

Integration of Learning Through the Use of Self-Constructed Diagrams: Opportunities and Challenges

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Abstract. The integration of what has been learned so that they become coherent is crucial for learning to become genuinely useful. Despite this importance, integration of learning (IOL) is not usually explicitly taught in formal education. Previous studies have examined various methods to facilitate IOL, and one method shown to be effective is the provision of diagrams to use. However, the usefulness of asking students to create their own diagrams to integrate what they have learned appears not to have been examined yet. That is therefore what we set out to explore in this study. We asked university undergraduate students to create a diagram to explain a process that required integration of information that had been covered in their course. The diagrams that 25 of the students produced were all variations of a flow chart, indicating that they were able to select the most appropriate kind of diagram for representing a process. However, the students varied in the quality of their representation of crucial components of the process, including connections between and within those components. Our findings suggest that constructing diagrams for IOL can serve useful learning diagnostic functions, and that it would be helpful to provide some instruction or guidance to some students so that they can effectively construct their own diagrams for IOL.

Keywords: Self-Constructed Diagrams, Integration of Learning, Apprehension of Meaning, Linking Learning, Student Instructional Needs.

1 Introduction

It has long been known and generally accepted that learning depends on the establishment of connections [1]: we learn because we connect different components of what we encounter and experience. However, apart from learning based only on a single or limited connections, such as a new word to its meaning or an action taken to its consequence, we usually connect clusters of these learnings together to achieve a more cohesive and comprehensive understanding. Isolated items of learning (e.g., rote memorized foreign vocabulary words and their definitions, without connection to sentence use in relevant contexts) are usually limited in usefulness and tend to be easily forgotten. Integration of learning (IOL) is crucial for learning to become genuinely meaningful and useful to us [2, 3]. However, despite its importance, IOL is not usually explicitly taught or cultivated in formal education.

Many teachers may have an implicit expectation that students will spontaneously integrate the appropriate components of what they are learning and/or that they will develop skills for integration as their knowledge base expands. Furthermore, some tasks given in class – such as writing summaries and working on tasks that require application of learning – may effectively facilitate IOL. However, unlike other thinking skills/competencies such as critical thinking, analysis, and logical thinking, not many teachers explicitly focus on IOL as a skill to develop and use in the process of designing curricula and in deciding instructional approaches to use.

Although not many, there are research studies that have investigated how effective IOL can be facilitated. Instructional approaches that have been found to work well include the provision of principles or normative concepts that would enable students to understand the connections between different components of knowledge they acquire [4, 5]; the use of constructivist learning environments in which the teacher provides a high degree of instructional support [6]; and the provision of opportunities for structured application and reflection so that students would apprehend the meaningful connections in what they learn and experience [7].

The provision of appropriate diagrams which illustrate the mechanisms that need to be learned has also been shown to be effective [8, 9]. This is quite understandable given that one important quality of diagrams is that they group together in the one location all information that needs to be used together [10]. These previous studies had provided the diagrams for students to use. As far as we are aware, the use of self-constructed diagrams as a tool for students to use in integrating various components of what they have learned has not been properly investigated. The present study therefore was an attempt at trying to understand the extent to which students are able to construct diagrams that might serve such integrative purposes.

The questions we were trying to answer were as follows: When asked to create a diagram to integrate several components of what they have learned,

- (i) What kinds of diagrams do students construct to represent and integrate the processes involved in those components?
- (ii) How well are they able to represent the necessary components?
- (iii) How well do they represent the connections *between* components?
- (iv) How well do they represent the connections *within* components?

2 Method

This research comprised analysis of one piece of coursework that undergraduate students completed as part of their regular class session task in a national university in Japan. No experimental intervention or manipulation was made in this study. The students provided written permission for use of their work, and the analysis was undertaken 6 months after the course had finished (it had no bearing on grades). The course was an introduction to educational psychology, and it was taught in English.

Participants. There were 33 students in the course, but 8 students did not submit the coursework in question, so we analyzed the work produced by 25 students (female = 10, male = 15; Japanese = 19, international students = 6).

Procedure. Prior to the class task, the students had received instruction over three class sessions about how humans interact with their environments, and how physiological functions (including those of subcortical and cortical regions of the brain) play crucial roles in that interaction. The task given to the students was to: “Draw a diagram that would show the process, mechanisms, and links from a ‘state of need’ to ‘satisfaction of the need’ in socially acceptable ways. Consider what happens when a human is in a state of need? Then what happens next?”. As this particular process had not been explicitly discussed in class yet, drawing the diagram would have required the students to integrate what they had learned. We determined that such a diagram would have required showing various connections between and within 7 components from the deficit in the person leading to a disequilibrium, to restoration of equilibrium, and including the hypothalamus, the limbic system, and the cortex of the brain and their functions.

