Designing a Holistic Digital Fabrication Interdisciplinary Curriculum for Elementary School Learners

Melvin LaPrade, Sherry Lassiter, Rodney Williams, Norma Andrade, Monica Aring, Jean Eisle, Larry Hulbert, Brian Purvis, Robert Shepard, Sarah Wallace

Melvin LaPrade, Fab-hood Network
United States
melvin@fabhoodnetwork.org

Sherry Lassiter, Fab Foundation
United States
sherry.lassiter@fabfoundation.org

Rodney Williams, Fab Foundation
United States
rodney@fabfoundation.org

Norma Andrade, Seattle Public Schools
United States
ncandrade@seattleschools.org

Monica Aring, InnoVuntu Initiative
United States
monika.aring@gmail.com

Jean Eisle, University of Washington, Bothell
United States
jeisele@uw.edu

Larry Hulbert, Independent Consultant
United States
larryhulbert@mindspring.com

Brian Purvis, BKB Education Consulting
United States
2gointernational@gmail.com

Robert Shepard, Independent Consultant
United States
bobshepard@comcast.net

Sarah Wallace, Cleveland Metropolitan School District
United States
sarahpwallace15@gmail.com

Abstract

This paper describes a pilot design process for STEM education, going beyond the traditional STEM focus to incorporate digital fabrication, disciplinary and transversal skills, project-based learning pedagogy, an Understanding by Design curriculum development process, and cross-school capstone approach for elementary school students. The approach provides a holistic, integrated approach to STEM education, incorporating communication, collaboration, creativity, critical thinking, and problem-solving skills, all essential for success in the 21st century.

In 2022 a Polish educational non-profit organization, The Holistic Think Tank (HTT), set out to discover what should be taught in K-12 schools, and to design interdisciplinary curricula to address those needs. The global discovery process led to the creation of 10 competency categories that HTT believed should lay the foundations for curriculum design, grounded by humanistic and transversal skill development, in combination with disciplinary learning. Fab Foundation was one of three organizations chosen to develop this interdisciplinary course.

The authors lay out the pedagogy, process and implementation approach to holistic, 21st century, integrated curriculum design for K-6 learners, providing guidance and a framework for teachers to design capstones. Overall, this paper offers a comprehensive and innovative way of teaching STEM that prepares students for the modern workforce and promotes lifelong learning.

Keywords

Curriculum Design, K-12 Digital Fabrication Curriculum, K-12 STEM Curriculum, Capstone Curriculum

1 Introduction

In an era characterized by rapid technological growth and global connectivity, education must extend beyond mere knowledge transfer to include life skills such as critical thinking, digital literacy, and socio-emotional competencies. Traditional methods that emphasize rote learning fall short of equipping students for the complex demands of the 21st century. Recognizing this, the Holistic Think Tank (HTT), a Polish non-profit educational organization, issued a global challenge in 2022, urging others to create an innovative curriculum called the Interdisciplinary School Subject (IDS). IDS represents a revolution in primary education, merging diverse literacies with a holistic approach to instill humanistic values while teaching traditional subjects.

In the face of global educational challenges, the Holistic Think Tank (HTT), undertook an extensive, AI-assisted study to decipher key competency areas essential for holistic child development. The meticulous approach involved sifting through worldwide educational data, distilling it into ten principal competency areas with 46 sub-competencies (HTT: Mission, 2023). These are collectively referred to as "What Schools Ought to Teach" (WSOT) (HTT: In Focus, 2023). This spectrum of competencies encompasses various facets of life and learning, including confronting challenges, functioning harmoniously with the world, nature, society, and oneself, scientific learning, cultural awareness, adaptability, entrepreneurship, interpersonal communication, and self-development.

Supplementing this AI-driven analysis, HTT conducted in-depth phenomenographic research, visiting schools across diverse settings in 10 countries (HTT: Mission, 2023). The research findings affirmed that imparting humanistic values should be the primary goal across all subjects. These values, rooted in freedom, respect for others, and the capability to foster good interpersonal relationships, are regarded as the cornerstones of culture and civilization. With its unique approach, HTT aspires to effectively transform what constitutes a well-rounded education, placing a higher emphasis on the interplay of various competencies and humanistic values within the learning environment. This innovative shift marks a milestone in pedagogy, heralding a new era of holistic, competency-based education.

2 Fab Foundation’s Design Approach

Once the key humanistic competencies were identified by HTT, the Fab Foundation, and two other educational organizations were challenged to bring their unique expertise to the table. In concert with HTT's findings, the Fab Foundation brought into focus the digital literacy competencies developed for its SCOPES-DF project (SCOPESDF, 2023). A specialized team was assembled, comprising in-service primary education teachers, fab educators, and master educators experienced in global curriculum design and development. Together, they tackled the challenge of designing interdisciplinary, holistic curricula that complemented and supported the competencies identified.

Emphasizing 21st-century digital skills such as design, fabrication, and computational thinking, the approach sought to foster digitally-literate global citizens from primary school. The curriculum we focus on in this paper, centered around "Thriving Natural Communities," advocated for sustainable living in harmony with nature. This effort marked a key step in providing a digital and STEM curriculum for an underserved age group.

