Redesigning Curriculum for Pandemic Pods

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Abstract

The Coronavirus pandemic has thrown public schooling into crisis, trying to juggle learning modes in classrooms, online, home-schooling and in student pods. There is an urgent need to redesign curriculum using available technology to implement approaches that incorporate the findings of the learning sciences, including the emphasis on collaborative learning, computer mediation, student discourse and embodied feedback. This paper proposes a model of such learning, using existing dynamic-geometry technology to translate Euclidean geometry study into collaborative learning by student pods.

Keywords

Online schooling, dynamic geometry, group practices, learning pods.

Design Context: Student Pods in the Pandemic

Alternatives to the traditional teacher-dominated physical classroom suddenly became necessary during the coronavirus pandemic to cover a variety of shifting learning options at all age levels. Although research in learning sciences has long explored pedagogies and technologies for student-centered and collaborative learning, the prevailing practice of schooling had changed little; students, parents, teachers, school districts and countries were poorly prepared for the challenges of the pandemic.

An abrupt rush to online modes found that the digital divide that leaders had promised to address for decades still left disadvantaged populations out. In addition to confronting these hardware issues and low levels of computer skill, teachers had access to few applications designed to support student learning in specific disciplines. They had to rely on commercial business software like Zoom and management systems like Blackboard, which incorporated none of the lessons of learning-sciences research.

While school districts planned for “reopening,” administrators prepared scenarios for combining in-class, online, hybrid, home schooling and small student pods. The plans kept shifting and little was done to train teachers to teach in these various combinations of modalities. Moreover, teachers were not guided in redesigning their curriculum for situations in which they were neither trained nor experienced.

The following describes how a research project translated the ancient pedagogy of Euclidean geometry into a model of computer-supported collaborative learning (CSCL), and how that could be further redesigned to illustrate pedagogy for pandemic conditions. If such a model can succeed during the pandemic, it can herald practical new forms of education for the future.

Emerging Design Solution: Approach for Virtual Math Teams

From 2004 through 2014, the Virtual Math Teams (VMT) research project was conducted at the Math Forum at Drexel University. The VMT research has been documented in five volumes (Stahl, 2006; 2009; 2013; 2016; in press), analyzing excerpts of actual student interaction from a variety of viewpoints and methodologies. This project cycled through many iterations of design-based research, developing an online collaboration environment for small groups of students to learn mathematics together. The software incorporated GeoGebra,[1] an app for dynamic geometry, which is freely available and globally popular. Dynamic geometry is a computer-based version of Euclidean geometry that allows one to construct figures with relationships among the parts and then allows the constructed points to be dragged around to test the dependencies—providing immediate visual feedback.

As part of the VMT Project, curricular units were designed and tried out in online after-school settings, with teacher training on how to guide the student groups and how to integrate and support the online collaborative learning with teacher presentations, readings, homework and class discussion. The geometry activities provided hands-on experience exploring the basics of dynamic geometry in small-group collaboration. Student peer discussion was encouraged that would promote mathematical discourse and reflection. In this way, the research project translated Euclid's curriculum into the computer age. The book that had inspired thinkers for centuries was reworked in terms of dynamic geometry and a learning-sciences perspective.

The VMT platform is no longer available, just when the need for online learning has become urgent. While teachers and students can download GeoGebra without VMT, that would not support full collaboration, where several students can work together on a shared geometric figure. Fortunately, GeoGebra has recently released a "Class" function, in which a teacher can invite several students (a pod) to work on their own versions of the same construction, and the teacher can view each student's construction work and discussion in a Class dashboard (Figures 1 and 2).

