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Teaching Tools and Strategies

Lateral Transfer Maps as a Metacognitivie Tool in First Year STEM Courses

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Abstract

We introduce the Lateral Transfer Map (LTM), a tool for students to actively and visually explore the transfer of ideas, skills, and concepts across concurrent coursework. The LTM is an extension of a concept map, replacing interconnected concepts with courses. Just as a concept map represents the interconnectivity of concepts and ideas, the LTM represent the connectedness of courses, illustrating how knowledge and information learned in one course is used in another. LTMs draw from the theory of knowledge transfer across disciplinary domains and contexts. LTMs are appropriate for use in any course; we describe its use in an introductory course for STEM majors to help students understand connections and motivations in first-year courses. LTMs also represent a useful diagnostic for instructors to better understand and address how students view connections (or lack thereof) among disciplines or concurrent coursework.

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Supporting Materials: Supporting File S1. Lateral Transfer Maps – Example of a LTM that includes Biology; S2. Lateral Transfer Maps – Example of a LTM that does not include Biology; and S3. Lateral Transfer Maps – PowerPoint to support activity.

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LATERAL TRANSFER MAPS: INTRODUCTION AND EXAMPLE

It is common for undergraduate STEM students to struggle to understand how required courses—physics, mathematics, or liberal arts requirements—contribute to their ultimate academic or career goals. To address this, we introduce the Lateral Transfer Map (LTM), a variation of a concept map (1). Concept maps are graphical representations that illustrate how concepts are connected, with explicit graphics and words articulating the nature of the relationships. Concept maps have been used in many different contexts and their impact on student metacognitive understanding of content is well established (2,3,4). The intellectual framework of concept maps draws on the educational tradition of constructivism, which posits that people create their own knowledge based on individual experiences (5). Vygotsky added to this tradition that knowledge is in essence a social construction that is built by the community and through social interactions in the individual's environment (6). More recent research in this area in science education has included such innovations as including systems thinking into concept maps in chemistry (7), techniques for analyzing patterns in concept maps (8), promotion of reflection and tools for assessment in biology (9), analysis of the thought processes used by students to construct concept maps in physics (10), and many more.

Lateral Transfer Maps apply this idea of graphical illustration of relationships to concurrent coursework, guiding students to reflect on how the courses they are currently taking impact one another. This exercise is designed to help students identify knowledge, skills and epistemologies that transfer between courses. The exercise also draws from the idea of expansive framing (11), which emphasizes the importance of the purpose of learned material and includes learners as part of the process of generating knowledge.

In a traditional concept map, key concepts are represented in boxes or bubbles, with lines connecting related concepts. Above each line is a key word or phrase that articulates the relationship between concepts. In a Lateral Transfer Map, concepts are replaced by course names, and lines with uni- or bi-directional arrows represent ideas or skills learned in one course that are referenced or used in another. A representative LTM is shown in Figure 1, which connects four common first-semester courses: introductory Biology, Chemistry, Calculus and Interdisciplinary Science (ITDS: the course in which the LTM was assigned). Several features are noteworthy. ITDS and Calculus are information "sources," with most arrows indicating ideas learned in those classes (e.g., graphing, arithmetic, and reflection) and used in the other courses. Biology and Chemistry, on the other hand, are notable for having arrows that both enter and leave. Chemistry in particular, introduces the students to many ideas used in Biology, including mass, bonds, forces, and reaction rates. Specific skills learned in biology (e.g., computer