The Fab Foundation's curriculum fostered empowerment, encouraging students to be change-makers. The theme of "thriving" underscored a holistic understanding of reality, respect for the environment, and nurturing relationships. Guided by the WSOT list, it aimed to equip youth to navigate today's complex world, promoting cooperation, respect and informed decision-making. In designing the curriculum, digital fabrication was combined with disciplinary and transversal skills in a project-based learning framework.

Utilizing an "Understanding by Design" curriculum development process and a cross-school capstone approach ensured the curriculum's focus on deep understanding and real-world application. This innovative K-6 curriculum offers a guide for teachers and a pilot framework for capstone project design. The project has yet to be piloted in classrooms. However, below, the authors of the project reflect on the

process and identify areas that need improvement. They also outline steps to achieve broader global adoption, demonstrating their dedication to iterative development, continuous improvement, and scalability.

3 Methodology

This research undertook an innovative and integrative approach to curriculum development. The methodology centers around four critical educational elements: interdisciplinary learning, socio-emotional development, project-based learning, and digital literacy. The aim was to furnish students with competencies necessary to thrive in a future increasingly defined by empathy, equity, and environmental stewardship. The approach anticipates a world where artificial intelligence and automation pervade daily life, necessitating students to synthesize diverse subjects, analyze data, and employ technology effectively.

The linchpin of our curriculum is a capstone project, "Thriving Communities," designed to span all elementary grades. We created syllabi based on grade bands—combining grades 1 and 2, grades 3 and 4, and grades 5 and 6. Each syllabus includes various learning activities, essential questions and understandings, rubrics for evaluations, and self-assessments. The project integrates tenets such as thriving people and nature, harmonious coexistence, a fair world for all, meaningful connections, exploration and understanding, and joy in learning. These principles aim to stimulate students to devise comprehensive, responsible solutions for real-world problems while enhancing societal and environmental well-being.

- For widespread adoption, our approach necessitates further professional development and strategic collaboration with educational stakeholders. We believe that our interdisciplinary curriculum can inspire and benefit educators and students alike. In the following section, we elucidate the elements of our innovative HTT IDS course, emphasizing its adaptability and integration of digital literacies to cater to a diverse range of learners.
- To implement this curriculum, we defined certain assumptions integral to the decision-making, planning, and evaluation processes. These assumptions facilitate communication and collaboration, ensuring alignment with the course's objectives and adaptation possibilities:
- Schools' access to digital fabrication equipment: The course assumes schools have access to basic digital fabrication tools, such as vinyl cutters or 3D printers, alongside some computers and hand tools for manual fabrication. These resources enable hands-on learning experiences, a core component of the course.
- Course independence from digital fabrication: Despite acknowledging the role of digital fabrication, the course is not solely reliant on these resources. It aims to weave the development of digital literacies with an interdisciplinary learning approach, ensuring student engagement regardless of the digital fabrication resources available.
- Interdisciplinary, experiential/discovery, project-based learning (PBL) approach: The course adopts an interdisciplinary approach, enabling students to explore multiple subjects within real-world contexts. It assumes an experiential and discovery-based pedagogy, engaging students in hands-on activities. Additionally, it utilizes a PBL approach, encouraging students to address authentic problems, thereby fostering critical thinking, collaboration, and problem-solving skills.
- Weekly course time allocation: We anticipate that teachers will have 2 to 3 hours weekly to deliver this course. This time can be distributed across several sessions or a single session, subject to each school's schedule and logistics. This assumption enables effective planning and allocation of instructional activities within the given timeframe. And we also leave open the possibility of this course becoming the entire curriculum for 3-4 weeks if a school is interested in an immersive experience.

These assumptions underpin the design and implementation of the proposed course, providing a foundational framework for its execution.

4 Understanding by Design

Understanding by Design (UbD) is a significant framework in our methodology. Developed by Grant Wiggins and Jay McTighe (Wiggins and McTighe, 1998), UbD utilizes a 'backward design' approach that first identifies end goals, then designs instructional materials to achieve them. This approach, centered on core principles of 'big ideas', understanding, and constant evaluation, involves three stages: identifying desired results, determining acceptable evidence, and planning learning experiences.

UbD Stage 1: Identifying Desired Results

This stage involves identifying learning objectives, such as fostering creativity and problem-solving skills through digital fabrication and HTT competencies like reflection and cultural awareness. We determine these objectives based on how digital fabrication and HTT competencies align with the curriculum's big ideas and essential questions.

UbD Stage 2: Determining Acceptable Evidence

The second stage entails identifying assessment tools that gauge not just knowledge but also skills and competencies. For digital fabrication, this could involve students using digital tools to solve real-world problems. HTT competencies could be assessed through reflective essays or discussions that demonstrate a student's critical engagement. Performance tasks may include students using digital fabrication tools to create products addressing social issues, reflecting HTT competencies like social responsibility and cultural awareness.

UbD Stage 3: Planning Learning Experiences and Instruction

The final stage involves designing learning experiences that align with the identified results and evidence. Here, digital fabrication becomes a hands-on learning tool. Educators may design a project where students create a prototype using digital fabrication tools to solve a specific challenge. They can integrate HTT competencies by having students work in diverse teams, requiring effective communication, collaboration, and problem-solving. Additionally, educators can facilitate discussions on the societal or environmental impacts of their projects, prompting students to contemplate the consequences and ethics of their creations.