[1] https://www.geogebra.org

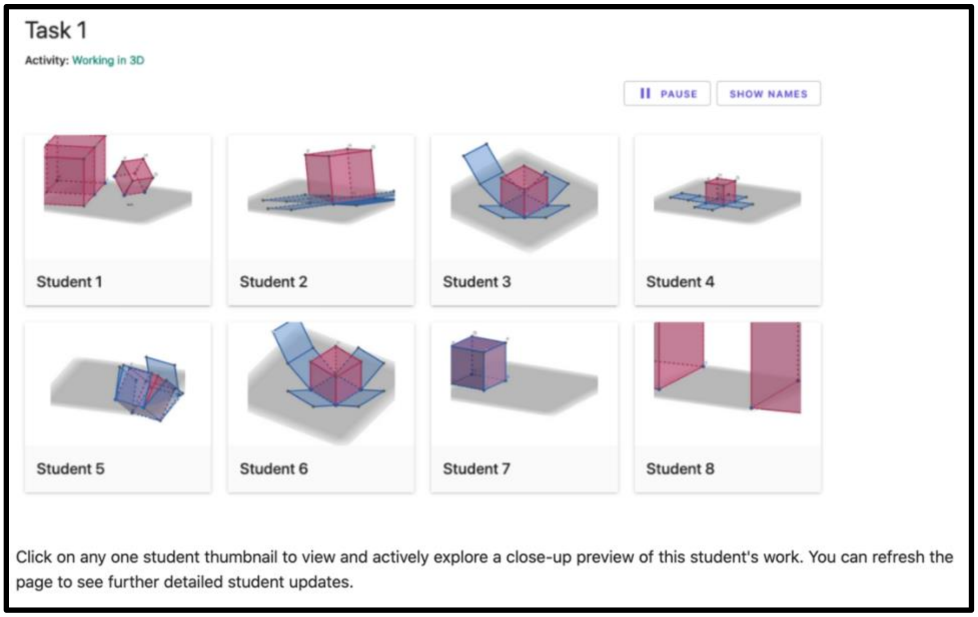

Figure 1. The GeoGebra Class dashboard. Displays current state of each student's work on a selected task.

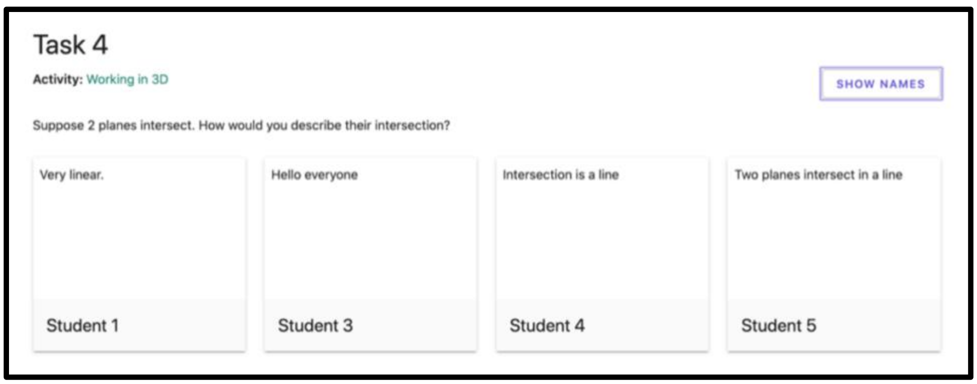

Figure 2. The GeoGebra Class dashboard. Displays each student's response to a selected question.

To take advantage of GeoGebra Classes, VMT's dynamic-geometry curriculum has now been adapted to small pods or even home-schooled individual students using the Classes functionality. The new curriculum is called *Dynamic Geometry Game for Pods* (Stahl, 2020). Using a set of 50 GeoGebra activities that cover much of basic high-school geometry, the instructions and the reflection questions were reworked for the new scenario (Figures 3 and 4). The sequencing of tasks was maintained from VMT, which closely followed Euclid's classic presentation as well as contemporary U.S. Common Core guidelines for geometry courses.

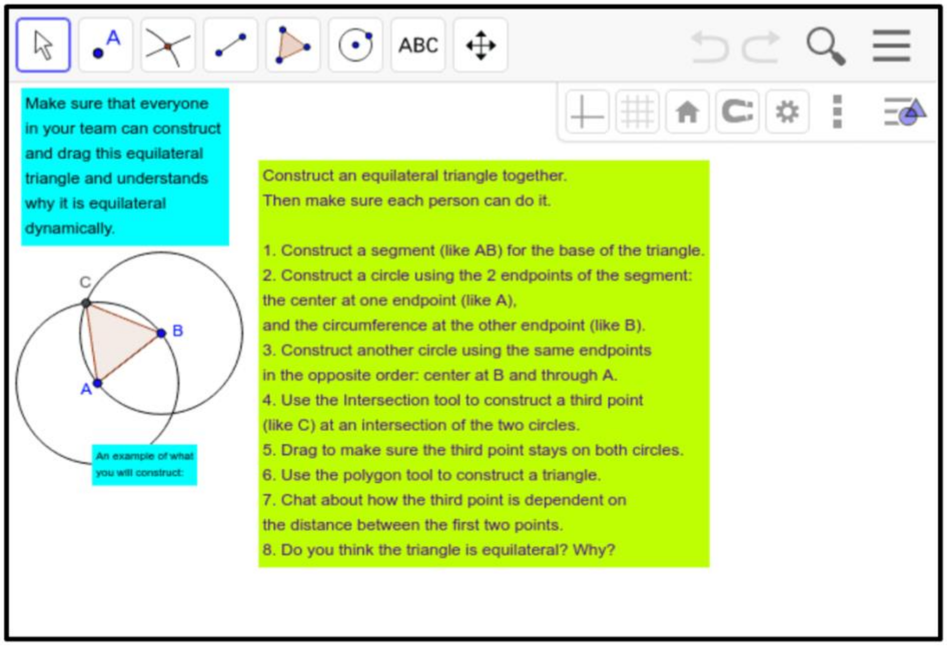

Figure 3. One of 50 tasks for students.