About 30 minutes of class time was spent on this task, during which students could not only consult their notes and other materials, but also talk with each other if they wanted to. If they did not finish their diagram during the class, they could continue working on it later to finish it. Like other class tasks, they were asked to include this work in their portfolio which they had to submit at the end of the semester.

Analysis of the diagrams. After discussing and deciding what a diagram that satisfactorily meets the requirements of the task ought to show, we drew up three sets of scoring rubrics to score for the presence and quality of components that needed to be included, presence and kinds of connections *between* components, and presence and kinds of connections *within* components. As an example, the rubrics for scoring the presence and quality of components are shown in the Appendix. We conducted the scoring of the diagrams independently, but in stages (i.e., first 5, next 10, and final 10 diagrams) so that we could check and discuss agreements and disagreements, and resolve the disagreements at each stage until we could reach perfect agreement [11].

3 Findings and Discussion

3.1 Kinds of Diagrams the Students Constructed

Even though at first glance many of the diagrams the students constructed did not look alike, they all fit into the broad category of flow charts. Examples are shown in Fig. 1. The construction of flow charts is probably understandable given that the students were asked to show a process that progresses from one state to another. We have in fact found in an earlier study that the kind of diagram most frequently used by students to portray processes was a flow chart [12], so this current finding provides confirmation of that. In both the earlier study and the current one, no explicit instruction was provided to the students on the kind(s) of diagrams to use, so these findings suggest that, by the undergraduate level, many (if not most) students can determine that flow charts are usually the most appropriate to use in representing processes. This would likely stem from having seen such diagrams representing processes in instructional materials, such as textbooks and their teachers’ presentation slides and/or board notes.

