Development of Learning Maps as Models of the Content Domain

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Abstract

Cognitive models are useful representations of the cognitive processes involved in the learning of a concept or domain. Learning maps are a type of cognitive model used to represent student learning in a content area, and they are ideal for students who are struggling or idiosyncratic learners, such as students with significant cognitive disabilities. These students demonstrate one or more disabilities that significantly affect their intellectual functioning and adaptive behavior. Accessibility is a critical issue when representing content learning for students with significant cognitive disabilities. This paper will describe the process used to develop the DLM content-area learning map models aimed at representing the learning of students with significant cognitive disabilities. It will also explain the intentional design decisions and the application of universal design for learning principles aimed at increasing the utility of the maps as cognitive models that are appropriate for all learners. Lastly, the paper will also describe how learning map models are useful in collecting and using student data to plan individualized instruction.

Keywords: learning maps, students with disabilities, accessibility

Learning Maps as Models of the Content Domain

A cognitive model is a descriptive representation of the cognitive processes involved in the acquisition of the crucial knowledge, skills, and understanding needed to learn specific concepts or domains (Ohlsson, 2008). Cognitive models help users to understand what is involved in learning a concept or related concepts within a domain and to make predictions about performance according to the learner’s current knowledge, skills and understandings (KSUs). Learning maps are one type of cognitive model that include large, fine-grained, and highly interconnected representations of student learning in a content area (Figure 1). Maps are based on a formal research synthesis process that evaluates literature from multiple content areas to represent the diversity of student learning patterns in a targeted domain. Due to their fine grain-size, learning map models are useful in measuring student growth in the short- and long-term. They also offer educators a framework to use when making decisions about the learning needs of individual students and can potentially provide guidance on planning individualized instruction, which is especially important for students who learn more slowly or idiosyncratically than their typically developing peers.

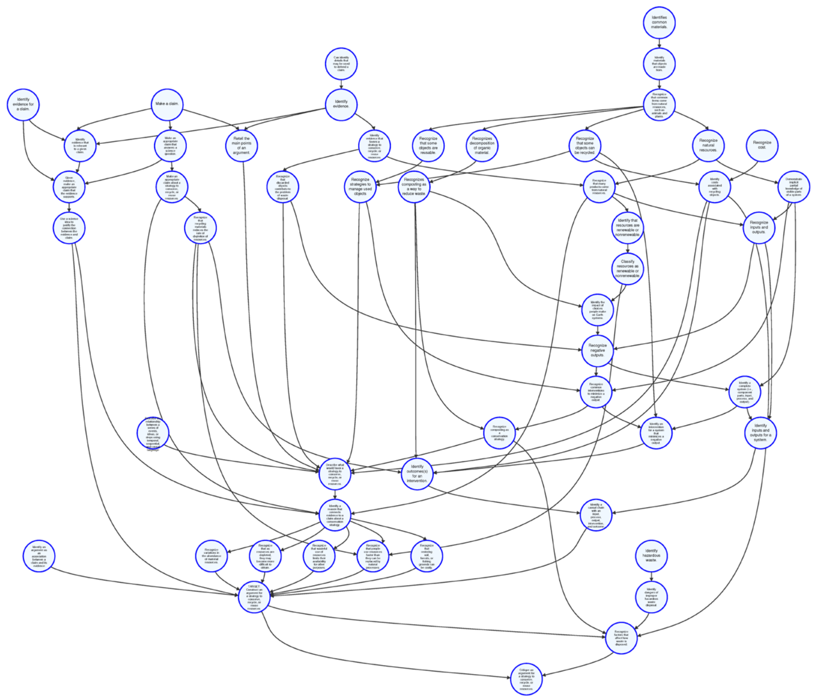

Figure 1. Sample section of the science learning map model that demonstrates their large, fine-grained, and highly interconnected characteristics.

