



TECHNIUM
SOCIAL SCIENCES JOURNAL

Vol. 16, 2021

**A new decade
for social changes**

www.techniumscience.com

ISSN 2668-7798



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Applications of Science of Learning Principles to support Teaching and Learning of Cognitive Pattern Recognition

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Abstract. This paper addresses the applications of the science of learning principles to support the teaching and learning of cognitive pattern recognition. The paper first provides a brief introduction to the science of learning and cognitive pattern recognition. Six science of learning principles have been identified to be relevant to the teaching and learning of cognitive pattern recognition and are discussed individually. The paper also offers suggestions on how to integrate the various science of learning principles for teachers to teach cognitive pattern recognition in the classroom. A teaching process model for cognitive pattern recognition is proposed and developed, which incorporates the various science of learning principles to optimize learning and minimize redundancies. Finally, this paper highlights the implications and provides several recommendations for educators to consider when they decided to incorporate the science of learning principles into their curriculum to teach cognitive pattern recognition.

Keywords. Science of Learning; Cognitive Pattern Recognition; Teaching and Learning

1. Introduction

The Science of Learning (SoL) is an interdisciplinary field of study that examines how people learn and how the teaching process can be enhanced to improve learning (Shank, 2016). It is an important area that includes various fields such as cognitive learning sciences, educational technology, artificial intelligence, etc. For many teachers and trainers, the use of SoL implies a reduction in unnecessary content (Mayer, 2008) and increases the rate at which students and working professionals gain knowledge and skills (Shank, 2016).

At the same time, good pattern recognition skills allow an individual to spot trends or to understand the relationships among different things in real life (Kidd, Gadzichowski, Gallington, Boyer & Pasnak, 2012). The skills were also critical elements necessary to achieve future academic successes (Claessens & Engel, 2013). Hence, teachers must be equipped with the knowledge of how to teach cognitive pattern recognition in their classrooms.

A literature review found six SoL principles to be relevant to the teaching and learning of cognitive pattern recognition: redundancy, signalling, spatial contiguity, multimedia, self-explanation, and feedback (Mayer, 2008; Ceballos, Camara & Taylor, 2020; Hattie, 2009). Each of these principles is discussed briefly in subsequent sections of this paper, and more importantly, the discussions attempt to connect the relevance of the SoL principles with cognitive pattern recognition, guiding teachers to improve their teaching and enhancing

students' learning experiences. Finally, a teaching process model for cognitive pattern recognition that incorporates elements of SoLs is proposed at the end of the discussions.

2. Literature Reviews

2.1. Science of Learning (SoL)

The SoL is an approach that appreciates the significance of cross-fertilization between various disciplines of conventional study, utilizing the myriad of teaching pedagogies to maximize learning (Johns Hopkins University, 2020). The meaning of cross-fertilization, in the context of genetic reproduction, is when two different types of organisms cross their genes to produce the next generation of the organism (Britannica, 1998). In SoL, this indicates that learners will be able to construct knowledge from a variety of disciplines to produce new knowledge and develop a deep level of learning (Sim & Kucinski, 2020).

In the design of multimedia instruction, Mayer (2008) proposed five SoL principles for minimizing extraneous processing (coherence, signalling, redundancy, spatial contiguity, and temporal contiguity), three principles for the handling of essential processing (segmenting, pretraining, and modality) and two principles to promote generative processing (multimedia and personalization).

Recently, Ceballos *et al.* (2020) also wrote about the five evidence-based SoL principles which can help to improve the instructional effectiveness of teaching children how to read. The five principles are modality and multimedia developed by Mayer (2008) as well as organization, self-explanation, and feedback (Hattie, 2009).

2.2. Neuroscience and Cognitive Pattern Recognition (CPR)

Cognitive pattern recognition (CPR) is the recognition of patterns by the brain through the matching of templates, features, prototypes, and sequences, with the help of visual and mental perceptions (Pi, Liao, Liu & Lu, 2008; Author & Loh, 2020). CPR is one of the most important cognitive processing skills in the twenty-first century (Miemis, 2010; Barkman, 2018; Lombardi, 2007) and also a critical skill necessary to achieve academic success in schools (Claessens & Engel, 2013). It is therefore, important that teachers introduce elements of CPR skills to students during classroom lessons.