Incorporating UbD's backward design approach into our methodology ensures our curriculum is centered on clear learning objectives, incorporates relevant assessments, and develops learning experiences that cater to our objectives and assessments. This approach thus forms an integral part of our innovative curriculum design.

5 Case Study

This case study seeks to demonstrate the effectiveness of pedagogical strategies through a focused examination of a course titled "Natural Habitats" intended for young learners (ages five to eight). This course thoughtfully intertwines elements of the Understanding by Design (UbD) framework, HTT competencies, and digital fabrication tools. The thematic focus on natural habitats leverages hands-on learning to foster an understanding of the community and the wider environment among students. Engaging in activities that elucidate the interconnectedness of flora, fauna, and humans, students culminate their learning journey with a capstone project where they design and present an educational trail through a local habitat.

The course is grounded in the HTT competencies, which entail comprehending our connection with nature, nurturing social responsibility, and refining interpersonal communication skills. The key educational outcomes of the course encompass the understanding that thriving communities hinge on symbiotic relationships and communal care and that alterations within the environment can generate far-reaching ripple effects. The pedagogical approach is three-pronged. Initially, students craft a community web diagram. Subsequently, they broaden their personal community webs to incorporate elements of their physical surroundings. Lastly, they populate a template with facets of their community and environment to visually represent the collective community. The digital dimension of the course utilizes

fabrication tools to cut out different human shapes or to digitize students' drawings, thereby generating a large-scale community map. Students also employ a user-friendly drag-and-drop program to construct a digital community map. The capstone project entails students researching, creating, and constructing information signage and activity stations that educate and engage the visitors to this “Thriving Natural Habitat“.

The subsequent sections delve into the alignment of the three stages of the UbD framework - identification of desired outcomes, determination of acceptable evidence, and planning of learning experiences and instruction - with the design and execution of the IDS "Natural Habitats" course. This exploration underscores the harmony between the course and the UbD methodology, exemplifying how well-considered curriculum design can amplify the learning experience and expedite the attainment of educational goals.

Stage 1: Identifying Desired Results

In the IDS Course on Natural Habitats, the desired learning outcomes are well-articulated and linked with the broader theme of the course. The course intends to strengthen students' ability to identify interrelationships among different members of a natural habitat. It aims to enhance their understanding of how plants, animals, and humans interrelate, both positively and detrimentally, and encourages students to propose ways of improving these relationships. The Essential Understandings section outlines these key learning goals, highlighting the emphasis on community dynamics, interrelationships, and the influence of changes within the community.

Stage 2: Determining Acceptable Evidence

The IDS Course clearly defines the evidence required to determine students' understanding and application of the learned concepts. The capstone project of creating an informational walking path through the local natural environment serves as an authentic assessment tool. Here, students showcase their understanding of ecosystems and the interrelationships between their components. They apply their knowledge to design and build the path, integrating physical activities, mindfulness tasks, and learning opportunities about the ecosystem. This project provides tangible evidence of students' understanding and their ability to apply their knowledge in a real-world context.

Stage 3: Planning Learning Experiences and Instruction

The course is structured around a series of learning activities that align with the identified desired results and the acceptable evidence. For example, the initial learning activities focus on building students' understanding of their personal communities and their environments. Later activities extend this understanding to their broader community, demonstrating the links and dependencies within their local ecosystem. The digital literacy and fabrication component, involving the use of digital tools like a laser cutter or a drag-and-drop program for designing a community map, exemplifies hands-on, experiential learning. These learning experiences are designed to progressively build students' understanding, ultimately leading to the capstone project that synthesizes their learning.

In summary, the case study highlights the benefits of integrating digital fabrication via the UbD framework. This integration fosters innovation, creativity, and holistic development among students, aligning the curriculum with specific outcomes and transferable skills, particularly in the context of digital fabrication, in the following ways:

> **Digital Fabrication Enhances Understanding:** It provides students with a hands-on way to explore essential questions. For example, the question, "How do we define 'thriving'?", can be examined more profoundly through visual aids created using digital fabrication, stimulating critical thinking and facilitating deeper discussions.
>
> **Supports Achievement of Learning Goals:** Digital fabrication aligns with critical learning outcomes such as proficiency in digital tools, creativity, innovation, and technological literacy. Students achieve these outcomes through hands-on technology projects that bring their learning to life.
>
> **Encourages Engagement and Assists in Assessment:** The use of digital fabrication fosters active student engagement, sparking curiosity and promoting problem-solving and critical thinking skills.

Additionally, the tangible products of digital fabrication give educators a concrete way to assess student understanding. This assessment can extend beyond the final product to include the problem-solving, and critical thinking processes students engaged in during the creation phase, allowing for comprehensive insight into students' learning and potential adjustments in instruction.