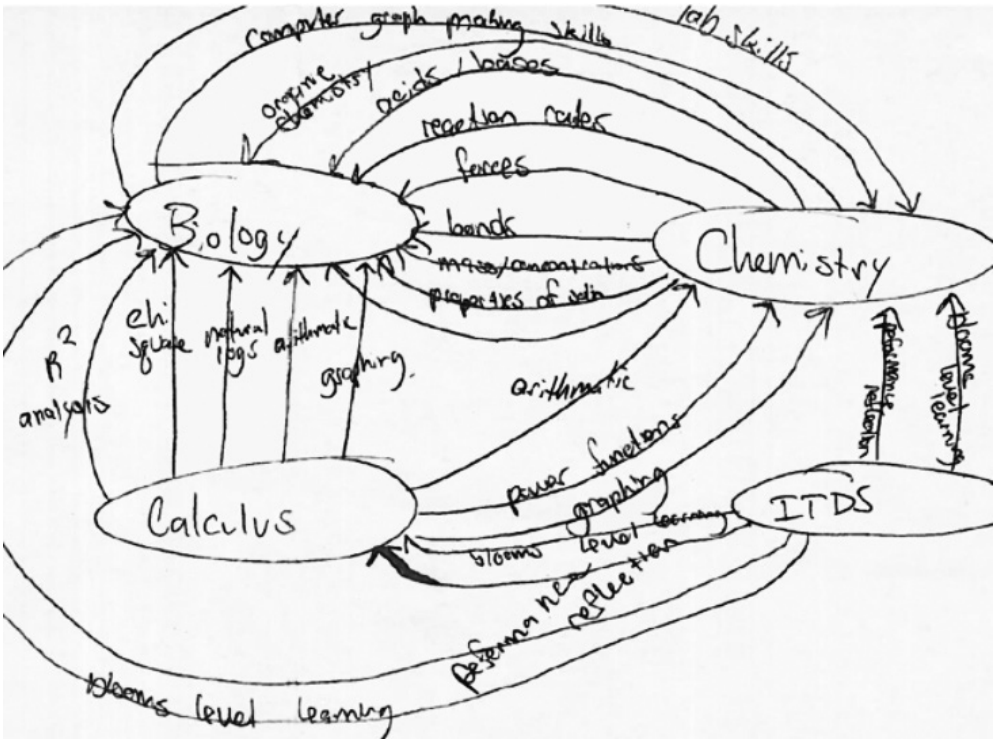

Figure 1. Lateral transfer map drawn by a student. in the Megacognition course to illustrate how she transfers information from one class to another. Current courses for this student are in circles with lines between showing content learned in one course and used in another. This student focused almost entirely on concepts, with only a couple of references to skills ("reflection"). ITDS refers to the Metacognition course.

graphing and lab skills) are recognized as being accessed in the Chemistry course. Analysis of the arrows across all maps may reveal interesting patterns in how students perceived their subjects. For example, in our student maps physics courses have significantly more arrows flowing into the course than out, suggesting that at least initially, students may have difficulty applying physics concepts to other subjects. Additional examples of student generated LTMs are included in Supporting File S1. Lateral Transfer Maps – Example of a LTM that includes Biology and S2. Lateral Transfer Maps – Example of a LTM that does not include Biology.

PROCEDURE

To introduce to students the concept of transfer and illustrate the lateral transfer map, we begin with a short interactive presentation (~15 minutes, example in Supporting File S3. Lateral Transfer Maps: PowerPoint to support activity) on the topics. If a reading is assigned (we have successfully used the chapter on transfer from *How People Learn* (12)), a short notecard response on the reading may be used to promote reflection and solicit questions on the reading. In a larger class, a teaching assistant or learning assistant could sort through the notecards while the instructor goes on with the presentation, and then after the brief introduction, the instructor can address the most common or most interesting questions. An interactive presentation with a think-pair-share in the middle is described in the slides and notes in Supporting File S3. Lateral Transfer Maps – PowerPoint to support activity.

The presentation is followed by an initial LTM activity in which students draw a map representing their courses (in bubbles). Students are explicitly instructed to link courses with arrows, not lines (direction matters). Each arrow should indicate a particular skill or concept that they feel has been transferred from one course to another. The initial activity takes approximately 10 minutes, and students are encouraged to continue their map development at home. It is also possible to assign this activity as homework, and software tools (CMAP, https://cmap.ihmc.us/) exist for digital submissions. If they draw the maps by hand, students can scan or take photographs of their maps if the course requires digital submissions.

An essential component of the Lateral Transfer Map activity is student reflection, and often class time is devoted to individual quiet reflection. Students must reflect iteratively on their LTM, considering which courses they have chosen as sources/sinks of information. We have also found that post-map reflection can be useful as students begin to appreciate both the connectivity of their classwork and how the LTM exercise helped reveal to them those connections. These reflections may be silent, shared, or written, depending on the course context. Written reflections may be turned in with the LTM and included as part of the assessment. It is particularly instructive to repeat the activity at multiple points in the semester so students can compare maps and consider how their perception of connections have changed over time.

