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Developing Coordination and Organizing Skills in K-12 Students through Systems Engineering Projects (RTP)

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Abstract

Building a complex multi-systems engineering project requires coordination between individuals from different engineering disciplines (Jonassen et al., 2006; Trevelyan & Tilli, 2007). To help K-12 students learn how to work in real engineering environments and prepare for the future, it was important to teach them how to coordinate and organize their projects (Pleasants & Olson, 2019). To support K-12 students working on systems engineering projects and help develop their systems thinking skills, we developed and implemented a project management board (Brennan et al., 2023) along with methods designed to aid students in completing various tasks and collaborating on a large-scale project. In February 2024, we ran a workshop with 13 elementary school students during a school break camp in Massachusetts, where they worked together to build a Smart Model of a City over four consecutive days. The students were divided into five sub-teams—Power, Roads, Buildings, Vehicles, and Trains—and then collaborated to integrate their builds into one cohesive Smart City.

On the third day of the project, we asked four students, one from each group, to meet in a separate room to come up with tasks for the entire project. In this paper, we focused on the task development group's conversation and design process to analyze how students worked within this group, shared ideas, and coordinated with other team members to assign tasks to both subgroups and the class as a whole. Additionally, we observed students having high motivation, with everyone focusing on their duty and remaining engaged.

Based on our initial analysis, we found that the structure of the systems engineering project and the use of the project board supported students in developing their coordination and organizing skills. We found that: 1) students were able to coordinate, define their roles, stay focused, and complete their duties with less teacher supervision; 2) students from different subgroups were able to sit together, share, and listen to each other, understand the other teams' roles in the overall project, and collaborate effectively as a new group to design new tasks; and 3) students in the task development group successfully negotiated and assigned tasks for their subgroups. This approach allowed students to apply their knowledge and solve complex problems together. In situations where there was too much material to teach all students, rather than covering every topic in depth, this method supported students' teamwork and shared understanding, preparing them for real-world collaborative problem-solving.

Introduction

Building a complex multi-systems engineering project requires coordination between individuals from different engineering disciplines (Jonassen et al., 2006; Trevelyan & Tilli, 2007). Collaboration is an important skill of the 21st century (Chou et al., 2012). Both the National

Educational Technology Standards and Performance Indicators for Teachers (ISTE, 2000) and the National Educational Technology Standards for Students: The Next Generation (ISTE, 2007) pointed out that collaboration was one of the core skills that students should have developed in their education programs. To help K-12 students learn how to work in real engineering environments and prepare for the future, it was important to teach them how to coordinate and organize their projects (Pleasants & Olson, 2019). However, Thieman's five-year research showed that 85% of preservice teachers could integrate technologies and knowledge into K-12 classes, but only 50% of preservice teachers supported students in developing their communication and collaboration skills in the samples (Thieman, 2008).

We found system engineering to be a good way to support K-12 students in developing their collaboration skills, and students reflected they liked this system engineering project in the post-interview. A system was "an arrangement of parts or elements that together exhibited behavior or meaning that the individual constituents did not" (International Council on System Engineering [INCOSE], n.d.). This implies collaboration across disciplines to combine different individuals' works. Applying system engineering at the K-12 level helped students learn the importance of collaboration for solving complex and interdisciplinary problems and developed their collaboration senses and skills. Many schools have provided engineering classes and projects in recent years; however, we did not find much research on developing students' coordination skills in engineering design and system engineering projects. To support K-12 students working on systems engineering projects and help develop their systems thinking skills, and also to be a resource that other teachers could use, we developed and implemented a project management board (Brennan et al., 2023) along with methods designed to aid students in completing various tasks and collaborating on a large-scale project. In this paper, we focused on kids as task developers in a systems engineering project.

Tool - Project Board

We developed a physical project board to support this project (Figure 1), which can also serve as a resource for other teachers interested in running systems engineering projects or enhancing students' collaboration skills. The project board consists of 5 main components: Teams, Task Bank, Done Tasks, Sprint Information, and Score. **Teams:** Students are assigned to their respective subteams. **Task Bank:** A collection of instructional tasks written primarily by the teacher, with students contributing tasks later in the project. These tasks are recorded on sticky notes. **Done Tasks:** A section where students place completed tasks from the Task Bank. **Sprint Information:** Displays details about the current sprint, including the sprint number, start and end dates, and the assigned Scrum Master. **Score:** A cumulative team score based on completed tasks, where each task has an assigned point value. The term sprint is derived from Agile methodology (Beck et al., 2001), which structures work into short, iterative cycles. Similarly, the Scrum Master role originates from Agile practices and is responsible for facilitating the process. In this project, the teacher acted as the Scrum Master, guiding students through the workflow.