As a brief highlight, the mental processes of CPR occur mainly in the neocortex of our forebrain. The neocortex is the part of the brain responsible for much higher-order thinking and processing, such as creative problem-solving, critical thinking, language learning, and definitely CPR. The cortex comprises four main lobes - the frontal lobes, occipital lobes, temporal lobes, and the parietal lobes (Jawabri & Sharma, 2020). Concerning CPR, the frontal lobes in the brain take charge of the decision-making, which equip us with the ability to select the correctly-identified pattern. The occipital lobes are associated with visual processing and take in information from the external environment and attempt to connect with our past knowledge. By comparing what we observe with our memories or past experiences, pattern recognition can take place. The parietal lobes enable the recognition of spatial patterns, allowing us to become conscious of our environment and position concerning surrounding physical entities. Last but not least, the temporal lobes are responsible for auditory pattern recognition, which allow us to differentiate the different types of music or rhythms (Erlauer, 2003; Jawabri & Sharma, 2020).

2.3. The Connections between SoL and CPR

The focus of this section is to discuss the concepts of the six identified SoL principles and their relevance to teaching and learning of CPR.

2.3.1. The Redundancy Principle. According to Mayer (2008), the redundancy principle states that people tend to learn better when on-screen text is omitted totally or reduced to a minimum in a multimedia lesson with a narrated animation. Not only do these contents waste valuable cognitive capability but also prevent the learner from forming meaningful cognitive representation. In 5 out of the 5 experiments conducted by Mayer (2008) involving computer-based lessons on lightning and environmental science, students performed better on the transfer assessment after they went through multimedia lessons with only animation and narration, compared to students who received multimedia lessons with animation, narration and on-screen text. The median effect size was $d = 0.72$ (Mayer, 2008), which is considered a medium effect (Cohen, 1988).

2.3.1.1. The Relevance of the Redundant Principle to CPR. In a typical process of pattern recognition, the development of the neural networks in the outer layer of the brain, mainly at the four main lobes and also at the hippocampus, helps to facilitate the analysis and matching of auditory and visual patterns (Ohio State University, 2018). With the presence of redundant contents in a given pattern problem, the speed of processing visual information by the neurons from one stage to another stage will be inevitably slowed down, based mainly on the feed-forward mechanism (Tovée, 1995). This affects the efficiency of the person to learn effectively.

2.3.2. The Signalling Principle. To reduce the mental processing of irrelevant materials, the signalling principle states that the essential contents should be highlighted to the reader (Mayer, 2008). This can be done in several ways such as by including a sub-heading to summarize the main ideas or to place the important segments in italics or bold. In all the six experiments performed in the laboratory involving both computerized lessons on airplanes and written-paper lessons on biology and lightning, Mayer discovered that students who received signalled lessons did better during the assessment as compared to students who did not receive the signalled lessons (Mayer, 2008). The median effect size was $d = 0.52$ (Mayer, 2008), which is considered a medium effect (Cohen, 1988).

2.3.2.1. The Relevance of the Signalling Principle to CPR. The inclusion of signals enables the reader to focus better on the essential contents, allowing the neural networks to run under its dynamics by reducing the energy and time required until a solution is reached (a pattern is correctly identified) (Gurney, 1997).

2.3.3. The Spatial Contiguity Principle. The spatial contiguity principle suggests that students learn better when relevant words and pictures are placed near to, instead of far away from, each other (Mayer, 2009; Moreno & Mayer, 1999). Out of 5 experimental tests conducted by Mayer (2008), which involved e-learning lessons on lightning and paper-based lessons on lightning and brakes, all the tests showed that students who received lessons where corresponding words and pictures are placed near to each other (integrated lessons) performed better on transfer tests than students who underwent non-integrated lessons (Mayer, 2008). The effect size was $d = 1.12$ (Mayer, 2008), which is considered a large effect (Cohen, 1988).