SCIENTIFIC TEACHING THEMES

Active Learning

This tool is designed to reinforce the principle of knowledge transfer by having the students reflect on their concurrent courses and physically connect the courses through the skills or knowledge that is transferred between them. Students must evaluate each course, the types of knowledge and/or skills

obtained and required in those courses to be able to establish the connections.

Assessment

Instructors can assess learning by evaluating features of the lateral transfer maps such as whether the connections between courses have directionality (arrows vs. lines), whether the connections are labelled with a skill or concept, and the density of connections. Students who put in minimal effort often have one connection going in or out of each class bubble, or they fail to label the arrows/lines. This activity can be paired with a written reflection that asks students to examine whether the activity helped them identify existing connections amongst their courses. This reflection can then be assessed as part of the assignment.

Inclusive Teaching

The Lateral Transfer Map is designed to be an individual activity that is open to all students, independent of academic background, identity, or major. As a result of doing this activity, students will be able to recognize and appreciate the contribution of the separate courses in the curriculum to one another and to their intended career, placing value not only on their STEM courses, but on their General Education courses as well. Through sharing their own experiences, students are exposed to the different perspectives of their peers, thus validating diverse perspectives and supporting contributions from other students. The use of LTM supports the development of metacognitive skills, particularly monitoring one's own learning. Aspects of identity, including being aware of ways in which learning and identity intersect, can be included in classroom discussions around the LTMs, especially if the assignment is expanded to include extracurricular activities (in addition to courses) or if a Longitudinal Transfer Map is done, which would include past learning as well as projected future learning needs. These metacognitive skills play an important role in the development of not just self-regulation of learning, but also self-efficacy (14). Developing these skills helps make classrooms more inclusive and supports the retention of students who might otherwise be excluded from STEM fields (15).

IMPACT ON STUDENT PERCEPTIONS

First year students often have little input or control over their schedules, and take courses because of institutional or programmatic requirements. Lateral transfer maps guide students into thinking about the motivations behind why they are taking specific courses. A quote from one student is illustrative (emphasis added):

> "*I'm not just going to a class and saying here I'm going to learn how to program in this language and here I'm going to learn to program in this language…instead its being able to take those and say I'm learning how to write in this language but I'm also learning how to perform these logic steps and* ***how I can transfer that over to these other languages****."*

Having students complete a short reflection, particularly after the second iteration of the assignment, can help guide them into recognizing connections they may have previously missed. Initially, students may be focused primarily on content and may miss connections based on skills. Another student reflected on this (emphasis added):

> "*Doing this assignment [LTM] this time made me think not just about the concepts - but I am also learning other stuff. Like how to work in a group with other people and not have group meltdown.* ***Like I can take this thing about working in groups that I learned in one class and use it in another class.***"

ASSESSMENT OF LTM STUDENT ASSIGNMENTS

Assessment of the Lateral Transfer Maps depends on the metacognitive skill desired. We found our students to initially draw lines (not arrows), indicating connections but not a direction of information flow, and also often failed to articulate the specific information, content or skills transferred. As a result, we graded specifically for these elements and did not, for example, count connections or connection density. We provided comments and suggestions for improvement on the LTMs, encouraging further exploration of areas of the map that appeared sparse or if there were few connections represented.

ALTERNATE USES: ADVANCED COURSES AND CURRICULAR PLANNING

While the tool was originally developed to help first-year students examine connections and transfer among their concurrent first-year courses, the tool can be used effectively in a wide variety of settings. Students in more advanced courses can use the tool to connect courses over an extended period of time (creating a "Longitudinal Transfer Map"). A common complaint from students about their general education courses, for example, is that they fail to see the connections among skills learned in their humanities and social science courses with the courses in their majors. Having students intentionally reflect on what they have learned, how they learned it, and when they have used that knowledge helps reinforce the interconnectedness of knowledge and the importance of transfer and connections. The importance of writing skills, presentation skills, using evidence and making arguments often surfaces in these reflections. Students may also recognize that they utilize and transfer skills and concepts learned from co-curricular activities such as clubs, sports or work experiences.