Teachers provided tasks for different teams at the beginning of the class on sticky notes, which included scores for each task, and put them in the Task Bank. There were 5 teams in this Smart City project: Power, Roads, Buildings, Vehicles, and Trains. Each team finished all tasks in the Task Bank, moving completed tasks to the Done Tasks column. Teachers released new tasks during the building process, giving teachers a lot of flexibility to adjust the tasks based on the class situation. Further, as a motivator, each task was worth a predefined number of points, and there was a score box in the top right corner, which showed the total score for the whole group based on the tasks they completed.

In traditional engineering projects in school, teachers usually provide the same set of instructions to the entire class. (Mills & Treagust, 2003) As a result, all students in the class follow identical guidelines when building their projects. However, in system engineering projects, students were responsible for different parts of the project, which created a demand for a project management tool as communication between people on the project. This tool also helped teachers assign students to sub-teams, as well as provide different tasks to individuals working on the project. The teams in the project board were color-coded, and we provided "hard hats" for students in the projects to color-match their teams in the project board. Each team also had a unique shape on the board so color-blind people also had access to it. This physical project management tool—the Project Board — enabled students to engage effectively with large boards or classroom whiteboards, offering a low-cost and accessible solution. (Brennan et al., 2023; Tonkal et al., 2024)

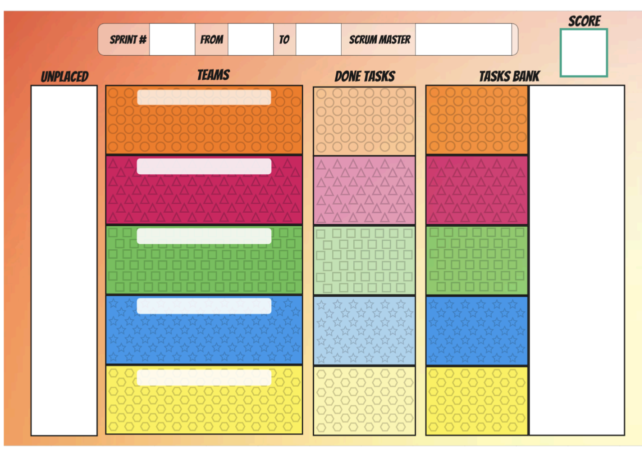

Figure 1. The project board

Method

In February 2024, we ran a workshop with 13 elementary school students who were 7–11 years old during a school break camp in Massachusetts, where they worked together to build a Smart Model of a City over four consecutive days. To support the project, we used the project board.

The students were divided into the five sub-teams—Power, Roads, Buildings, Vehicles, and Trains—and then collaborated to integrate their builds into one cohesive Smart City. Each group had 2 to 3 kids, and the subteams contributed to the overall project. The learning goals for this project were to support students in learning collaboration, sub-project integration, and the planning/scoping/organizing of the engineering project. On the third day of the project, we asked five students, one from each group, to meet in a separate room to come up with tasks for the entire project.

The data sources included videos of the camp, researchers' fieldnotes, and pictures of students' work and final projects. In this paper, we focused on the video piece of the planning/scoping session, which included 5 kids who came from different subteams and reorganized a new group to construct tasks for all of the other groups to complete. We applied an inductive coding approach. (Thomas, 2006) We went through the classroom observation transcripts, field notes, teacher reflections, and student post-interview transcripts, and assigned codes based on what we saw. The initial rough codes included "student engagement", "negotiation", "collaboration", "assign duties", "leadership" and so on. Then we refined and grouped codes and we focused the code and signal moments that evidenced 1) students were able to coordinate, define their roles, stay focused, and complete their duties with less teacher supervision; 2) students from different subgroups were able to sit together, share, and listen to each other, understand the other teams' roles in the overall project, and collaborate effectively as a new group to design new tasks; and 3) students in the tasks development group successfully negotiated and assigned tasks for their subgroups. In this paper, we focused on the task development group's conversation and design process to analyze how students worked within this group, shared ideas, and coordinated with other team members to assign tasks to both subgroups and the class as a whole.

Our research question is: How does the systems engineering project (with the project board) support students in developing their coordination and organizing skills?

Findings

In this research, we found that building the Smart City supported students' development of coordination and organizing skills. There were three major findings: 1) students were able to coordinate, define their roles, stay focused, and complete their duties with less teacher supervision; 2) students from different subgroups were able to sit together, share, and listen to each other, understood the other teams' roles in the overall project, and collaborated effectively as a new group to design new tasks; and 3) students in the tasks development group successfully negotiated and assigned tasks for their subgroups.