Students with significant cognitive disabilities (SCD) are an example of a population who may benefit from a map-based approach to domain modeling for both instructional and assessment purposes. Students with SCD demonstrate one or more disabilities that significantly affect their intellectual functioning and adaptive behavior. Some students in this population also have additional disabilities (e.g., vision, hearing, mobility, and/or communication) that make it more difficult for teachers to elicit evidence of their content knowledge. The Dynamic Learning Maps (DLM) Alternate Assessment System sought to provide these students with opportunities to demonstrate what they know and can do by developing learning map models that depict their progress towards the acquisition of alternate grade-level academic content standards (DLM, 2016). Learning map models include multiple cognitive and learning pathways that all students could potentially follow when progressing towards the acquisition of the critical knowledge, skills, and understandings involved in the mastery of each content standard (Bechard, Hess, Camacho, Russell, & Thomas, 2012).

The DLM learning map models were developed using principles of universal design for learning (UDL). The goal for using UDL to develop the learning map models was to increase their accessibility to all students. In UDL, the needs of individual students are identified and considered from the outset (Council for Exceptional Children, 1998; Hitchcock, Meyer, Rose, & Jackson, 2002; Spooner, Dymond, Smith, & Kennedy, 2006). The principles of UDL aim to improve the flexibility in the design of a curriculum by increasing a student's access to the grade-level instructional content, improving the student's active participation in the instruction, and creating challenging but attainable academic targets. For students with significant cognitive disabilities, performance improves when educators include UDL when planning and implementing instruction (Dymond & Renzaglia, 2004; Spooner et al., 2007). The DLM system applied UDL to ensure that the learning development represented in the learning map models would reflect the diversity of students' learning and reduce barriers when the maps were ultimately used as organizing structures to support instruction and assessment.

The current paper will explain how learning maps can be used to represent the complexity of student learning in a content area through a description of the process used to develop the nodes and connections comprising the DLM content-area learning map models. It will also describe the criteria used to determine the appropriateness of each node and connection included in the models. Finally, we will explain the process used to improve the accessibility of the DLM learning maps for students of diverse ability levels, specifically those with significant cognitive disabilities.

Map Development

Learning map models include two basic components, nodes and connections. Nodes represent not only the content-area KSUs associated with grade-level academic standards but also the critical foundational skills that support student learning prior to and upon school entry. Connections indicate the order of skill acquisition and represent the relationship between two more nodes. The following sections will describe the process used by the DLM system to develop the nodes and connections in the content learning map models.

Node Development

The nodes and connections in learning map models depict the critical KSUs that students need to learn in order to master grade-level content standards and their order of acquisition. For these nodes to provide an accurate representation of student learning and to be useful for educators in decision making and planning individualized instruction, they must reflect current knowledge on the development of knowledge in the content area. To meet this requirement, the DLM project staff used three major sources of information to develop the nodes and connections in a learning map model: cognitive and developmental empirical research, common instructional practices and interventions, and other relevant curricular information.

For **cognitive and developmental empirical research**, the DLM project staff focused primarily on edited book chapters, research syntheses, and handbooks that broadly surveyed the literature on student learning within a specific domain of a content area. These sources typically provide a developmental learning trajectory of the critical knowledge, skills, and understanding in the domain, which is helpful in identifying and ordering the information to be included in the learning map models. This process began with the identification of the key search terms and then locating relevant information sources. The knowledge, skills, and understanding depicted in the grade-level content standards highlighted the key search terms to use in the literature review. Summary findings from individual and important research studies within the domain then filled in any gaps uncovered by the book chapters, research syntheses, and handbooks. These studies sometimes used longitudinal and cross-sectional samples that provided additional insight in the acquisition of the critical knowledge, skills, and understanding over time.

Besides the cognitive and developmental empirical research, the DLM project staff also identified the **common instructional practices and interventions** used in the domain. These instructional practices and interventions provided additional insight into a domain of a content area by suggesting potential methods for improving student learning. Because these practices and interventions are typically depicted as a series of individual steps, stages, or benchmarks, they highlight additional knowledge, skills, and understanding critical in the learning of a domain that could be included in the learning map models. Similar to common instructional practices and interventions, **other curricular information,** in the form of additional content standards, lesson plans, or views on instruction within the domain, was also a source of information considered by map developers for potential nodes and connections.