6 Framework and Implementation

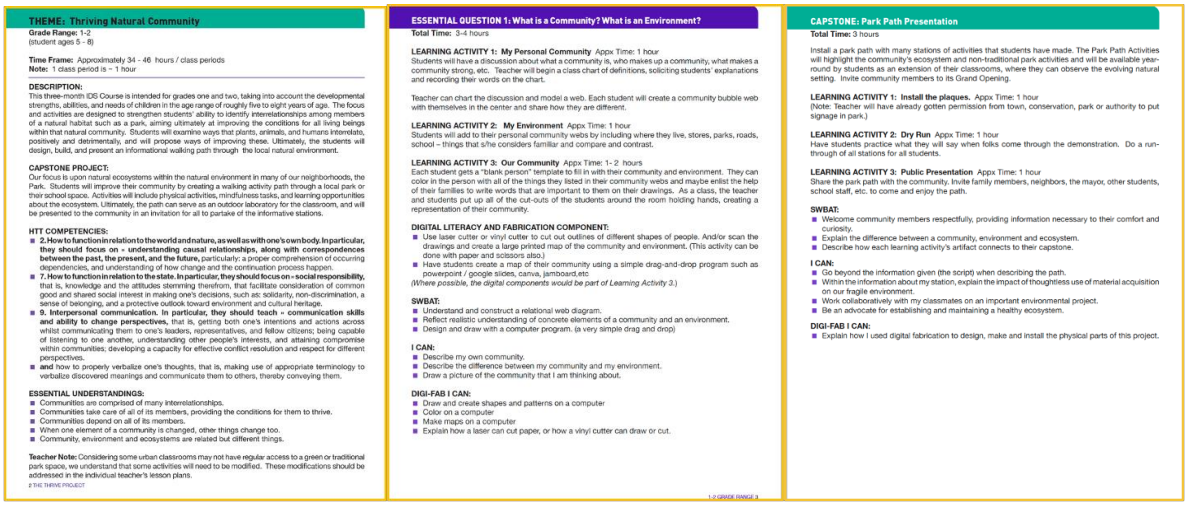
The framework and implementation components of our Interdisciplinary Studies (IDS) offer a comprehensive approach that seamlessly merges various disciplines into an overarching curriculum. IDS transcends singular disciplines by emphasizing the interrelationships, convergences, and dynamics among different knowledge fields. This approach nurtures critical thinking, problem-solving, and creativity by prompting learners to explore interconnected subjects from multiple perspectives. IDS broadens students' understanding of complex issues and prepares them to tackle challenges in our interconnected global society. The IDS course implementation encompasses diverse facets that collectively provide a well-rounded understanding of the curriculum.

The Fab Foundation's IDS course implementation package for teachers includes an overview, framework, learning activities, assessment tools, and a teacher's guide (Fab Foundation: HTT-IDS, 2022). These components synthesize to offer a complete picture of the curriculum design, expected learning outcomes, and support materials for effective teaching. The overview furnishes a comprehensive understanding of all syllabi and associated learning activities within the IDS course context, illuminating how the capstone course integrates into the overall curriculum and its connection to other IDS courses. The implementation template example shown in Figure 1 introduces the fundamental elements of the capstone, such as syllabi structure, learning objectives, skills development, and alignment with HTT Thriving competencies. This framework fosters interdisciplinary learning and facilitates integration across various subjects.

The course implementation package also includes tailored syllabi for different grade bands (1-2, 3-4, 5-6), outlining learning activities, objectives, and skills that correspond to the HTT competencies. These syllabi are designed to meet students' developmental needs and capabilities within their respective grade bands. Assessments within the IDS course include capstone demonstrations, teacher rubrics, and student self-assessment, aligning with learning objectives and competencies to evaluate student achievements and provide constructive feedback. A robust teacher's guide is also provided, offering support for implementing the IDS curriculum. It includes HTT competencies, usage suggestions, age-appropriate adaptations, pedagogy, definitions, examples, and implementation and assessment resources.

The Framework for Course Implementation in Table 1 provides a comprehensive and effective approach to develop, implement, and evaluate the IDS curriculum, ensuring seamless integration and interdisciplinary learning in various educational settings. The complete IDS course implementation package includes six capstone syllabi across three grade bands, each featuring two themes, providing a total of twelve unique capstone options. Each capstone requires an approximate time commitment of 30 hours, allowing for in-depth exploration and learning. Four essential questions are incorporated into each capstone, guiding students' inquiry and critical thinking. Furthermore, each capstone includes 12 lessons, ensuring a structured and engaging learning experience. In total, the IDS course implementation encompasses a project with 72 lessons, offering a comprehensive set of outcomes and a rich and extensive curriculum that covers a wide range of interdisciplinary topics and competencies.

Figure 1: Implementation Form



THEME: Thriving Natural Community

Grade Range: 1-2
(student ages 5 - 8)

Time Frame: Approximately 34 - 46 hours / class periods
Note: 1 class period is ~ 1 hour

DESCRIPTION:
This three-month IDS Course is intended for grades one and two, taking into account the developmental strengths, abilities, and needs of children in the age range of roughly five to eight years of age. The focus and activities are designed to strengthen students' ability to identify interrelationships among members of a natural habitat such as a park, aiming ultimately at improving the conditions for all living beings within that natural community. Students will examine ways that plants, animals, and humans interrelate, positively and detrimentally, and will propose ways of improving these. Ultimately, the students will design, build, and present an informational walking path through the local natural environment.

