Examples of student responses*
Changing things	"Yes, because we normally don't work with changing things." "Yes, because we were working with changing something in our city, which is something we don't do in class."
Something in the real world	"It was something that could happen in the real world." "Yes, a lot, because it concerns the real world and it involved problems we could solve for the entire (name of neighborhood) neighborhood." "Yes, because in school we do, for instance, grammar and math, while in City at Play, we were supposed to help others make (name of neighborhood) a better place to be." "Yes, because in a way, it did not involve problems related to school subjects but something in the real world."
About helping people, not just working for one's own benefit	"In school, we work more for our own benefit. In City at Play, we made something that everybody could benefit from" "In school, you need to improve your grades. Here, we needed to help other people … #Thatwasnew." "Yes, because we had to consider whether it would work because here, it's all about people." "Yes, here you can do something for a group of people and not just do math." "We helped other people and not just ourselves." "We had to make something that would benefit other people."
Decided more	"We decided more." "What we had to make was not decided ahead of time." "It's kind of good because we had to decide on what we needed to build and so on. It's not like that in daily teaching, where teachers have the right to decide." "We were allowed to determine/decide most things."
Using one's imagination and inventiveness	"We had to use our imaginations." "We don't usually talk to architects and invent things."
Being active	"We didn't sit down all the time." "You were free to choose what to do." "We got to move around and independently decide things." "We were active in City at Play"
Other tools	"We used other tools." "We had to play a game to do our assignment." "We were building with LEGOs and made models with them." "No books, a lot of collaboration."

* *Students responded to the following two open-ended qualitative questions: "Think about the City at Play course: Did you possess knowledge about (name of neighborhood) that the architects redeveloping it did not have?" and "What, for instance, did you know more about?"*

> other side of the residential area, so I was not in the socially disadvantaged area like the others, but I still went to school over there and had all my friends over there.

The data indicate that it is not just essential to focus on bridging schools to local communities, but to ensure that local student expertise can also create new student experts and new types of student communities, which can be central to improving vulnerable communities. Our results show that some student groups marginalized in the community or at school can gain new expertise and roles in CCS projects.

Discussion

The goal of the current study was to understand how it is possible to create educational designs that bridge collaboration practices between school, professional, citizen, and new types of student communities in CCS projects. To do this, we created a preliminary bridges model that could then be explored through design iterations and empirical work to start systematically refining our understanding of the relations between communities involved in CCS. The objective of bridging communities and schools arises from central challenges in the CCS field related to developing CCS, both to serve educational and scientific goals. Our findings shed light on ways that educational projects can be designed to bridge collaboration between school, professional, and citizen communities outside school. As Ballard et al. (2018) assert, CCS has developed from a sociocultural perspective whereby science learning and participation are situated in the activities, tools, places, and objects in the cultural context of communities (Lave & Wenger, 1991; Wenger, 1999). From this view, learning involves mastering and understanding the values and practices of communities (Harris et al., 2020; Rogoff, 2014), which is also the background for the current study's approach to designing educational bridges between communities and school. Students can beneficially work with professional approaches to analyze city spaces and empathize with local citizens through activities that potentially allow students to learn the values and practices of another community and how to apply the practices to generate designs based on their own local knowledge.

In this study, the urban development projects focused heavily on the local context and the local communities that the students were to help develop, laying the groundwork for developing an educational design with a two-pronged emphasis: students as members of the local community and other members of their local community with other needs, values, and challenges regarding their neighborhood (Mechlenborg & Neergaard, in press). This approach can potentially alter the overall roles of students when they act as both students and local citizen experts (Hemme & Thorø, 2021). When bridging community and school education in CCS projects, it is essential to understand the roles, knowledge, and experiences that students bring to the table both as students and as citizens of their local communities. Thus, this adds a new dimension to the multi-sector approaches that citizen science and CCS projects have recently conceptualized as taking (Benichou et al., 2022). Instead of just seeing the roles of participants from each sector in a multi-sector partnership as being unitary, the present research suggests that participants may have a multiplicity of overlapping roles and identities that should be considered and capitalized on.