The development of the DLM content-area learning map models began with node development. Nodes provide the learning map models with the important stepping stones or stages used to represent and track student learning. The first step in this process focused on the identification and representation of grade-level academic targets within the content area including the Common Cores State Standards (CCSS) and the alternate standards linked to them, the DLM Essential Elements (EEs). The EEs describe rigorous, academic, grade-level expectations for students with SCD that are linked to the general education standards. These expectations became the grade-level academic targets used to develop the DLM learning map models. Each EE was represented by one or more nodes in the learning map model, depending on its complexity. These EE-related nodes were then arranged in order of developmental acquisition in the learning map model, using an intensive literature review and expert judgment of the map developers.

The next step in the node development process consisted of the identification and representation of the critical knowledge, skills, and understanding supporting the acquisition of the grade-level EEs. This information provides students with individual learning benchmarks that progress towards the EEs and result from gradually increasing cognitive resources and instruction. The cognitive and developmental empirical research, common instructional practices, and other curricular information provided the input for this step. Based on the extensive literature review, the DLM project staff created the supporting nodes in the learning map model that students need to master in order acquire the grade-level EEs (Figure 2), thereby filling in the gaps between consecutive grade-level EEs. Because lower grade-level EEs form the basis for the acquisition of higher grade-level EEs, the DLM project staff employed a bottom-up developmental process by initially investigating the critical early cognitive development knowledge, skills, and understanding that promote the learning of the more-advanced grade-level EEs.

Figure 2. Sample node that represents the critical knowledge, skills, and understanding that supports the acquisition of grade-level science standard.

Students with significant cognitive disabilities typically demonstrate diverse learning and communication skills and may also have one or more disabilities that significantly affect their intellectual functioning and adaptive behavior. The understanding of some students in this population is currently located before the targeted grade-level EEs, so these students require additional learning targets that will help them to progress towards these EEs (Kleinert, Browder, & Towles-Reeves, 2009). Due to these student characteristics, the DLM system expanded on the learning map models to represent the learning of the basic and content-general knowledge, skills, and understanding that develop between birth and school entry. This information primarily focuses on attention, self-regulation, language, and cognitive skills that promote the learning of each content area. The DLM system then created foundational nodes for these basic and content-general knowledge, skills, and understanding to foundational nodes to form the base of the learning map models. Figure 3 represents some foundational nodes that support the acquisition of grade-level nodes in each content area. In essence, they depict the learning and cognitive growth occurring during this period by demonstrating how the nodes gradually represent increasingly more complex knowledge, skills, and understanding.

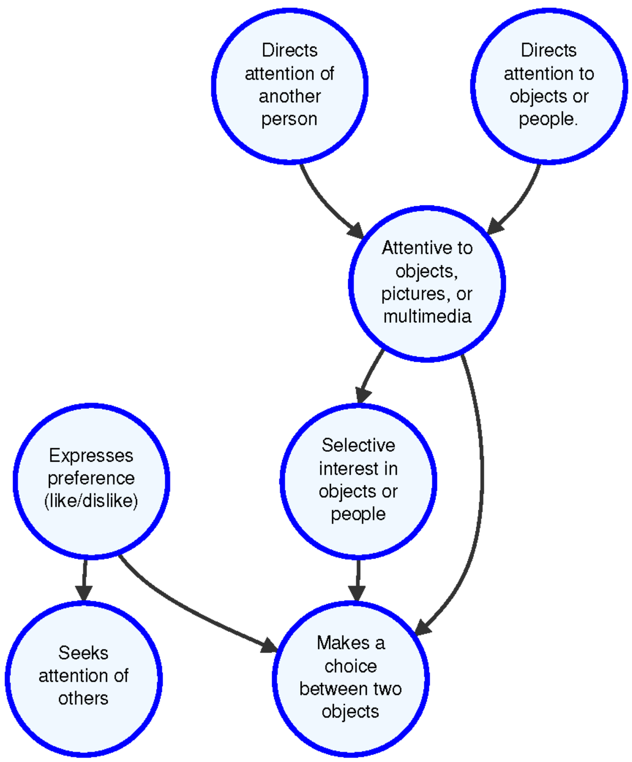

Figure 3. Sample foundational nodes that support the acquisition of grade-level nodes in each content area.