CAPSTONE PROJECT:
Our focus is upon natural ecosystems within the natural environment in many of our neighborhoods, the Park. Students will improve their community by creating a walking activity path through a local park or their school space. Activities will include physical activities, mindfulness tasks, and learning opportunities about the ecosystem. Ultimately, the path can serve as an outdoor laboratory for the classroom, and will be presented to the community in an invitation for all to partake of the informative stations.

HTT COMPETENCIES:
- **2. How to function in relation to the world and nature, as well as with one's own body. In particular, they should focus on – understanding causal relationships, along with correspondences between the past, the present, and the future,** particularly: a proper comprehension of occurring dependencies, and understanding of how change and the continuation process happen.
- **7. How to function in relation to the state. In particular, they should focus on – social responsibility,** that is, knowledge and the attitudes stemming therefrom, that facilitate consideration of common good and shared social interest in making one's decisions, such as: solidarity, non-discrimination, a sense of belonging, and a protective outlook toward environment and cultural heritage.
- **9. Interpersonal communication. In particular, they should teach – communication skills and ability to change perspectives,** that is, getting both one's intentions and actions across whilst communicating them to one's leaders, representatives, and fellow citizens; being capable of listening to one another, understanding other people's interests, and attaining compromise within communities; developing a capacity for effective conflict resolution and respect for different perspectives.
- **and** how to properly verbalize one's thoughts, that is, making use of appropriate terminology to verbalize discovered meanings and communicate them to others, thereby conveying them.

ESSENTIAL UNDERSTANDINGS:
- Communities are comprised of many interrelationships.
- Communities take care of all of its members, providing the conditions for them to thrive.
- Communities depend on all of its members.
- When one element of a community is changed, other things change too.
- Community, environment and ecosystems are related but different things.

Teacher Note: Considering some urban classrooms may not have regular access to a green or traditional park space, we understand that some activities will need to be modified. These modifications should be addressed in the individual teacher's lesson plans.

THE THRIVE PROJECT

ESSENTIAL QUESTION 1: What is a Community? What is an Environment?
Total Time: 3-4 hours

LEARNING ACTIVITY 1: My Personal Community Appx Time: 1 hour
Students will have a discussion about what a community is, who makes up a community, what makes a community strong, etc. Teacher will begin a class chart of definitions, soliciting students' explanations and recording their words on the chart.

Teacher can chart the discussion and model a web. Each student will create a community bubble web with themselves in the center and share how they are different.

LEARNING ACTIVITY 2: My Environment Appx Time: 1 hour
Students will add to their personal community webs by including where they live, stores, parks, roads, school – things that s/he considers familiar and compare and contrast.

LEARNING ACTIVITY 3: Our Community Appx Time: 1- 2 hours
Each student gets a "blank person" template to fill in with their community and environment. They can color in the person with all of the things they listed in their community webs and maybe enlist the help of their families to write words that are important to them on their drawings. As a class, the teacher and students put up all of the cut-outs of the students around the room holding hands, creating a representation of their community.

DIGITAL LITERACY AND FABRICATION COMPONENT:
- Use laser cutter or vinyl cutter to cut out outlines of different shapes of people. And/or scan the drawings and create a large printed map of the community and environment. (This activity can be done with paper and scissors also.)
- Have students create a map of their community using a simple drag-and-drop program such as powerpoint / google slides, canva, jamboard,etc

(Where possible, the digital components would be part of Learning Activity 3.)

SWBAT:
- Understand and construct a relational web diagram.
- Reflect realistic understanding of concrete elements of a community and an environment.
- Design and draw with a computer program. (a very simple drag and drop)

I CAN:
- Describe my own community.
- Describe the difference between my community and my environment.
- Draw a picture of the community that I am thinking about.

DIGI-FAB I CAN:
- Draw and create shapes and patterns on a computer
- Color on a computer
- Make maps on a computer
- Explain how a laser can cut paper, or how a vinyl cutter can draw or cut.

1-2 GRADE RANGE 3

CAPSTONE: Park Path Presentation
Total Time: 3 hours

Install a park path with many stations of activities that students have made. The Park Path Activities will highlight the community's ecosystem and non-traditional park activities and will be available year-round by students as an extension of their classrooms, where they can observe the evolving natural setting. Invite community members to its Grand Opening.

LEARNING ACTIVITY 1: Install the plaques. Appx Time: 1 hour
(Note: Teacher will have already gotten permission from town, conservation, park or authority to put signage in park.)

LEARNING ACTIVITY 2: Dry Run Appx Time: 1 hour
Have students practice what they will say when folks come through the demonstration. Do a run-through of all stations for all students.

LEARNING ACTIVITY 3: Public Presentation Appx Time: 1 hour
Share the park path with the community. Invite family members, neighbors, the mayor, other students, school staff, etc. to come and enjoy the path.

SWBAT:
- Welcome community members respectfully, providing information necessary to their comfort and curiosity.
- Explain the difference between a community, environment and ecosystem.
- Describe how each learning activity's artifact connects to their capstone.

