Developing and Testing a Learning Progression for Middle School Physical Science Incorporating Disciplinary Core Ideas, Science and Engineering Practices, and Crosscutting Concepts

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Project Goals

This three-year Level I Learning Strand project, targeting the exploratory study stage, has THREE main goals (PGs):

1: Develop a three-dimensional learning progression (3DLP) that incorporates DCIs with CCCs and SEPs to support a wide variety of middle school students (with respect to their ethnicity, gender, socioeconomic status, and cultural and educational background);

2: Use the 3DLP as a framework to guide teachers in adapting their existing curriculum, instruction, and assessment to support the knowledge-in-use development of a broad range of students; and

3: Study and monitor student knowledge-in-use development in the 3DLP-adapted science classrooms across the middle grades.

Levels and Pathways of 3DLP Development

In Phase I-2 (see Figure 1), we developed the levels and pathways for the 3DLP that incorporate multiple DCIs (matter, interaction, and energy) with several CCCs and SEPs and established essential design principles. We articulated a design process for developing levels and pathways for the 3DLPs (see Figure 3):

Stage 1: defining problems of LPs from literature and classroom practices,
Stage 2: designing principles for developing LPs,
Stage 3: receiving feedback and iteratively refining the LPs, and
Stage 4: reflecting on the existing work and informing next round of developing and implementing LPs.

Our design research process uses an iterative refinement cycle that allows the designers to revise levels and pathways in the 3DLPs and design principles. In the current work, we received 4 experts' feedback and interviewed 12 students in two middle schools. Those data are analyzed to develop our initial 3DLP (See Figure 3).

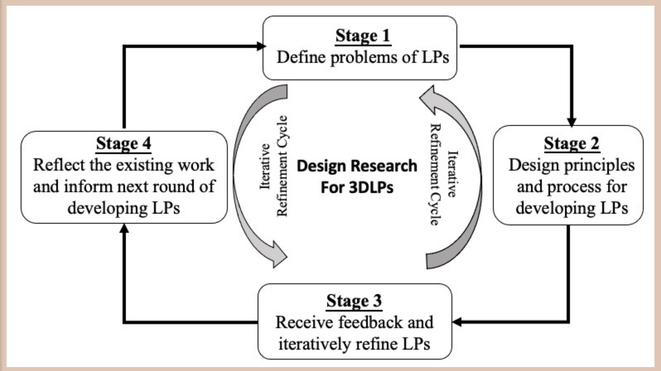

Figure 2. Developing Levels and Pathways for the 3DLP

3DLP Design Model

We used a design-based research approach to address the three goals.

Phase I: We will create design principles and develop a 3DLP of *Matter and Its Interaction, and Energy* with the SEPs of *Developing and Using Models* and *Construct Explanations*, and CCCs of *Systems and System Models* and *Cause and Effect* based on evidence from teachers, students, and experts (PG1). We will unpack the NGSS standards and articulate levels and pathways for the 3DLP (PG1).

Phase II : We will then develop principles for using the 3DLP for teachers to adapt their curriculum materials, instruction, and assessment. Based on the design principles, teachers will work with us to revise their materials (PG2). We will collect teacher and student data when using the adapted curriculum materials and to support the revisions of the 3DLP (PG1).

Phase III : We will analyze the data to demonstrate student development of knowledge-in-use based on the 3DLP and track students' progression of knowledge-in-use based on the 3DLP when teachers use the adapted materials (PG3). The data will support the revisions of the 3DLP (PG1) and the adapted materials (PG2).