Questions.

Did you construct your own equilateral triangle?

Did you use the DRAG TEST to make sure it works properly?

The equilateral construction opens up the world of geometry; if you understand how it works deeply, you will understand much about geometry.

In geometry, a circle is defined as the set of points that are all the same distance from the center point. So every radius of a certain circle is the same length.

Drag each point in your triangle and discuss how the position of the third point is dependent on the distance between the first two points.

Is your triangle equilateral (all sides equal and all angles equal)?

Figure 4. A set of reflection questions for the task in Figure 3.

Introductions guide classroom teachers, home-schooling parents, pod tutors or self-guided students to use the curriculum. The ideal usage would be by pods of students working online and communicating through the dashboard. A coordinator or teacher can provide all participants with access to the real-time dashboard, so that everyone can observe and discuss what everyone else is doing in GeoGebra and typing in the Class interface. Furthermore, GeoGebra can be shared in Zoom, to provide spoken interaction and recording of sessions for student reflection, teacher supervision or researcher analysis.

The revised curriculum is available on the GeoGebra repository site as an interactive GeoGebra book.[2] It is structured as a sequence of five levels, each including about 10 of the hour-long curricular activities, grouped by geometry topic and degree of expertise required. The format

[2] https://www.geogebra.org/m/vhuepxvq#material/swj6vqbp.

is that of a game with successively challenging levels, which must be conquered consecutively. Additionally, a free e-book[3] is available so people can conveniently review the curriculum offline.

The goal is that math teachers and others can adapt the use of this curriculum and technology to diverse and rapidly changing teaching conditions and learning modalities. If used with full online access—including the Class dashboard shared by everyone, possibly embedded in Zoom—the collaborative learning experience can approach that envisioned in the VMT research. However, it can also be used in other ways and across various presentation modalities.

Review Process: Findings from Previous Trials

The VMT Project was conceived and executed as extended design-based research (DBR), as detailed in (Stahl, 2013). This involved innovations in technology, pedagogy, assessment and theory. Each aspect has been reviewed in multiple formats and contexts, involving international researchers from relevant disciplines.

Findings from the project have been discussed in about 250 publications,[4] including peer-reviewed workshops, conference papers, journal articles, dissertations and books. The project evolved over a decade, prototyping and testing technologies and curricula that underwent multiple iterative revisions each year. The current Game for Pods is the latest iteration, moving from the VMT software platform to the GeoGebra Class function.

Although a variety of analysis approaches were applied to identify successes and problems during VMT trials, most of the published analyses used a form of conversation analysis adopted from informal conversation to the interaction of online school mathematics, as described in (Stahl, 2009). While most of the analyses focused on brief interactions among small groups of students, some included longer sequences, sometimes spanning multiple sessions. In (Stahl, 2015), the entire interaction of a group was followed across eight hour-long online sessions, including micro-analysis of all the discourse and geometry construction.

As captured in the title of (Stahl, 2013), *Translating Euclid*, the pedagogy was converted away from the classical pedantic style of expecting students to accept and memorize concepts, theorems and techniques based on authority. Instead, the project promoted a student-centered and inquiry-based approach of exploration, feedback and discourse based on situated and embodied interaction with computer-based artifacts and guided discussion practicing the use of mathematical terminology.

Although the VMT Project was originally intended to investigate and document phenomena of *group cognition*, in the end it proposed a methodological focus on *group practices* (Stahl, 2016). The sequencing of challenges in the Game for Pods is carefully designed to guide student groups and individuals to adopt group practices and individual skills needed to progress through the process of collaboratively learning dynamic geometry. The VMT research indicates that such an approach can be effective. The Game for Pods is based on this body of findings, as well as on the extensive learning-science literature that underlies the VMT project's theory of group cognition (Stahl, in press).

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[3] http://gerrystahl.net/elibrary/game/game.pdf
[4] http://gerrystahl.net/vmt/pubs.pdf

Constructive Critique and Reflections: Supporting Group Cognition

This paper is proposing that teachers, parents and pod organizers use the GeoGebra book with its 50 challenges for courses in high-school geometry. Educators in other fields could follow this example and develop analogous curriculum and technology usage. Then the results of such educational interventions could be collected, shared and analyzed. Analysis techniques honed during the VMT Project could be used along with other methods to investigate collaboration patterns in interaction discourse, the adoption of targeted group practices and advancement of learning goals.