LTMs can also assist faculty members in curricular planning. By examining LTMs created by students, faculty can gain insight into the student perception of how courses fit together. For example, a typical curriculum might have first-year biology majors taking Introductory Biology, Calculus and Introductory Chemistry concurrently. When students are asked to connect ideas and skills from these courses, they may struggle to see the applicability and relevance of calculus concepts. We see this manifest as students using statistical concepts in the LTM (e.g., r^2 and X^2 between Calculus and Biology in Figure 1) because they recognize the use of these statistical techniques to understand biological data. While these are mathematical concepts, they are typically taught in a Statistics course rather than in Calculus. Faculty may consider whether first-semester students should instead take Statistics rather than Calculus. Alternatively, the finding suggests that biology instructors should consider ways to demonstrate calculus concepts within the introductory biology courses.

CONCLUSION

In conclusion, we found the student reflections suggested that the LTMs improved student perceptions of how knowledge and/or skills are transferred from one class to another. The LTMs have the potential to help students to identify relationships between courses, improve metacognitive and higher-level thinking about their coursework, as well as engaging creatively and metacognitively with the topics, and deepening their understanding of the content. The LTMs are an activity that promotes inclusion by eliciting, validating, and supporting different experiences and perspectives from the students, by fostering self-reflection, and by supporting the transfer of skills. Additionally, LTMs were helpful to instructors in providing feedback of how students conceptualized connections among their courses, and elucidated areas where more examples would improve transfer.

SUPPORTING MATERIALS

- S1. Lateral Transfer Maps – Example of a LTM that includes Biology. Figure originally printed in (13) and reprinted with permission.
- S2. Lateral Transfer Maps – Example of a LTM that does not include Biology.
- S3. Lateral Transfer Maps – PowerPoint to support activity.

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REFERENCES

1. Novak JD. 1998. Learning, creating, and using knowledge: Concept maps as facilitative tools in schools and corporations. Lawrence Erlbaum Associates: Mahwah, NJ.
2. Novak JD. 1964. The importance of conceptual schemes for teaching science. Sci Teach 31:10-13.
3. Novak JD. 1990. Concept maps and Vee diagrams: Two metacognitive tools to facilitate meaningful learning. Instr Sci 19:29-52. https://doi.org/10.1007/BF00377984
4. Ritchhart R, Turner T, Hadar L. 2009. Uncovering students' thinking about thinking using concept maps. Metacogn Learn 4:145-159. https://doi.org/10.1007/s11409-009-9040
5. Piaget J. 1936. Origins of intelligence in the child. London: Routledge & Kegan Paul.
6. Vygotsky LS. 1978. Mind in society: The development of higher psychological processes. Cambridge, MA: Harvard University Press.
7. Aubrecht KB, Dori YJ, Holme TA, Lavi R, Matlin SA, Orgill M, Skaza-Acosta H. 2019. Graphical tools for conceptualizing systems thinking in chemistry education. Journal of Chemical Education, 96:2888-2900.
8. Kinchin IM, Hay DB, Adams A. 2000. How a qualitative approach to concept map analysis can be used to aid learning by illustrating patterns of conceptual development. Educational Research, 42:43-57.
9. Kinchin IM. 2000. Concept mapping in biology. Journal of Biological Education, 34:61-68, DOI: 10.1080/00219266.2000.9655687
10. Roth WM, Roychoudhury A. 1993. The concept map as a tool for the collaborative construction of knowledge: A microanalysis of high school physics students. Journal of Research in Science Teaching, 30:503-534.
11. Engle RA, Lam DP, Meyer XS, Nix SE. 2012. How does expansive framing promote transfer? Several proposed explanations and a research agenda for investigating them. Educational Psychologist. 47:215-231, doi: 10.1080/00461520.2012.695678
12. Bransford J, Brown AL, Cocking R. 2000. How people learn: Brain, mind, experience and school,.Washington, DC. National Academies Press.
13. Franklin, SV, Hane, E, Kustusch, MB, Ptak, C, Sayre, EC. 2018. Improving retention through metacognition: A program for deaf/hard-of-hearing and first-generation STEM college students. J Coll Sci Teach 48:21-27.
14. Tanner KD. 2012. Promoting student metacognition. CBE-Life Sciences Education. 11:113-120. https://doi.org/10.1187/cbe.12-03-0033
15. Hane E, Franklin S. 2019. Improving inclusivity and diversity in college STEM programs through metacognitive classroom practices. Paper presented at 2019 CoNECD - The Collaborative Network for Engineering and Computing Diversity, Crystal City, Virginia. https://peer.asee.org/31770