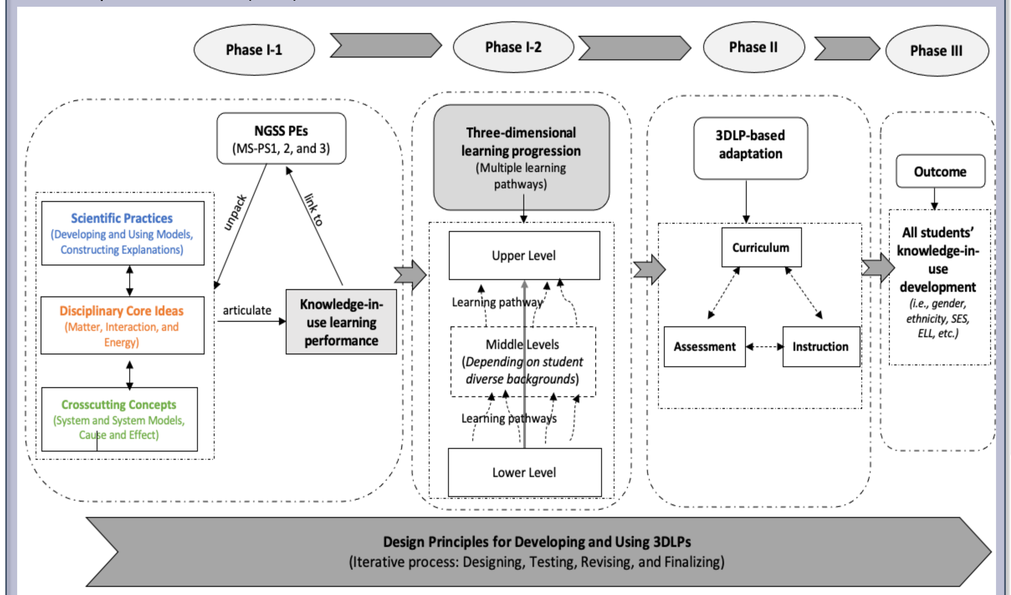

Figure 1. Research Design

In Phase I, the development of the 3DLP was an iterative process that emphasizes learning goal alignment and the logic of evidentiary reasoning. Our 3DLP design process consists of five steps:

1) identifying the constructs in targeting NGSS performance expectations,
2) unpacking DCIs, SEPs, and CCCs,
3) articulating 3D learning performances,
4) determining 3D learning progression with levels and pathways, and
5) developing tasks and rubrics.

The first and second steps describe the unpacking of three dimensions in the performance expectations. The third and fourth steps focus on developing the 3DLP. Regarding the 3DLP levels, we specify the lower boundary and upper boundary from the NGSS performance expectations and identify student challenges and potential phenomena. Next, we describe possible learning pathways between the starting and ending points to describe student progression toward knowledge-in-use. Then, we create claims for the 3DLP and specify the evidence for students' achievement at each level. The final step develops the 3D assessments to match the claims and evidence of the 3DLP.

The Initial 3DLP

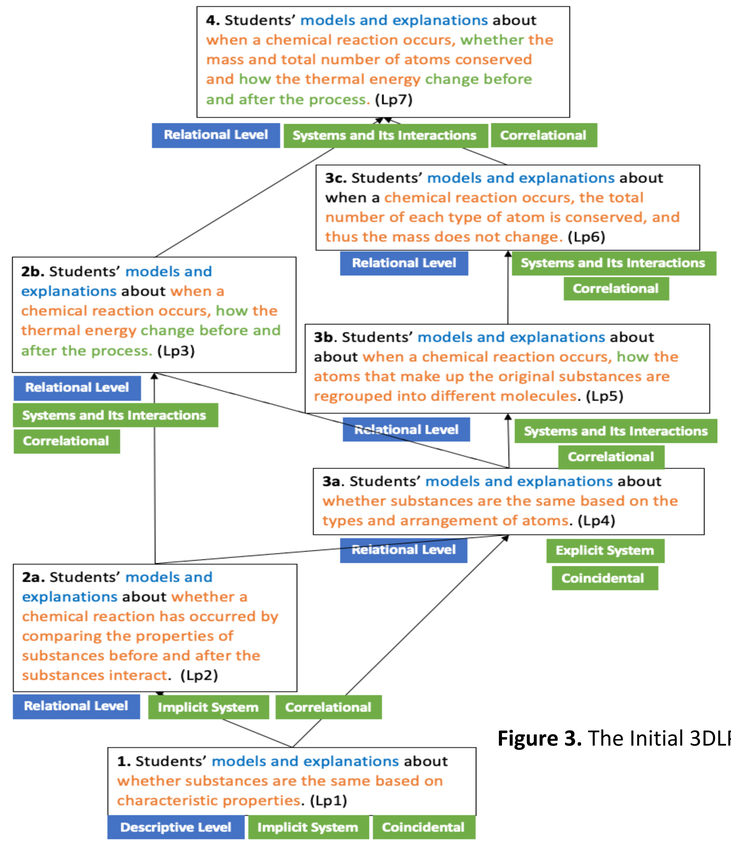

Figure 3. The Initial 3DLP

Figure 3 presents our initial 3DLP focusing on properties and structure of matter and chemical reactions. During the development stage, we used expert feedback to identify separated levels of DCIs, SEPs, and CCCs (see the levels from the orange, blue, and green colors, respectively). We used the analysis of student interviews to identify the potential levels of integrated 3D learning performances. We highlighted the separated levels of DCIs, SEPs, and CCCs in each level, which provides the guideline to develop/modify 3D assessment tasks. The arrows demonstrate student learning trajectories with multiple pathways. For instance, one pathway can be 1a-2a-2b-3a-3b-3c-4; another possible way is 1a-3a-2a-2b-3b-3c-4.

Our next step will collect more student interview data from diverse backgrounds, particularly with underrepresented groups to further improve the initial 3DLP; we will interview our participant teachers on their feedback on the initial 3DLP and perceptions of using the 3DLP to adapt their local curriculum, instruction, and assessment materials.

Conclusions

The design process guided us to develop the initial 3DLP and can be beneficial to the researchers in science education. We conducted design-based research to iteratively develop and revise our initial 3DLP based on the evidence of expert feedback and student interviews. We believe our design process and the initial 3DLP will shed lights on evidence-based 3DLP development and guidance to support student long-term and coherent science learning.

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