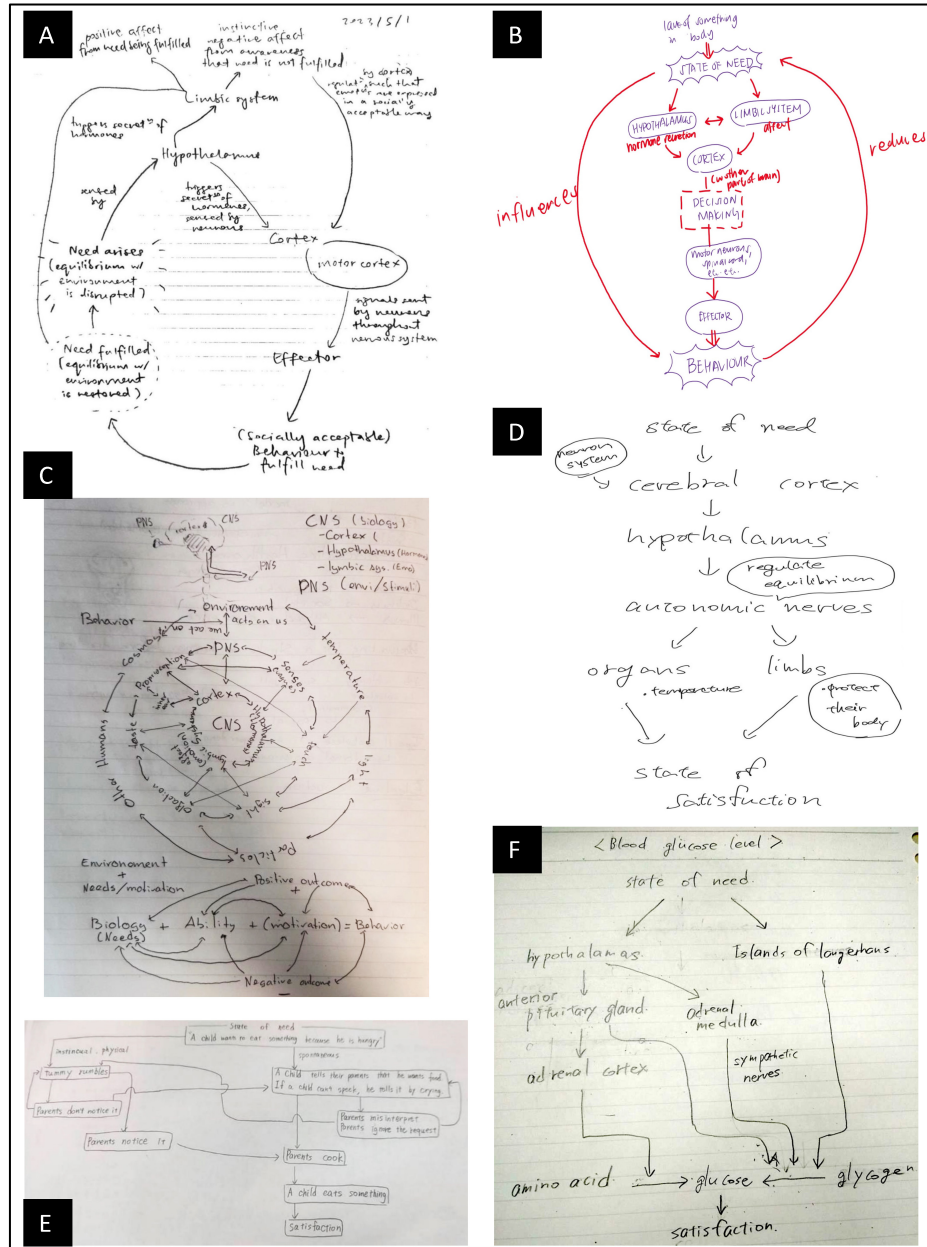


Fig. 1. Examples of diagrams that the students constructed to integrate learning

3.2 Representation of the Necessary Components in the Students' Diagrams

The students' diagrams also varied in the extent to which they represented the components deemed necessary for the task (shown in the Appendix). Fig. 1 shows diagrams

A and B which scored the highest in components score (they represented all the components) and in the *quality* of representation of those components. In contrast, E and F scored the lowest in both components represented and in quality of representation.

The correctness of the details portrayed in the diagrams mattered. While in Fig. 1 diagrams A and B show those details correctly, in diagrams E and F the details included are mostly incorrect or irrelevant to the task given. In diagram E, none of the details about the parts of the brain and their functions have been included; and in diagram F, the details contain errors and are mostly different from those covered in the course.

There were also differences in the extent to which the components were represented, and how well the students represented them. While Component 2A (“the hypothalamus enables awareness of the need”) was represented by 84% of the students and also scored the highest in quality of representation (mean = 2.40, $SD = 1.53$), Component 1 (“need leads to disequilibrium”) was only represented by 24% of the students and scored the lowest in quality of representation (mean = .68, $SD = 1.35$), a score which was significantly lower compared to those of Components 2A, 2B, 3 and 4 (range of Cohen’s d for the planned comparisons of presence: 1.24–2.08, and of quality: 1.39–1.99). We also found that Component 6 (“reduction of need leads to restoration of equilibrium”) was second lowest in representation (52%) and quality score (mean = 1.52, $SD = 1.73$), supporting previous findings that processes that are more abstract (i.e., in this case, not involving tangible organs/parts of the brain) are more difficult for students to visualize and visually represent [13]. Such processes may have also been more difficult for students to comprehend as the ability to create alternative forms of representation of what has been learned is one indicator of deeper learning [14]. This suggests that instructors may need to pay more attention to explaining more abstract processes, and consider asking students to try to construct diagrams as one way to gauge their understanding.

3.3 Representation of Connections *Between* Components

In the task they were given, because the students were integrating the necessary components of a process, it was important for them to show the correct connections between those components in their diagrams. Of course, it was important for the components to be represented in the first place if the connections between them are to be shown, and we found a significant correlation between scores in inclusion of necessary components and in the representation of connections between components, $r = .766$, $p < .01$. In diagrams like A and B in Fig. 1, all the connections between the necessary components are shown, but in diagram D, those connections are missing or incorrectly shown.

Regarding the kinds of connections used: on average, 42% of the connections used arrows, 15% used words (e.g., “influences”, “reduces” in diagram B of Fig. 1), and 4% used lines. Thus, arrows were the most popular way used to connect components in the flow charts. However, the arrows were rarely labelled, making the actual effect or influence they represent somewhat unclear in some cases (e.g., the numerous two-headed arrows shown in diagram C of Fig. 1). This clarification of what connectors mean in diagrams and how those can be made clearer warrants investigation in future research.

Connections 5 (Cortex to action to reduce need), 6 (Cortex to control to ensure social acceptability), and 7 (Needs reduction to restoration of equilibrium) were the least

represented of the *between* components connectors, with only 36% of students including each of those. Where connection 7 is concerned, the low representation may be understandable in terms of the components not being adequately concrete or tangible, as we noted earlier. Where connections 5 and 6 are concerned, it may just be that many students did not fully comprehend the different parts of the cortex, the functions they serve, and how those relate to everyday human actions. Not fully understanding those details would have made it hard, for example, to see the cortex – and more specifically the frontal lobe areas responsible for decision making – being connected to responding in a socially acceptable way to fulfil a need.