This approach contrasts with the traditional view of learning as primarily a psychological process of changing an individual's mental contents. Rather, individual learning is seen as largely a result of group and social processes in which multiple people, artifacts, technologies and discourses interact to evolve cognitive products at the group level, such as mutual understandings, intersubjectivity, distributed cognition, communal conceptualizations, common interpretations of problems, collaborative problem solving and shared knowledge. While individuals contribute to these group phenomena, the collective products have a life of their own.

One way that group cognition can result in individual learning is through the adoption of group practices, which then provide models for individual behavior. For instance, a pod of students working on a geometry problem can encounter a concept, theorem or technique that may originate with a pod member, from the problem description, from the history of geometry, etc. The pod discussion may then explicitly discuss what was encountered, come to a shared understanding of how it applies to the pod's current situation and even overtly all agree to use it. In subsequent interactions, the pod simply applies the new practice without discussing it again. It becomes a tacit group practice, recognized by everyone in the pod. Pod members may also retain this practice as an individual mathematical skill when they work outside the pod.

While the theory of group cognition and group practice has been discussed at length in the reports of the VMT Project, it will be interesting to see these theories are manifested in new situations in which the Game for Pods or analogous curricula are enacted. In addition to these quite broad theories, the VMT Project developed characteristics that may be more specific to digital geometry; it will also be important to investigate the applicability of these in new contexts.

A central focus of the Game for Pods is on the notion of dependency as central to dynamic-geometric constructions. For instance, in constructing an equilateral triangle with radii of equal circles, it is essential that the length of the three sides are dependent upon the equal radii, even when a triangle vertex or a circle center is dragged to a new location. Indeed, the proof that the triangle is equilateral hinges on this dependency—and has for thousands of years since (Euclid, 300 BCE). Viewing constructions in terms of dependencies (rather than visual appearance or numeric measurements) is quite difficult for students to learn. One can observe such a view as it emerges in the discourse of a pod, assuming that the curriculum has been effectively designed to promote such a group practice.

One aspect of curriculum design to support the adoption of specific group practices in dynamic geometry is to sequence tasks and associated practices carefully. This is clear in Euclid's presentation and in the hierarchies of theorems in every area of mathematics. However, in collaborative learning of geometry, groups must adopt more practices than just the purely mathematical ones. Specifically, (Stahl, 2016) identified about sixty group practices that the team explicitly, observably enacted. These practices successively contributed to various core aspects of the group's abilities: to collaborate online; to drag, construct, and transform dynamic-geometry figures; to use GeoGebra tools; to identify and construct geometric dependencies; and to engage in mathematical discourse about their accomplishments.

Some of these group practices are specific to the collaborative learning of dynamic geometry with GeoGebra. In addition to the focus on construction of dependencies and the associated discourse of how different elements of a figure are dependent upon each other, the use of GeoGebra introduces other aspects that would be different in other disciplines. For instance, it was necessary to design the VMT technology to allow all group members to observe each other's construction processes in detail, because the animation of those processes could be quite informative. In addition, the immediate feedback afforded by GeoGebra—for instance when someone dragged a point and the whole construction changed, revealing what was and what was not dependent on that point—was crucial for group behavior, discourse and learning.

These features of the VMT experience will need to be reconsidered in the design and analysis of future research along these lines, particularly to the extent that curriculum and technology diverge from previous forms.

Implications and Next Steps: Broadening the Model

Dynamic geometry is just one area of mathematics covered by GeoGebra. The software supports all of school math from kindergarten through junior college. It is available in over a hundred world languages. Thus, a teacher, parent or student who masters dynamic geometry through the curriculum discussed here can go on to explore other areas of mathematics with this kind of computer support. Learning scientists can develop curriculum units for all ages in all countries following this model.

It is difficult to convert courses from in-class to online. Typically, much of the effort goes into designing the curriculum and student tasks in advance and setting the procedures and expectations for the students. It takes several iterations to work things out, and in each course it requires teacher patience while students adjust. Students must be guided to communicate with their collaborators and to let go of competitive instincts. Grading has to be redefined in terms of group participation and group accomplishments.

The model proposed here is not a panacea for the current crisis of schooling, but rather an indication of a potential step. We still need to overcome the digital divide, promote collaborative learning, develop educational technology for exploring many domains, train teachers in online teaching, redesign curriculum to make it flexible for shifting modes of schooling. If we do not do this, then the learning sciences will have missed an opportunity to promote new forms of collaborative, inquiry-based and computer-supported learning. Only by meeting this challenge can we avoid the looming destruction of public education and the resultant serious worsening of social inequity.

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