Content and Accessibility Criteria

The DLM system employed a set of criteria to ensure that the nodes included in the learning map models represent the critical knowledge, skills, and understanding need to acquire the grade-level content EEs and are accessible to students with significant cognitive disabilities. The evaluation of each node was made according to both expert judgment and relevant information gathered from the three major information sources used in learning map development process.

The criteria for node development focused on whether each node is crucial to student learning in a content area. Each node had to be **essential** to the acquisition of at least one grade-level content EE for it to be included in the learning map models. It also had to be **unique** from the knowledge, skills, and understanding depicted in the surrounding nodes. Although nodes reflect gradual increases in complexity based on the needs of the student population, they had to be distinct enough to warrant their inclusion in the DLM learning map models. Similarly, each node had be of a **similar complexity level** to the surrounding nodes in order to represent the gradual flow from less to more complex knowledge, skills, and understanding. A fourth node development criterion focused on whether a node in the learning map model was of an **appropriate size**. It ensured that the node only covered an appropriate amount of content. If a node covered too much content, it was divided into separate nodes. Another node development criterion targeted whether the content covered in each node were **observable and testable**. Students must be able to demonstrate their learning of the node's content if the node is to provide the valuable information about their ability level. Lastly, a node that represents a grade-level EE must reflect a **clear relationship** to the content of the EE. Items written to this node must provide information on whether a student has mastered the EE and not on knowledge, skill, or understanding that is only tangentially related to it.

Another set of criteria attended to whether each node is accessible to students with significant cognitive disabilities. The goal of the DLM learning map models is to represent the learning of these students on the grade-level EEs, and the nodes were developed according to the principles of UDL to account for variability in student learning. The first accessibility criterion ensured that the node's content is **accessible to all students** regardless of ability level. All students must be able to demonstrate their learning of the node's content when provided with the necessary support. The final accessibility criterion evaluated whether the node's content is **free from significant barriers** for students with sensory impairments, limited mobility, or limited communication. This criterion prevents a node from being only accessible to students without sensory, mobility, or communication disabilities.

Connection Development

The next phase in the development of the content-area learning map models focused on the creation of connections between the nodes. This phase began with the organization and arrangement of the nodes in the learning map models. The nodes representing the content EEs and the supporting knowledge, skills, and understanding were arranged according to when they are expected to be acquired based on the academic standards and the three major information sources used in the node development phase. They were also grouped according to the content and domain areas to which they belong. The organization and arrangement of the nodes provide the learning map models with the framework on which to link individual nodes together.

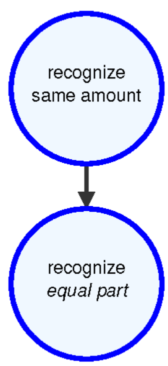

Figure 4. Sample connection between two nodes in the mathematics learning map model.

The next step in this process was to create the connections between individual nodes in the learning map models (Figure 4). Connections indicate the order in which nodes develop and the relationship between two nodes, the origin node and the destination node. Origin nodes precede and are predicted to develop before destination nodes. Although each connection only covers two nodes, each node may have multiple preceding and succeeding nodes, depending on the nature of the knowledge, skill, or understanding covered in the node. Critical nodes in a domain area will have more preceding and succeeding connections than will less critical or more focused nodes. Similarly, connections between nodes within and across domain and content areas were also included in the learning map models when the relevant empirical research or expert judgment suggested a relationship between the targeted knowledge, skills, and understanding. These connections produced the multiple pathways (Figure 5) toward each grade-level EE inherent in learning map models, allowing students of diverse ability levels to achieve the same academic target by following pathways best aligned to their current ability. They also highlight how the learning of a domain or content area does not occur in a vacuum but rather occurs simultaneously with and contributes to the learning of other domain or content areas.