I CAN:
- Go beyond the information given (the script) when describing the path.
- Within the information about my station, explain the impact of thoughtless use of material acquisition on our fragile environment.
- Work collaboratively with my classmates on an important environmental project.
- Be an advocate for establishing and maintaining a healthy ecosystem.

DIGI-FAB I CAN:
- Explain how I used digital fabrication to design, make and install the physical parts of this project.

Table 1: Framework for Course Implementation

Overarching Capstone (annual theme)	*Related HTT Competencies*	*Essential Understandings*	*Essential Questions*	*Learning Activities/ Projects*	*Digital Fabrication Components*	*Formative Assessment: I CAN statements* *Student self-evaluation + Teacher evaluation of knowledge and skills in each lesson*	*Summative Assessment Rubrics (Teacher evaluation of acquisition of competencies)*
DS THRIVE COURSE: Design a community where everyone can thrive (with focus on nature).							

7 Assessment and Evaluation Process

The assessment process for a course aimed at enhancing humanistic HTT competencies, Social Emotion Learning (SEL), transversal skills, and digital literacies, especially in a landscape where these areas lack well-defined evaluation measures, presents a complex challenge. The Fab Foundation team breaks down evaluation into two fundamental categories: teacher-based assessment (formative and summative) and student self-assessment. We believe that a blend of these assessment methods paves the way for a more holistic learning journey. It also empowers students, granting them greater control over their learning and numerous opportunities for reflective contemplation.

For teachers, we offer guidelines on methodology as we shape the modular framework for each IDS course design within the Teacher's Guide:

1. All of our IDS courses anchor themselves in a capstone approach employing PBL methodology. The capstone, defined as the ultimate group project, is a collective effort to construct a community impact project. Here, each student contributes parts to the final demonstration or

project prototype. PBL methodology places all activities and learning outcomes within the context of intricate, real-world challenges. This allows students to draw upon disciplinary knowledge as needed while simultaneously cultivating critical thinking, problem-solving, communication, and collaboration skills during the design and prototyping process. Teachers are urged to include digital literacy components not just in the capstone but also in the PBL activities leading up to the capstone project.

2. For summative assessments, teachers are advised to retroactively incorporate relevant competencies into their assessment rubrics after determining the capstone project. Given the expansive nature of the HTT competencies, the novelty of digital literacies for many teachers, and the lack of established rubrics for transversal and SEL skill development, supporting teachers in this uncharted assessment territory is crucial. To this end, we supply quick reference lists for HTT and digital skills, along with a customized, dynamic assessment rubric based on one developed by Alice Keeler (Keeler, 2015). This rubric is tailored for HTT, SEL, and transversal skills and competencies. It outlines the student content/skill criteria (which have been mapped to the competencies) and the scoring criteria, enabling teachers to assign weightage to each content/skill relative to the whole course and define the skill level for each criterion. Consequently, teachers can dynamically evaluate each student based on harmonized, integrated criteria.

The framework offers a systematic approach that includes learning objectives—SWBATs (Students Will Be Able To)—and a rubric for teachers, specifically tailored to appraise transversal and humanistic skills.

SWBATs (Students Will Be Able To): SWBATs are precise, measurable, and achievable learning goals outlined for students. By employing SWBATs, educators can establish clear expectations for the knowledge and skills students should acquire, facilitating the design of effective lessons and assessments. These explicit learning objectives serve a dual purpose: they guide the instructional design and also boost students' motivation and engagement by clearly communicating the learning targets.

Rubric for Transversal and Humanistic Skills: The IDS course incorporates a specially crafted rubric, shown in Figure 2 below, allowing educators to evaluate students' transversal and humanistic skills. Transversal skills, essential in a wide array of disciplines and contexts, encompass elements like critical thinking, collaboration, communication, and problem-solving. Humanistic skills involve attributes such as empathy, ethical decision-making, social responsibility, and cultural sensitivity.

Figure 2: Summative Rubric for HTT Interdisciplinary Subject Courses (Fab Foundation, 2022)