1) ***Students were able to coordinate, define their roles, stay focused, and complete their duties with less teacher supervision***

In the Smart City project, students used the project board (Figure 2) as a reference to guide their work, allowing instructors to focus on more technical support, such as coding or building mechanisms. Subgroup meetings were productive, as they helped students follow the task system outlined on the project board to organize and assign tasks. During these meetings, students navigated multiple phases of discussion. Initially, they reviewed the roles and progress of each sub-team. They then systematically developed the next set of tasks for each team. Students in the subgroup naturally adopted distinct roles that contributed to the meeting's success. One student took on the “note-taker” role by writing down tasks, another acted as the “leader” or “scrum master,” initiating and guiding discussions, and a third served as the “timekeeper,” ensuring the group stayed on schedule. The first student started the conversation *“So what can the power [group] do?”*, based on our observation and fieldnotes she took the leader role organically, and the second student who is a “note-taker” took the pencil and paper and started writing down other students’ ideas when the conversation started. The third student went out to find teachers and asked for a timer, she was the timekeeper who kept track of the time and reminded people every 5 minutes. These roles emerged organically, without prior assignment or explicit acknowledgment during the meeting. By collaboratively writing tasks on sticky notes, as instructed, the students demonstrated their ability to independently manage discussions and achieve their goals. This showed students’ capacity to run meetings effectively without direct instructor facilitation.

Figure 2. The project board was used in the Smart City project.

2) ***students from different subgroups were able to sit together, share, and listen to each other, understand the other teams’ roles in the overall project, and collaborate effectively as a new group to design new tasks***

Something also worth noting that happened in this meeting (Figure 3) was when one of the students, from the trains team, who kicked off the meeting (holding a pen and sticky notes), said, *“Let’s see what power can do, umm, maybe, let’s say, [smiled], I had no idea what power did.”* The student from the building team jumped in, looked at the power team representative, and said, *“What did power do? Let’s have some more information.”* Then the power team representative was able to talk to these two students about what had been assigned to the team and what contribution the team had made to the project. The other two students were able to use this information to suggest more tasks, like building an automatic door and building a power plant that generated electricity, even though they had little to no idea what that team had been doing before the meeting. This demonstrated that students were able to effectively listen to other students who were not part of their subteam and understand what they were saying. It seemed that the students had realized the importance of understanding each other to achieve the goals of this meeting.

All the students took part in this meeting. There were different levels of students’ contribution to the meeting. Some students talked more, and others were quieter. Students were not given specific instructions on meeting norms beforehand, they were simply told to hold a meeting. As a result, students explored their own strategies for their meetings. Since they didn’t have too much experience as hosts and lead meetings, there was some space for them to improve their time management strategies. Although there was a “timekeeper” who constantly reminded the whole group of how much time was left, they weren’t efficiently using the meeting time to finish all the assigned tasks. When it was the pre-set ending time, students asked the instructor to give them some extra time and promised they had learned from this experience and would do better time management in the future. In the additional time instructors provided, we saw students pay more attention to their time management and the meeting structures. The “leader” gave more clear instructions to control the conversation: *“You go first.” “What’s your idea?”* and when other students tried to interrupt the talking the “leader” said: *“Guys, we are going to go one by one.”* When people talked about random things which not related to the topic, the “timekeeper” said: *“We are really wasting time, [face to one student] what’s your idea?”* and forced the conversation back to the task development topics.

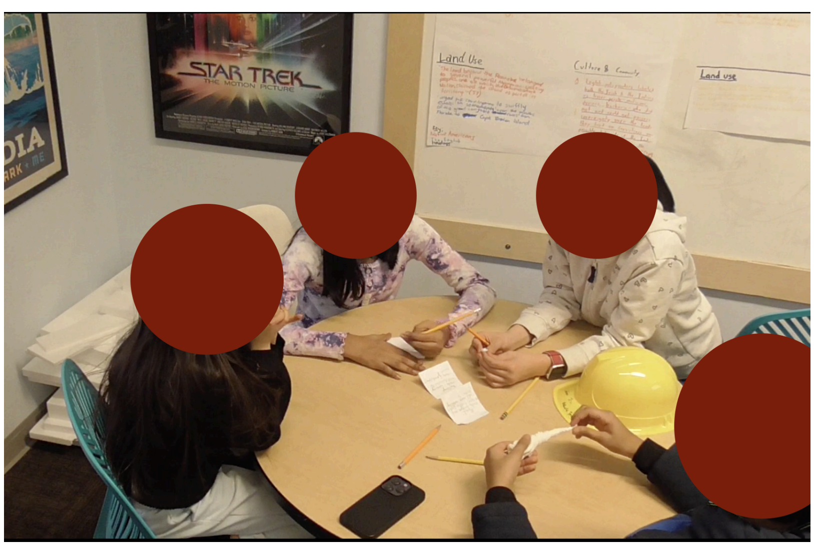

Figure 3. Tasks development group in a meeting.