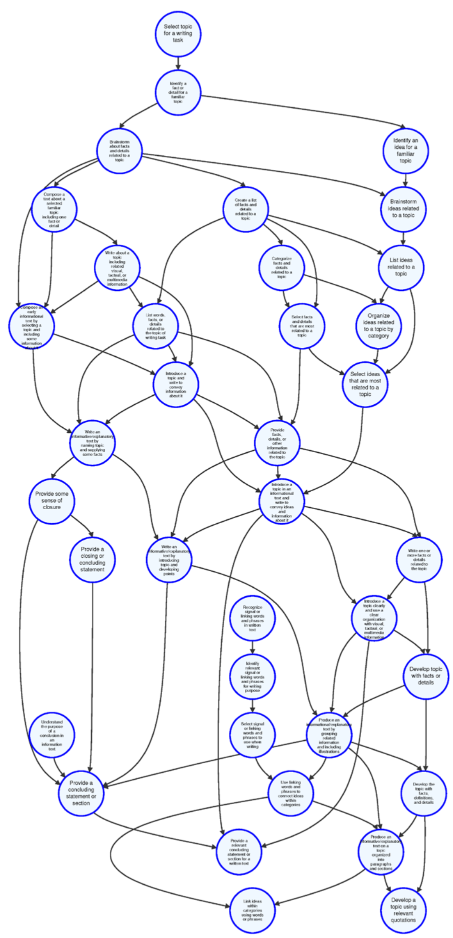

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Figure 5. Sample of the multiple pathways inherent in the learning map models.

All stages of map construction were heavily influenced by the UDL guidelines (CAST, 2011) which describe methods to ensure that curricula, and in this application, cognitive models can be constructed to ensure that students may access multiple means of engagement, multiple means of representation and multiple means of action and expression. Map developers considered the need to develop models that reflected a diversity of pathways that students could take to achieve individual learning targets. Additionally, as the maps were developed and revised specific conventions were developed for describing KSUs in language that would reduce potential barriers for students to demonstrate what they know and can do. Examples include the broad use of the term "indicate" across many nodes to ensure that students could use multiple means of action and expression to demonstrate their understanding.

Content and Accessibility Criteria

The DLM system also employed a set of criteria to ensure the appropriateness of the connections included in the learning map models in reflecting student learning towards grade-level content EEs and in being accessible to students with significant cognitive disabilities. Similar to the criteria used in node development, the criteria used in connection development also focused either on the connection's content or accessibility, and the evaluation of each connection included both expert judgment and relevant information gathered from the three major information sources used in learning map development process.

Only three criteria were used when considering the suitability of including a specific connection in the learning map models. Regarding its content, each connection had to be **accurate** in its depiction of the progressive nature of student learning. It had to link a less complex origin node to a destination node of either a similar or greater complexity level. Similarly, the first accessibility criterion ensured that each connection represented an **appropriate learning sequence for all students**. For the learning map models to represent student learning, the connections must reflect the learning sequences that students of varied ability levels typically follow towards the acquisition of an academic target. The second accessibility criterion determined whether each connection **described a logical learning sequence for students with sensory, mobility, or communication disabilities**. Because some students with significant cognitive disabilities have sensory impairments, limited mobility, or limited communication, connections need to link only nodes on which these students would be capable of demonstrating their learning and mastery of the content.