3.4 Representation of Connections *Within* Components

For each component of a process to make sense, the information within it needs to be sufficiently cohesive, and that requires depicting any necessary connections. The importance of connections within components of a diagram is confirmed in the present study by our finding of a significant correlation between the scores in quality of the diagram components and in representation of connections *within* components, $r = .934$, $p < .01$. This means that the clarity of what each component of the diagram conveys depends on whether or not crucial connections between elements within those components are shown or not. Again, diagrams A and B in Fig. 1 are good examples where the connections within each component are all shown. In contrast, diagram F in Fig. 1 portrays none of the necessary connections within components.

Regarding the kinds of connections that the students used to depict connections within the components, 27% used arrows, 18% used words, and 2% used lines. These percentages are lower than those the students used for depicting connections *between* components (see above), but the distribution across the kinds of connectors is more or less the same (i.e., arrows were used the most, while lines were used the least).

Connection 1 (Need leads to disequilibrium) was the least represented of the within component connections with only 21% of students depicting that connection in their diagrams. However, connection 5 (Cortex to motor area, action and/or behavior), 6 (Cortex to control of action for social acceptability), and 7 (Need reduction leads to restoration of equilibrium) were also not well represented in the diagrams with only 36%, 32%, and 28% of the students depicting them, respectively. The reasons for the low representation of these are likely to be similar to those previously explained. Connections 1 and 7 were likely due to their elements being less concrete/tangible in nature (i.e., not including any part of the brain or human physiology), and connections 5 and 6 were likely due to students not fully comprehending those connections to begin with.

3.5 Conclusion: Opportunities and Challenges in Using Diagrams for Integration of Learning

From the analysis of the students' performance in this study, it appears that giving the task of drawing a diagram to integrate various components of what has been learned can potentially serve very useful functions for both students and teachers. For students, drawing the diagram can confirm their understanding and/or enable them to identify

aspects that they may not have fully understood (i.e., the parts that they may struggle or even fail to represent). For teachers, the student-constructed diagrams can likewise confirm the students' grasp of the subject material, as well as reveal any gaps and/or misconceptions in their understanding of that material.

There are, however, also challenges. One of those is that some components of learning and their connections – especially those that are more abstract – can be very difficult for students to effectively visualize and represent in diagrammatic form. Hence, developing and evaluating the efficacy of methods for cultivating student skills in visually representing more abstract concepts and processes would be useful to pursue in research. It would also be useful to investigate the use of different kinds of diagrams (other than flow charts) to match variations in the nature of the learning content that needs to be integrated. Finally, it would be valuable in future studies to determine the extent to which successful integration of learning might depend on understanding of the content to be integrated. The opposite should also be investigated: the extent to which IOL through diagram construction might lead to improvements in understanding.

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Appendix

Rubrics for Scoring the Presence and Quality of Diagram Components

Components that need to be shown

- [1] Need leads to disequilibrium: Need (lack or deficit in the person) leads to upsetting of equilibrium, or creates an imbalance in equilibrium
- [2A] Hypothalamus enables awareness of need: Disequilibrium is detected by the hypothalamus which produces hormones that enable awareness of hunger, thirst, etc.
- [2B] Limbic system enables emotional reactions: Limbic system also detects disequilibrium which leads to emotional reactions like unhappiness and motivation to find food
- [3] Hypothalamus and limbic system connect to cortex: This enables actual awareness/sensations of need (sensory cortex), and awareness and expression of emotions
- [4] Cortex enables movement/action to reduce need: Through the motor cortex movements can be made to find food, water, do what is necessary to reduce need
- [5] Cortex controls the response to ensure it is socially acceptable: Through the frontal lobe (responsible for executive functions) thinking and deciding what is appropriate to do becomes possible (e.g., not just grab another person's food or drink)
- [6] Reduction of need leads to restoration of equilibrium: Once the need is reduced, the hypothalamus stops producing hormones for hunger, etc., leading to feelings of satiation and pleasure through the limbic system and cortex, and action to reduce need stops

Quality Scoring of Representation of the Components Above

- 5 = The relevant part(s) of the brain/process is(are) included, and what happens is clearly shown or stated
- 4 = The relevant part(s) of the brain/process is(are) included, and what happens is shown or stated, but may be a bit vague
- 3 = The relevant part(s) of the brain/process is(are) included, and what happens is shown or stated, but either or both of these may be incomplete or contain a minor error
- 2 = The relevant part(s) of the brain/process is(are) included, OR what happens is adequately shown or stated - but not both (either the part or what happens is missing)
- 1 = The relevant part(s) of the brain/process is(are) included, OR what happens is shown or stated - but not both (either the part or what happens is missing), AND there is some lack of clarity in what is included or shown
- 0 = Not included or shown