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Geometry around Us

Abstract

Are you a mathematics teacher interested in using place-based learning in geometry instruction? This activity draws links between geometry topics and the place where students live. Students start by exploring a selected local monument for basic geometric concepts and figures. In addition, students can try to create their own 3D model of a selected local monument or building and include it in a 3D map of the community. To conclude the minilesson, students can present the resulting map with 3D models to other community members.

Unit type and duration

The minilesson requires 1–6 45-minute lessons, during which the teacher and students gradually climb up the Place-Based Learning Ladder. The interlinked teaching units can be used as a whole or separately. Even a single unit can be applied on its own. Implementation of several interlinked lessons leads to a more in-depth understanding of the topic's implications and complexity. The entire minilesson can be implemented as a day-long programme.

Target group

Mostly lower secondary programmes and upper secondary programmes. However, the different activities can be adapted for primary programmes.

Context and cross-curricular links

The topic of geometry is gradually extended across the curriculum. The different activities can be linked with courses such as:

- History (what we know about the era from which the monument originates, characteristic building trends in local history; researching the technologies available at that time for building the monument and how our predecessors were able to induce the strength necessary to transport the monument, can be compared with historic sources – a chronicle, historic photographs);
- Arts;

- Geography (other local or global monuments, working with maps, urban plans, measurement, orientation in a place);
- Information and communication technologies (working with online maps, 3D models);
- Civics education (our community, cooperating with it);
- Geology (weathering, mineral types and processing);
- Physics (physical quantities, calculating the mass of a figure based on a density table);
- Science (identifying/comparing density/mass per unit volume figures as characteristics of different minerals).

Goals and outputs

Goals:

- Students understand the relevance of geometry in everyday life and various occupations.
- Students inspect a local monument for basic plane and solid geometric figures.
- Students can apply measurement and calculation to determine the volume and surface area of geometric figures, and they can apply the knowledge in practice.
- Students learn new information about important built structures in the community.
- Students are spatially oriented in their community, evaluate local objects, phenomena, and processes, and share their findings with other community members.

Outline of the activities

Activity 1: Plane figures, mapping figures using arbitrary parallel projection

Duration: 30 minutes
Location: classroom (or only outdoors, at the site of a local monument)
Materials: photographs of a selected local monument (memorial, statue, ...), list of basic geometric figures (equilateral/isosceles/obtuse/right triangle, parallel lines, perpendicular lines, right angle, circular arc, line segment) that are (not) found on the selected monument.

Activity description:
Start by asking students about the different figures they know. You may invite them to look around and search for geometric figures on various objects in the classroom (furniture, windows, windowpanes, ...). Now present the basic types of plane figures and their characteristics. Students will verify the new information on a concrete example from the community. Give them photographs of a selected local monument. Their task is to name (or circle on a list) geometric figures found/not found in the picture of the monument, or of which the monument is composed.

Other assignments can be added to the worksheet. For example, students can mark or caption the figures directly in the photograph. Furthermore, you can delve into the difference between plane and solid figures, again exemplifying some of them on the photograph of your monument.

Recommendations: Ideally, the students themselves should pick the monument they want to examine. This is a way of supporting their active participation in the educational process. Should the students' choice turn out unrealistic (the monument unsuitable for inspection), return to your prepared option; even this is a significant participative experience for the students.

Activity 2: Geometric solids and their characteristics
Duration: 25–45 minutes (depending on distance between school and monument)
Location: outdoors
Materials: instruments to measure the figure's volume and surface area, student notebooks.

Activity description:
Take students outside to the selected monument. Directly on its site, invite students to think and inspect the monument for its constituent solids. Conclude the activity by reviewing or summarising students' findings. Limit this part to naming the solids and demonstrating in which parts of the monument they are found; identifying their characteristics will be assigned to student teams. To identify the characteristics of the solids found in the monument, the teams inspect the monument and formulate traits of the geometric solid such as number of faces, edges, vertices, their constituent plane figures, etc. Now invite student teams to share their findings with others. If necessary, add more information or a depiction: vertices, edges, bases, edges of bases, faces, opposing faces, etc.
Students will also try practical application of volume and surface area formulas for different solids using on-site measurement. Together present the different formulas needed, then ask students to apply them by inserting actual numbers identified through measurement. You can calculate the approximate volume and surface area of the entire monument by "decomposing" it into parts roughly represented by basic geometric solids.

Activity 3: 3D modelling built structures on a smaller scale
Duration: 4 45-minute lessons
Location: classroom/outdoors
Materials: writing supplies
Activity description:
Start the activity by debating which industries importantly rely on geometry (construction, architecture, gardening, land surveying, programming, etc.) Now focus on the construction industry and present a challenge for students: to apply what they know about the

monument in making its small-scale 3D model. For example, students will draw on paper planar projections of the lateral surfaces of the monument's constituent geometric figures, assemble them, and thus create a model of the monument; alternatively, they will use a 3D printer to create the model. Now inquire whether the solids students found in the monument are also found in other local places. Students will likely state some other built structures in the community as examples. You can dwell on the structures mentioned and try to name all their constituent solids. Invite students to create a partial model of the community by modelling additional structures. Recommend prioritising key structures that either shape the face the community or reveal some important information about it, such as structures:

- of architectural value/interest;
- built or used by a celebrity;
- housing an important institution;
- where people often gather/spend time;
- that are the oldest/newest/largest/most controversial;
- where something important took place;
- where something is manufactured or a service is provided to local people;
- where people go to get some culture;
- that are old, dilapidated, in need of renovation;
- that (no longer) serve their original purpose;
- featuring a green roof/green façade, ...