Student / Group Name			Enter Assignment Name Here			
Final Score 100.00%						
Criteria Score	Criteria Weight	Rubric Criteria	5	3	1	5 4.5 4 3.5 3 2.5 2 1.5 1 100% 95% 90% 80% 85% 75% 70% 60% 50%
ENTER SCORES HERE: Options are 5, 4.5, 4, 3.5, 3, 2.5, 2, 1.5, 1			Exceeds Expectations 100%	Meets Expectations 85%	Not Yet 50%	
5	20%	Mastery of Content	complete understanding of all content and material, able to make connections and discuss the content without notes	Content is mastered with only one or two small misunderstandings or mistakes	various small mistakes and large misunderstandings	20%
5	20%	Project Outcome	project is impressive and meets all specifics in project description	project is complete but may have one or two small mistakes	project is complete with many mistakes or misunderstanding OR project is NOT complete	20%
5	5%	Presentation	Presentation is neat and includes all parts of the project, all group members participate and no one requires notes	presentation is neat and all group members participate but some members may read off notes	Presentation is messy and does not include all group members and some or all reads off notes	5%
5	5%	Use of Time and Resources	was on task and focused furing work time and used all materials appropriately at all times	was on task and using resources correctly for the majority of the work time	Time and resources were not used appropriately by most group members	5%
5	5%	Addressing a Problem	is able ask questions to better understand a problem, break it into smaller pieces, create a plan and use multiple methods to solve the issue	can break down a problem into smaller components, and come up with multiple options to solve the issue	stuggles to break down the problem, understand how the problem relates to other issues, think of different options to solve the problem	5%
5	5%	Understanding Relationships	understands causual relationships and can abstract ideas to other situations while showing empathy towards all	understands how one one things affects another, how thigns change over time, can show empathy and the ability to work for the common good	has trouble seeing how components are connected within a set of parameters or over time and struggles to put themselves in the shoes of other	5%
5	5%	Information Analysis and Synthesis	seeks out alternative view points to gain a better understnding of their own reserach, uses knowledge gained in related situations	can compare multiple sources and can recognize the validity of differing opions	does not take information past face value, stuggles to see connections between topics	5%
5	5%	Social Understanding	understands that participation, respect for others and self reflection are key to being able to empathize with others	participates and is aware of difference between groups is aware of their own personal situation	stuggles to see themselves as part of a large social group, or how bias can affect the whole	5%
5	5%	Personal, Local, and Global Connections	makes connection between one's personal, local and global impact through multiple lenses	sees themself as a part of a larger community in a given scenario and works towards bettering the situation	can not make connections between different groups or levels of community	5%
5	5%	Self Awareness, Collaboration and Communication	is able to self-assess and self-evaluate while working with others being able to share concrete and abstract opionions	able to convey one's point of view while understanding that others exist while working towrds a common goal	stugles to verbalize abstract ideas, understand that differing opions can coexist or work well with others	5%
5	5%	Creativity	project is comletely new and unique	project is creative and unlike any examples or similar works	project has some different components but is a copy of an example	5%
5	5%	Grit	showed resilience, determination, and tenacity while working proactively to solve a problem	showed perseverance and respect while working together and problem solving	struggled when faced with a challenge and were unable to sucessfully work together	5%
5	5%	Use of Design Process	multiple rounds of iteration are clear and all group members can speak to the design process	one round of iteration is clear and all members fully understand the design process	no iteration is clear and/or not all group members understand the design process	5%
5	5%	Use of Technology	used advanced technology to help make their project better more so than the project called for and handled it correctly	used technology to help make their project better and handled it correctly	used technology at minimum, or only used it appropriately most of the time	5%
Total Percentage:	100.00%	Please download the functional rubric here: HERE				

2 HTT ASSESSMENT RUBRIC

HTT ASSESSMENT RUBRIC 3

The rubric provides a structured approach, consisting of varied components and criteria to assess students' competency in these skills. It forms a systematic platform for evaluation, aiding educators in pinpointing students' strengths and areas needing improvement. The nurturing of these skills is vital for effective interdisciplinary instruction, paving the way for an inclusive and supportive learning environment.

"I Can Statements" in K-12 education are simplified, student-friendly sentences that guide learning and help students track their progress. These are derived from educational standards and serve as navigational tools for students in their educational journey.

"Fab I Can Statements" are an extension of this concept into the realm of digital fabrication education, born out of the SCOPE-DF project. These statements articulate unified principles and practices for digital fabrication, integrating it into K-12 classrooms (SCOPESDF, 2023).

These statements encompass six developmental domains: Design, Computation, Electronics, Modeling, Fabrication, and Safety. Each domain imparts specific, transferable skills, making these principles not just curriculum-specific but also life skills. These domains also weave in broader educational standards like Common Core/NGSS and noncognitive abilities such as grit and a growth mindset.

The Fab I Can Statements are rooted in Vygotsky's (Vygotsky, 1978) theories on the Zone of Proximal Development (ZPD) and Bruner's (Bruner, 1960) work on scaffolding, thus promoting individualized learning. They are also part of a continuous formative assessment approach, offering real-time feedback that informs both individual achievement and the quality of the learning experience.

The Fab I Can Statements serve as navigational aids for teachers and students alike, outlining clear goals, learning expectations, and a roadmap for growth. They help align digital fabrication learning with traditional classroom teaching, supporting the overall educational journey.

Teachers and students can use the Fab I Can Statements to set precise learning goals. This structured approach empowers learners to take charge of their educational journey, promotes active participation, and facilitates experiential learning.

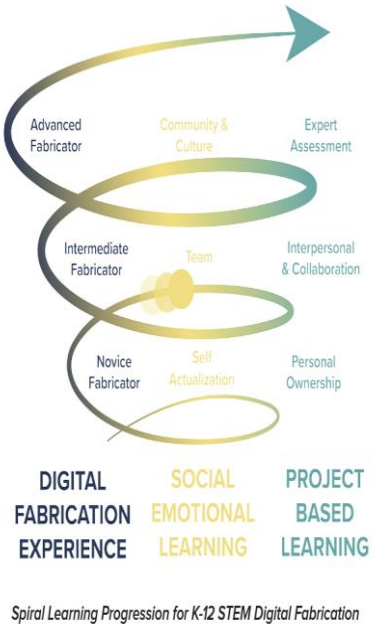
Although in the nascent stage, the Fab I Can Statements model signifies a promising pathway for the integration of digital fabrication education into mainstream K-12 education. This model represents the

future of formative assessment, where learners take the reins of their education while being guided by clear, measurable, and student-friendly goals.