Alternate Paths

Developing challenging but attainable alternative standards for students with significant cognitive disabilities alone does not increase accessibility to all of the content represented in learning map models. Some students in this population have specific disabilities that produce additional challenges when providing evidence of learning for some nodes. To resolve this issue, the DLM system created alternative paths around these problematic nodes, thereby increasing the inclusiveness of the learning map models to all students, if provided increased access to appropriate instruction based on the principles of UDL. Alternative paths include nodes and connections that explicitly depict the specific skills that students with specific disabilities must master in order to acquire a grade-level EE.

The first step in creating alternative paths consisted of evaluating each node in the learning map models on its accessibility. Our collaborators at the Center for Literacy and Disability Studies at the University of North Carolina, Chapel Hill determined the accessibility of each node to students with a specific set of disabilities. These disabilities included vision, hearing, mobility, and communication (e.g., autism). Nodes were flagged as inaccessible only if they could not be successfully adapted to allow these students to demonstrate their learning. The flagged nodes tended to be clustered within small sections early in the learning map models, and they represent areas that pose a difficulty in being able to gather evidence of learning for students with specific disabilities.

The second step in the development of alternative paths involved adjusting current nodes and creating new nodes and connections in the learning map models for students with specific disabilities. The current nodes were adjusted to increase their accessibility for these students, while the new nodes depicted content that only these students would need to acquire. Students without these disabilities would use the flagged nodes and the connections between them. When inserted into the learning map models, these nodes and connections represent an alternative path that students with a specific disability would use to circumvent these problematic areas. The alternate paths also allow these students to achieve grade-level EEs that would have been inaccessible without them. Figure 6 represents an alternate path in the ELA learning map model that students with mobility impairments would follow, using an assistive technology device, around nodes focused on the production of orthographic letters and words in written text.

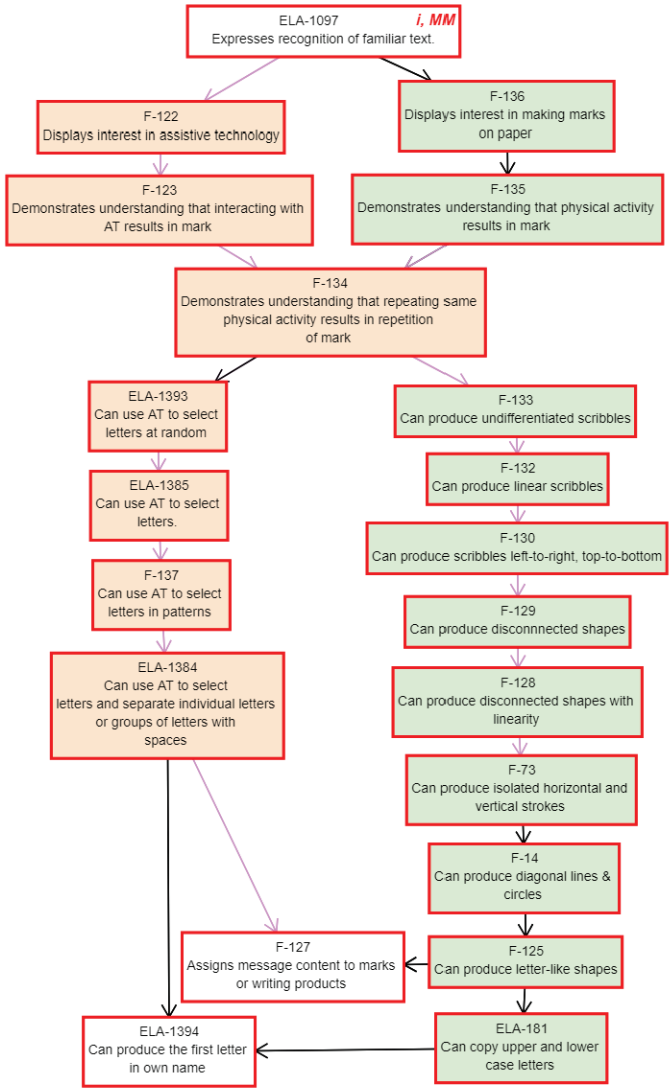

Figure 6. An alternate path in the ELA learning map model around the physical production of orthographic letters and words for students with a mobility impairment. The green nodes depict the development of mobility-typical students, while the orange nodes depict the alternate path that students with mobility impairment can follow in their writing development using assistive technology.