2.3.3.1. The Relevance of the Spatial Contiguity Principle to CPR. When corresponding words and pictures are placed in proximity to one another instead of far away, it reduces extraneous processing and processing time required by the reader to understand the question (Mayer, 2008). This is because the reader is not required to visually scan through the pictures and then separately scan through the words to identify and match the patterns to the correct template

solution. This is in-lined with the Gestalt Principles of Visual Perceptions, which are important theories for effective CPR. In particular, the principle of proximity states that objects which are close together will usually be perceived to be together as a group (Gordon, 2004). The spatial contiguity principle, together with the principle of proximity, both support the teaching and learning of CPR.

2.3.4. The Multimedia Principle. The multimedia principle states that a person can learn better from both text and pictures together, instead of pure word text alone (Mayer, 2009). 11 experiments were conducted by Mayer (2008) which involved computerized lessons on pumps, brakes, arithmetic, and lightning as well as paper-based lessons on pumps, brakes, generators, and lightning. In all the experiments, students who received the lessons with both word text and pictures outperformed students who only received word text alone in the transfer tests. The median effect size was $d = 1.39$ (Mayer, 2008), which is a large effect (Cohen, 1988).

2.3.4.1. The Relevance of the Multimedia Principle to CPR. When both words and pictures are present simultaneously, a person can engage in deeper learning by creating associations between a verbal representation and a pictorial portrayal (Mayer, 2008). By constructing such associations, the associative memories in the person will allow for the recall of information depending on the amount of similarity between the input patterns to the patterns stored in the memory (Du & Swamy, 2014). This increases the chance of recognizing the correct patterns and hence increasing the efficiency of learning.

2.3.5. The Self-Explanation Principle. The self-explanation principle states that a person can learn well by engaging in self-management of learning (Ceballos *et al.*, 2020). To apply the self-explanation principle, the learner needs to identify the most important information from the lesson contents, formulate and interpret his or her own set of frame-work, and then synthesize the new and current knowledge (Fiorella & Mayer, 2016). The application of the self-explanation principle has been studied in various academic disciplines of mathematics, sciences, and reading comprehension (Fiorella & Mayer, 2016, Matthews & Rittle-Johnson, 2009, McEldoon, Durkin, & Rittle-Johnson, 2013, Griffin, Wiley, & Thiede, 2008). In particular, when students think out loud, post inquisitive questions about lesson contents, perform self-monitoring, and creating connections between concepts, they can better understand the lesson contents and answer text-related questions (Jozwik, Cuenca-Carlino, Mustian, & Douglas, 2019).

2.3.5.1. The Relevance of the Self-Explanation Principle to CPR. In medical education, the self-explanation principle allows a trainee doctor to engage in stages of clinical reasoning, in which the fourth stage of script activation (recall of medical cases through experience) is done through the use of pattern recognition (Chamberland & Mamede, 2015). However, during the learning process, the application of self-explanation is more effective when students need to develop robust mental connections for more challenging problems instead of simpler domains where patterns cannot be deduced logically, such as in the mastering of second-language grammar (Wylie & Chi, 2014).

2.3.6. The Feedback Principle. The feedback principle refers to the detailed information provided by another person concerning the performance of assessment or level of mastery of the learner in a particular domain (Ceballos *et al.*, 2020). It is advocated that feedback must be given as soon as the instruction has been delivered to the learner to minimize the knowledge

gap between what has been learned and what should have been learned (Hattie & Temperley, 2007). Also, Hattie and Temperley (2007) suggested that the provision of feedback should be a repetitive cycle so that the teacher can closely monitor the learning progress of the student so that any knowledge gap can be bridged as soon as possible. Feedback is in fact, one of the top factors that influence student achievement, with an effect size of $d = 0.79$ (Hattie and Temperley, 2007; Yusoff, 2013).