In addition to formative and summative assessment rubrics for teachers, as well as self-assessment tools for students, the Fab Foundation's design team has based its desired learning progression on the research conducted during the SCOPES-DF community of practice project in 2019. This research was aimed at developing teacher training interventions for public school settings. The SCOPES-DF project was instrumental in synthesizing a spiral learning progression, seen below in Figure 3, that illustrated learning across three distinct but interconnected domains: digital fabrication experiences, social-emotional learning experiences, and project-based learning experiences. This model enables students to progress from each learning experience in each domain, periodically revisiting each domain and moving along the trajectory from novice to expert with each interaction. Excerpted from the SCOPES-DF Playbook:

> The SCOPES-DF spiral model has key features. Firstly, students revisit the concepts of digital fabrication, social-emotional learning (SEL), and project-based learning (PBL) multiple times throughout their educational journey. Secondly, the complexity of each of these three areas intensifies with each revisit. Lastly, new knowledge is always tied to prior learning.
>
> The benefits of the SCOPES-DF spiral model are manifold. First, the skills associated with digital fabrication are reinforced and consolidated each time the student revisits the subject area. Second, the spiral model allows a logical progression of SEL skills from basic self-actualization to complex ideas of community and culture. Lastly, PBL is driven by a central question that students explore as they continually revisit and integrate new concepts related to personal ownership, collaboration, and expert assessment.
>
> In essence, the SCOPES-DF model facilitates the development of the critical 21st-century competencies that students need to be successful in both their college years and future careers. These competencies span both cognitive and socio-emotional skills." (Fab Foundation: SCOPESDF Playbook, 2019, p.25).

Figure 3: SCOPES-DF Learning Progression Spiral (Fab Foundation: SCOPESDF Playbook, 2019, p.25)



Spiral Learning Progression for K-12 STEM Digital Fabrication

In this way, the SCOPES-DF learning progression aids in reinforcing the core learning objectives and competencies, providing a robust model for iterative, in-depth learning that adjusts with the growing proficiency of the students.

8 Conclusion

Reflecting on the journey of building a comprehensive curriculum framework that includes digital literacies, and its subsequent application in schools, we've identified several crucial areas that warrant additional attention. The evolving framework shows immense promise but falls short of unlocking the full potential of a holistic curriculum. We suggest the following areas for further development:

1. Design a new set of competencies that seamlessly merge disciplinary, digital, social-emotional, and transversal literacies into a unified competency map.
2. Develop an age-appropriate, formal, integrated learning progression for experiential learning. While we've proposed a theoretical progression, an integrated and dynamic model should be the subsequent step.
3. Create an integrated summative assessment rubric aligned with the holistic, capstone curriculum.

Currently, the curriculum framework and the sample capstone syllabi for HTT have not been trialed in schools. Our design team plans to submit the framework and curriculum for external review and evaluation in both formal and informal education environments, with both students and teachers participating in the evaluation process. Both the specific course syllabi and the customizable framework, designed to assist teachers in creating their own capstones, must undergo pilot testing. We believe the flexible nature of the framework will empower teachers to offer comprehensive education, molding students into global citizens with empathy, critical technical knowledge, and 21st-century skills. The scalability of the program depends on testing and iterating the framework and syllabi, making piloting a critical step.

Key insights that have emerged through the creation and planning of the HTT IDS course include:

Holistic Approach: Fusing digital fabrication technology, disciplinary knowledge, and social-emotional skills is paramount for providing a rounded learning experience. The HTT IDS course aims to integrate these aspects, fostering technical as well as interpersonal skills in students.

Technology Integration: Incorporating technology, particularly through fab labs, is critical for hands-on learning. It gives students a tangible connection between theoretical knowledge and practical applications, nurturing digitally literate individuals ready for the tech-centric world.

Educator Support: Supplying modular support resources for teachers ensures effective implementation of the HTT IDS course. Given the tight schedules of educators, concise yet comprehensive guides can facilitate smoother adoption and execution of the curriculum.

Reflective Iteration: The evolution of this framework is a continuous process, relying on cyclical reflection, feedback, and refinement. Constructing integrated competencies, formal learning progressions, and assessment rubrics is integral to the framework's growth.

Pilot Testing: It's essential to conduct pilot tests and external evaluations with students and educators before large-scale implementation, to ensure the framework's resilience in a variety of educational settings.

In conclusion, the HTT IDS course represents a significant opportunity for educational reform, fostering critical thinking, digital literacy, and holistic development in students. As global education systems confront a rapidly changing landscape, innovative curriculum frameworks like this are essential for preparing students for the future. We call on educators, policymakers, and researchers to collaborate in refining, implementing, and evaluating the HTT IDS course and similar initiatives. Through such joint efforts, we can aspire to an education system that not only disseminates knowledge but also cultivates global, empathetic citizens, proficient in technical knowledge and transversal skills, ready to make valuable contributions to an increasingly interconnected world.

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