The specific findings of this research speak mainly to two of the bridges that we outlined in the bridging framework (Fig. 1). Namely, results regarding bridging professional communities and schools illustrated how the discourse between urban developers and students with local knowledge takes on different forms that cover various phases of design-thinking, including discovery (Empathizing), defining, ideation, constructing models, and presenting. Students were provided with opportunities to draw on their informal understandings of these ideas as they slowly enculturated more complex terminology and understandings of the practices of urban developers. As the results showed, as students increasingly engaged in these processes, they grew aware of their own expertise in providing the urban developers with meaningful input with regard to physical buildings or facilities in the area, experiences or feelings concerning locations or facilities in the neighborhood, and social aspects

of the community in the neighborhood. This represents a culturally-focused, asset-based approach that is the foundation of culturally-relevant pedagogies that strive towards educational equity and justice (Ladson-Billings, 2021). That is, culturally-relevant pedagogies are educational approaches – such as multicultural education and community-based learning – that value the cultural backgrounds, experiences, and perspectives of (typically marginalized) students from diverse cultural and ethnic backgrounds, aiming to help them develop a sense of their own cultural identity. By positioning students as experts of their own communities, an innovative approach to see students' knowledge as an asset was developed in this research.

The results regarding bridging citizen and student communities with schools similarly show how CCS takes asset-based approaches, and in particular how this can differ from their traditional schooling even if they were used to collaborating or working with groups in their classrooms. The results showing the growth of students' understanding that they had something meaningful to contribute to the learning process provides evidence for this point. It also shows the importance of making multi-sector partnerships so that students can engage in real and authentic learning tasks. These were reflected in the various themes found from the analysis of students' post-survey questions, such as when they shared that their ideas can change things, can help people, and allow them to use their own imagination and inventiveness. Bringing these two ideas together, the theoretical contribution of this research is that it shows how designing multi-sector partnerships in CSS, whereby students play multiple roles including those of local experts, may be a vital aspect of designing asset-based learning that foster more equitable futures (Jurow & Shea, 2015).

Practical implications

The bridges model as well as the two instantiations of it through City at Play and Community Drive that were developed as part of this research should be seen as a tool for supporting educational designers interested in establishing CCS projects. These ideas can be applied to guide educational designers and teachers in making decisions on what key practices or values in another community are central for students to understand or learn when collaborating with other communities and what educational bridges are needed to attend to, to support this development.

As this paper primarily attempts to discover how educational designs can bridge schools and communities, this section presents several guidelines that we have developed as a result of our work. Overall, the model is designed to help teachers and CCS educators establish a community learning focus when designing and implementing local CCS projects, as well as to guide decision making in connecting the learning goals of students and to focus on collaboration with various types of communities. These specific design guidelines can aid stakeholders such as teachers and educational researchers or designers in applying the model to developing future educational CCS designs:

1. Need for knowledge: Consider if there is a need outside school for the knowledge students generate.
2. Expertise: Define what students, professionals, and other participants' central expertise is in the CCS context.

3. Learning needs: Define what skills participants need to learn to be able to collaborate with other communities.
4. Designs for learning: Consider how the CCS environment can be developed into an educational design.

Study limitations and future studies

While this study takes the field a step forward by advancing our understanding of educational bridges and how to attend to them in CCS projects, there are several limitations that we hope will open opportunities for future research. First, the studies were only conducted in the context of urban developers collaborating with students. Future studies should focus on applying the proposed model to other contexts.

A second limitation is that the focus of the present study is exclusively on educational designs and how students learn, but CS and CCS projects involve learning environments with multiple types of learning between all participating actors, which would benefit from additional focus in future studies. Accordingly, the types of learning outcomes regarding our model can be defined more closely. For example, Phillips et al. (2018) synthesized the possible learning outcomes of citizen science projects in a framework comprising six types of learning outcomes: interest; self-efficacy; motivation; content, process, and the nature of science; inquiry skills; and behavior and stewardship. Such a framework could be useful to investigate learning in such a complex setting, and possibly work orthogonally across the bridge or the learning cycle in our model (Fig. 4). Further exploration of these issues in future studies can better define the types of learning and skills developed in CCS projects.

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