2.3.6.1. The Relevance of the Feedback Principle to CPR. In the domain of training to use prosthetic hands, Kristoffersen, Franzke, van der Sluis, Murgia, & Bongers (2019) found that training is effective to improve pattern recognition control by the user of the prosthetic hands with or without feedback. Although the study indicated a weak correlation between feedback and pattern recognition, the researchers did discuss how the different levels of feedback (no external feedback, visual feedback, and visual feedback with coaching help) can be utilized to enhance the effectiveness of control training through pattern recognition (Kristoffersen *et al.*, 2019). In the field of the neural network developed for pattern recognition, the use of feedback signals is critical to be collected by the input layer to improve the overall performance of the network (Du & Swamy, 2014; Kemp, 1999).

3. SoL Support in the Teaching and Learning of CPR

This section of the article presents several perspectives on how SoL principles can be used to support teachers in their teaching of CPR.

3.1 Use of the Redundancy Principle to teach CPR

In terms of curriculum development, teachers need to be aware of the problem of dealing with redundant contents in the teaching materials. When there are unessential contents in the materials given to the students, they tend to spend more time trying to identify the essential components instead of understanding the components. Similarly, when it comes to assessment, teachers need to bear in mind that under a time constraint, students should not be wasting their time trying to distinguish the essential information from the unwanted information. Crafted questions should be relevant, concise, and clear.

For example, in the teaching of number patterns in mathematics, teachers should limit the information given in a question as long as the information is sufficient to allow the reader to identify the unit of repeat (Liljedahl, 2004; Author & Author, 2020). In Figure 1 below, the first four terms are sufficient for students to write out the next two terms. The fifth term, however, is excessive and should be removed from the question.

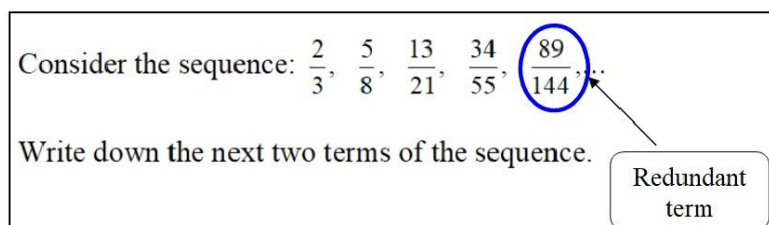


Figure 1: Number Pattern with a Redundant Term

Therefore, when teachers are developing materials for the lesson or to create an assessment paper for the students, such unneeded information should be discarded.

3.2 Use of the Signalling Principle to teach CPR

The use of the signalling principle is not a new idea in the educational setting. In fact, it is a common practice for teachers to segment their materials into headings and sub-headings, and to make essential contents more noticeable by highlighting them or placing them in bold or italics. The main consideration is that the signal should be placed at the appropriate place in the curriculum materials or appeared at a suitable moment during the lesson.

For example, in the teaching of geometrical pattern sequences and series to a class of mathematics students, the section should be clearly segmented into headings and sub-headings, with essential keywords highlighted in italics or even to include cues in the contents. This not only enables the teacher to provide clear explanations of the various sections but also allows the students to construct meaningful knowledge using the signals when they read through the materials. Figure 2 illustrates two contrasting examples of the general presentations of lesson materials with and without the signals.

WITHOUT SIGNALS	WITH SIGNALS
<p>Geometric Pattern Sequence and Series</p> <p>A geometric sequence is one where the ratio of successive terms is a constant, i.e. $\frac{U_{n+1}}{U_n} = r$ where</p> <p>'r' is called the common ratio which is a constant, and U_n is the n^{th} term.</p> <p>For example, 3, 9, 27, 81... is a geometric sequence as the common ratio is 3.</p> <p>We can let 'a' represents the first term, 'r' to denote the common ratio between successive terms, then the general n^{th} term of a geometric sequence can be written as: $U_n = ar^{n-1}$</p>	<p><u>Geometric Pattern Sequence and Series</u></p> <p>A geometric sequence is one where the ratio of successive terms is a constant, i.e. $\frac{U_{n+1}}{U_n} = r$ where</p> <p>'r' is called the <u>common ratio</u> which is a constant, and U_n is the <u>n^{th} term</u>.</p> <p>For example, 3, 9, 27, 81... is a geometric sequence as the common ratio is 3.</p> <p>The General n^{th} Term</p> <p>We can let 'a' represents the first term, 'r' to denote the common ratio between successive terms, then the general n^{th} term of a geometric sequence can be written as: $U_n = ar^{n-1}$</p>