Students conduct an exploration around the community and identify which buildings meet a criterion. Now each student tries to pick one additional local structure, identify its constituent solids and dimensions (by measuring in the field, consulting the owners, or measuring online by hand using a map application). They also build a scaled-down 3D model of the structure based on a defined scale. Students should agree on a suitable scale and decide who will model the different structures. After the models have been built, ask students to place their structures in an area in a way that represents their relative positions in reality. Students conclude by discussing the structures at hand.

Recommendations: Your discussion can go beyond geometry (Which structure did you choose? Which and how many solids did you use? What were their dimensions? What is the surface area of the structure in reality and in the smaller scale? How did you proceed in building your model?), but you can also discuss with students:

- what types of structures they chose,
- what was interesting about them,
- what new information they learned about them,
- the implications of their work for built structures/the construction industry/architecture in our community.

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Prerequisites and possible follow-up minilessons:

A prepared additional follow-up activity is provided below.

Activity 4: Preparing and using a 3D map of the community focusing on a selected local problem

Activity description:
Motivate students to continue working with 3D models (add more structures, mark certain elements etc.) and to focus on specific aspects that are characteristic of or important for the community and should be included among the criteria for selecting a structure or identified by students in Activity 3, such as:

- disused/recently added parts of the community;
- structures from the same era that importantly shaped the face of the community;
- structures serving under-privileged groups;
- areas vulnerable to natural disasters (flood zones).

In addition to their 3D models, students should also prepare a map key and accompanying information/presentation. In classes, you can revisit the aspects or problems on which students have focused and present additional examples from other regions or countries.
To complete the project or find out about a problem, invite an expert that might bring important information from areas like data modelling, map making, construction, history, urbanism, urban planning, etc.
Finally, plan additional uses of the resulting map by other community members. For example, plan an exhibition or presentation – in geometry and civics education classes for younger students, at a local visitor centre etc. Your map can initiate a discussion on addressing certain problems or support the visibility/further presentation of some important aspects. Students find it motivating and important to create a product that people actually continue using and that makes an apparent contribution in practice.
The activity invites students to learn various architectural styles, regional differences in community appearance, and the history of the local community or a local area (the historic district, the industrial district...)

Integrating the place and the community in the minilesson

The minilesson focuses on the local community, its historic monuments and outstanding buildings. Students work in the classroom using the monument's photographs or outside at local places. Students obtain information from community members and from an expert.

Application of PBL principles and the PBL Rung attained

Principles:
On-site learning – As learning steps outside the classroom, the community and its surroundings become the classroom.
Learning about the place – Local themes and contexts are used for learning – here specifically local heritage sites and important buildings.
Learning through the place – Students examine local heritage sites and important buildings for geometric shapes and encounter questions such as: Why was a given monument built, who is taking care of it, and has that always been the case? Why do people keep remembering old events? Are there similar conflicts in the world these days? What were their causes? Etc.
Learning for the place – The subject students focus on is a genuine and serious one. The outcome of their work provides a real and useful contribution to quality of life and environmental quality in the community. The teaching unit draws students' attention to the community, its monuments and important buildings in the context of local history and present.
Place attachment – The minilesson relies on and develops personal attachment to one's place. Students explore local heritage sites and buildings shaping the face of the community, viewing them from a novel, different perspective.
Adapting to local situation – Students focus on specific needs and conditions of the place.
Personal relevance – Students find the learning process personally relevant, being able to see how it relates to their own lives. Students experience that the geometric knowledge they have learned can be found directly in their area, at places they know and inhabit, and geometry has its applications in everyday life.
Active student involvement/participation – Ideally, the students themselves pick the heritage site they want to examine. This is a way of supporting their active participation in the educational process. Should the students' choice turn out unrealistic (the monument unsuitable for inspection), return to your prepared option; even this is a significant participative experience for the students.
Community partnership – To conclude the final activity, students are invited to present the results of their work to the community or to engage in knowledge sharing.
Interdisciplinarity – The interdisciplinary, inter-curricular teaching unit helps students understand mutual links between different curricular areas.

Full-fledged teaching tool – The minilesson integrates different areas across the curriculum. It touches upon the following subjects and curricular areas: Geography; Mathematics; Civics education; Arts; Physics; History; and Information and communication technologies.
Cooperation – The teaching unit is centred on group work, with teamwork-based assignments.

Place-Based Learning Ladder (the rung attained by the minilesson is in bold):
Rung 1
Lessons are adapted by adding local examples to existing teaching units.
Rung 2
Lessons are designed to include direct experiences of the place (or direct experiences of the place are added to existing teaching units).
Rung 3
Teaching unit is designed to use the advantages of the place and form a community partnership.
Rung 4
Integrated teaching unit based on PBL that involves service learning and a strong community partnership.