Conclusion

Learning map models provide a useful representation of student learning in specific content areas by depicting the complexity of learning through the inclusion of multiple pathways toward the same academic target. Unlike learning progressions that focus only on the acquisition of a single grade-level academic target, learning map models are web-like networks of nodes and connections that represent the acquisition of multiple grade-level academic targets within and across multiple domain and content areas. They also accurately characterize the complexity of student learning by depicting how the mastery of the critical knowledge, skills, and understanding in one domain area relates to and interacts with the mastery of the critical knowledge, skills, and understanding in other domain areas. Similarly, learning map models provide students with multiple routes to follow towards the acquisition of the same academic target, thereby allowing students who differ in their ability level to follow pathways best aligned to their needs.

Learning map models can also enhance educators' pedagogical knowledge of the content area. Because they depict the critical knowledge, skills, and understanding necessary for the acquisition of grade-level academic targets within and across domain and content areas, learning map models provide educators with an understanding of how students progress between grade-level academic targets. Furthermore, they can promote the use of formative assessment by educators within the classroom by increasing the systematic gathering and analysis of student data on the nodes leading to the mastery of grade-level academic targets. Educators could then use this data to plan individualized instruction focused on potential next steps derived from what students currently know and can do (McLeskey, Rosenberg, & Westing, 2017). Using this information, they can track student growth within and across grade levels. Tracking student progress over time leads to improved learning outcomes for students with disabilities (Quenemoen, et al., 2003). However, educators are sometimes more confident and skilled in assessing a student's current ability level than they are in employing the student data to understanding the student's strengths and weaknesses and then identifying potential next steps in instruction (Heritage, Kim, Vendlinski, & Herman, 2009; Troia & Graham, 2016). They do improve in their collection and use of student data to plan individualized instruction when provided with appropriate content and pedagogical knowledge (Mandinach & Jimerson, 2016). Because learning map models include multiple pathways that consist of individual and discrete stepping stone knowledge, skills, and understanding toward the mastery of the grade-level content standards, they can provide educators with some of this information by highlighting some pathways that students could follow towards the acquisition of an EE.

Just as learning map models are useful in providing educators with the content and pedagogical knowledge needed to collect and use student data, they are also ideal for representing the learning of students who learn more slowly or idiosyncratically, such as students with significant cognitive disabilities. The DLM system prioritized accessibility when developing the content and structure of the learning map models due to the learning and sensory characteristics of students with significant cognitive disabilities. Multiple steps were taken to ensure that the content-area learning map models were inclusive for all students. One step was the creation of an alternate set of challenging but attainable grade-level academic standards (EEs) that reflect the content of the original standards. Second, currently inaccessible nodes for students with specific disabilities (e.g., vision, hearing, mobility, communication) were identified and flagged. The DLM system then adapted current nodes or created additional nodes and connections that these students would use to circumvent the problematic areas and progress towards the acquisition of grade-level content EEs. With the development of the alternate grade-level content standards and paths, the DLM learning map models represent the content learning of all students regardless of their needs and ability level. Another strategy used to ensure that the maps provided an accessible model of the domain was the application of principles of UDL in the construction process.

The DLM learning map models provide an ideal organizational structure for both the development of an assessment on student learning and the use of the assessment results to plan individualized instruction. For specific grade-level content EEs, sections of the learning map models can highlight not only the academic targets but also the critical knowledge, skills, and understanding leading up to and supporting their acquisition. These nodes can form the basis for item development to determine where students are located within the learning map model in their progress towards the acquisition of the EE. The results would provide educators with information about what each student knows and can do. This information and the pedagogical knowledge and structure provided by the learning map models can then guide educators in planning individualized instruction through the identification of the ideal pathway toward the EE, according to the student's needs and ability level.

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