Figure 2: Examples of lesson materials with and without the signals

Based on Figure 2, the diagram on the left presents a segment of the geometrical pattern sequences lesson materials with no sub-headings, and neither the keywords nor formulas are shown in bold, italics, or enclosed with a border. On the other hand, the diagram on the right illustrates the same segment of the contents with proper sub-headings to introduce the sub-concepts, together with the key terms and formulas highlighted appropriately with bold, italics or enclosed with a border. Clearly, the presentation on the right allows for easier reading and understanding with the inclusions of the signals (Mayer, 2008).

3.3 Use of the Spatial Contiguity Principle to teach CPR

The use of the spatial contiguity principle is important in various aspects of teaching CPR, such as curriculum development, lesson presentation as well as in crafting of assessment items.

Although the idea that relevant words and pictures should be placed near to, instead of far from, each other sounds intuitive when it comes to curriculum development and lesson presentation, teachers need to make a conscious effort to ensure that the principle is applied throughout their

work. A suggestion to demonstrate the spatial contiguity principle in the lesson explanation of pattern recognition is shown in Figure 3.

In Figure 3, diagram 'a' shows the descriptive words for the pattern transformations placed near to the components, and diagram 'b' illustrates the contents when the descriptive words for the pattern are placed at the bottom of the diagram. It is clear that for diagram 'b', the reader needs to keep referring to the bottom of the text box to connect the explanations to the respective parts; however, in the diagram 'a', lesser cognitive effort is required to understand the explanations as extraneous processing has been reduced (Mayer, 2008).