3) ***students in the tasks development group successfully negotiated and assigned tasks for their subgroups***

In the tasks development group's meeting (Figure 3), students from different groups provided different ideas and assigned tasks for the subgroups. There were some examples of the tasks students came up with: *build the city lighting; make lightning rods; AI police; make the train track more stable; make the back wheel on the train more stable; build small cars; build a school bus…* We also noticed that students considered the subgroups they came from and tried to negotiate with others to provide suitable tasks to their groups. We observed that the project board not only helped students break down the problem into manageable tasks but also facilitated meaningful conversations across groups. During the group meeting, students used the meeting outcomes and the tasks written on sticky notes to populate the appropriate slots on the board. They then communicated these new tasks to other students who were not part of the meeting but were involved in the project. This process demonstrated how the structure of the Smart City system engineering project (Figure 4), combined with the project board as a tool, supported the development of students' coordination and organizational skills.

A conversation between students at the project board that students negotiate for the assigned tasks:

> A student from the road team: *"I don't like it that I have to do three bridges. That's way too much."*
> A student from the meeting group: *"Okay, why don't we make it two bridges?"*
> A student from the road team: *"Okay, why don't we make it two bridges?"*
> A student from the meeting group: *"One."*
> A student from the road team: *"Okay, one bridge."*

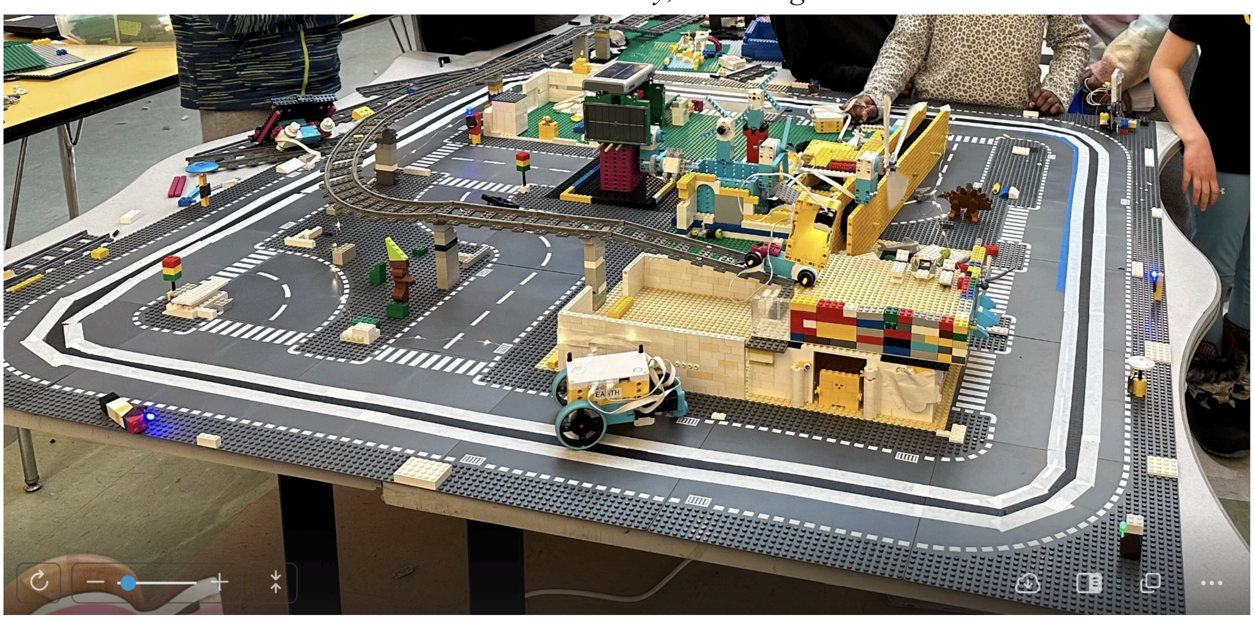

Figure 4. Smart City - Students' final work.

Conclusion

Our findings highlight how the structure of the system engineering project - Smart City and the use of the system engineering tool we developed - Project Board effectively supported students in developing coordination and organizational skills. Through this approach, students took ownership of their roles, managed tasks with minimal teacher supervision, and engaged in meaningful cross-team collaboration. The Project Board served as both a reference material and a communication tool, supporting students to break down complex problems, negotiate responsibilities, and integrate diverse perspectives.

This system engineering project not only enhanced students' teamwork and problem-solving abilities but also demonstrated an alternative instructional strategy for handling complex engineering topics. Rather than requiring every student to learn all aspects of the project in isolation, the structure encouraged students to contribute their expertise in different subgroups, where students relied on one another's knowledge to drive progress. This approach is the way of real-world engineering collaborative problem-solving and prepares students for future interdisciplinary teamwork.

Beyond this study, Project Board offers a way for K-12 educators seeking to foster student collaboration in systems engineering and similar project-based learning environments. Future research could explore its adaptability across different educational contexts and age groups, and further complete its role in enhancing student coordination and engagement.

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