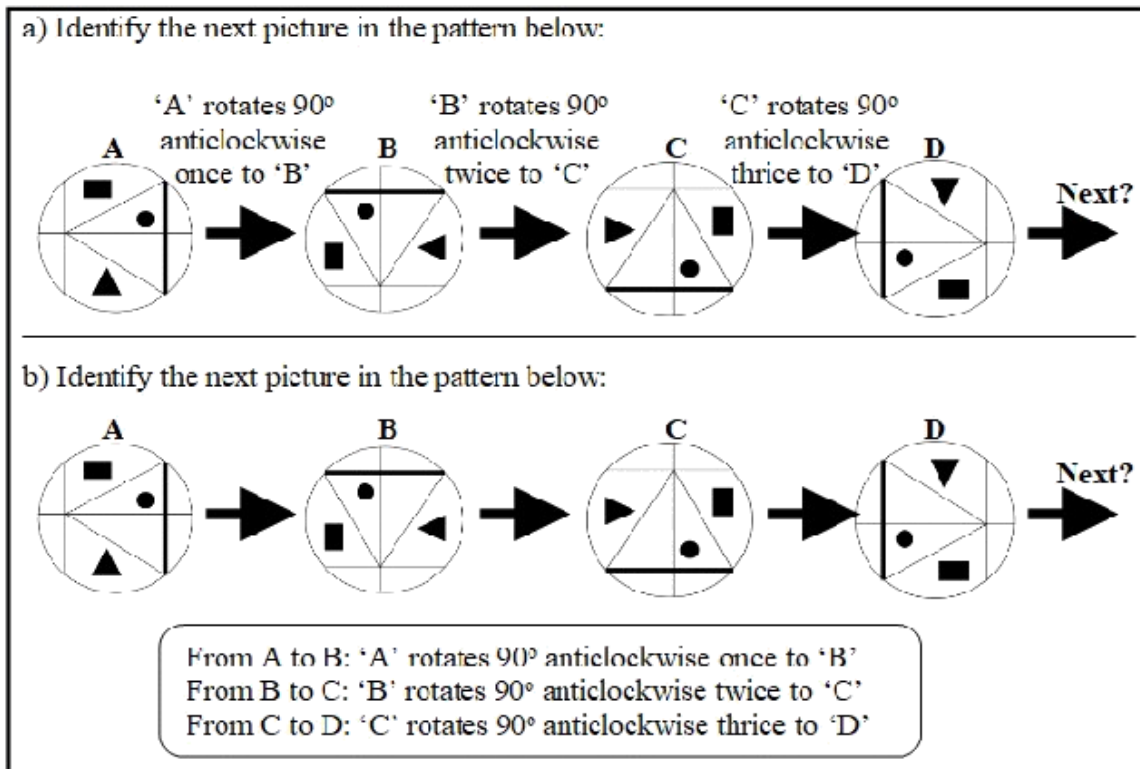


Figure 3: Example of lesson materials with a) pattern and word explanations are close together, and b) pattern and word explanations are not close to each other

Hence, when designing the lesson materials or crafting tutorial questions, teachers need to pay attention to where the written explanations should be placed. If power-point presentations are involved during the delivery of the lesson, the author proposes to create simple animations of the right-pointing arrows in figure 3 appearing sequentially from left to right, together with the corresponding written explanations placed close to each pattern transformation near the arrows.

3.4 Use of the Multimedia Principle to teach CPR

The use of the multimedia principle in the teaching of CPR is applicable during lesson deliveries where teachers intend to present the pattern recognition concepts using animations. Similar to the spatial contiguity principle, the use of the multimedia principle is rather intuitive at times. The idea is basically to present both the written explanations and pattern pictures simultaneously to the learners.

In classroom teaching, this often happens during power-point presentations with simple animations. Using the example from figure 3, the explanations of the pattern sequence occur

when the arrows, the next pattern, and the written explanation appear together during the presentation (figure 4).

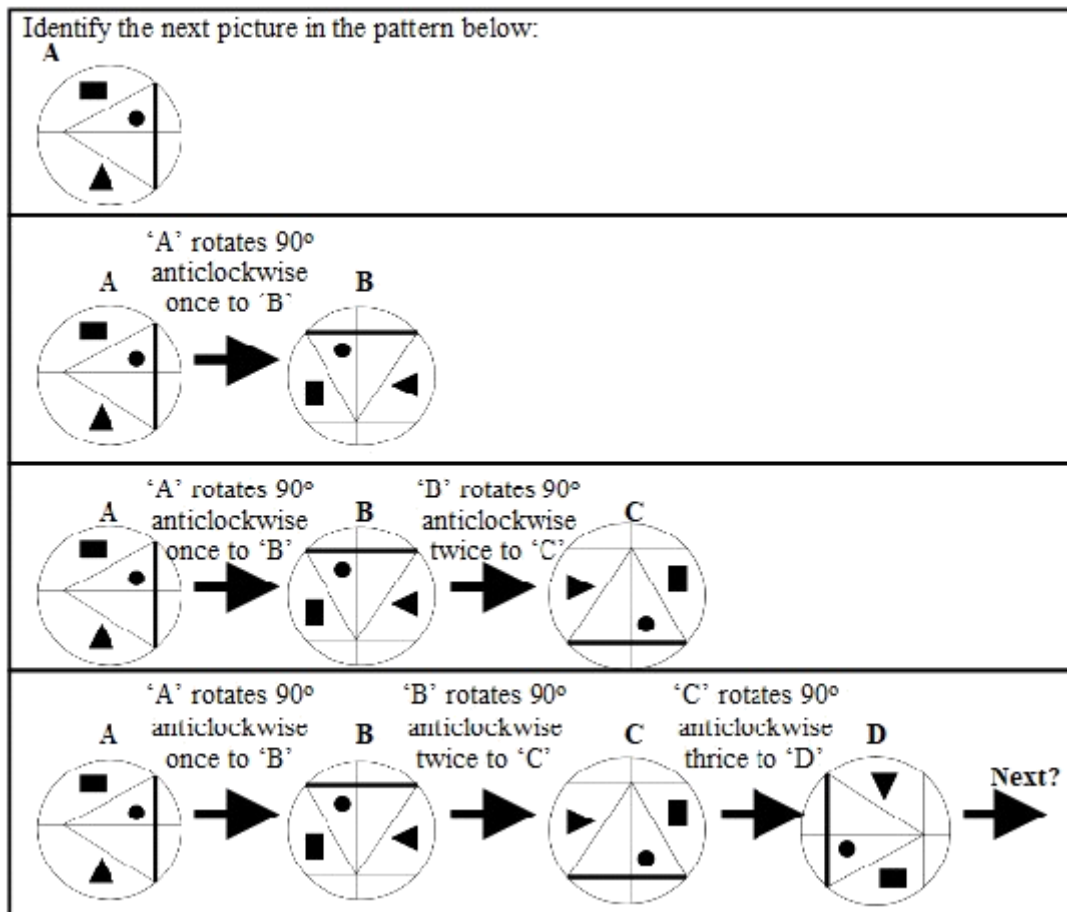


Figure 4: An example of the multimedia principle where the words, arrows, and next pattern are shown simultaneously

When teachers make the constant effort to apply the multimedia principle in the teaching of CPR, students will build stronger connections between the pattern pictures and the written representation, and hence, engage in deeper learning and focus (Mayer, 2008). The multimedia principle is rudimentary but yet necessary.

3.5 Use of the Self-Explanation Principle to teach CPR

The use of the self-explanation principle is an effective tool for classroom teachers to incorporate CPR elements into their lessons, and the subject discipline may not be confined to only mathematics. One suggestion to do this is to include a summary segment at the end of each lesson or chapter, together with critical questions such as 'Can you identify connections with concepts that you have already learned?' or 'Is there a pattern of learning that you can recognize among the concepts that you have learned so far?' When teachers ask the right questions in the right way (Long, Blankenburg & Butani, 2015; Astrid, Amrina, Desvitasari, Fitriani, & Shahab, 2019) and together with the help of summary points, serve as powerful tools for students to start consolidating their thinking and to carry out CPR processing across different topics or even subjects.

Besides, teachers can encourage students to develop their own concept maps to integrate the new and existing knowledge into a framework, and in the process, attempt to identify any relevant patterns embedded in the concepts. The use of concept mapping has been known to reinforce understanding (Akçay, 2017) and promotes deep learning (Nuuyoma & Phillipus, 2020). Coupled with the application of the self-explanation principle, the learning experience of the students in CPR is further enhanced.

3.6 Use of the Feedback Principle to teach CPR

It is known that the proper use of feedbacks improves academic performances (Vollmeyer & Rheinberg, 2005; Yusoff, 2013) and enhances learning experiences (Hounsell, 2003). In the classroom, teachers serve as feedback agents to provide valuable comments to the students in their learning journeys. Through the use of feedbacks, teachers know the extent of new knowledge that students have acquired, and students understand the amount of work needed to improve their learning (Hattie, 1999; Yusoff, 2013).

A modified feedback model from Hattie and Timperley (2007) to support the teaching of CPR is shown in figure 5. The model starts with the purpose of the feedback mechanism, which is primarily to reduce the knowledge gap between what has been learned and the desired knowledge. This is followed by the use of various tools such as summary points and questioning by the teacher to help the student develop strategies to learn CPR. In the process of giving and receiving feedback, the student has to bear in mind the three feedback questions: where am I going (learning objective)? How am I doing (performance so far)? Where to next (next course of action)? This serves as a form of self-monitoring on the learning progress. There are also four levels to work for each feedback question, namely – task level, process level, self-regulation level, and self-level (Hattie & Timperley, 2007; Yusoff, 2013).

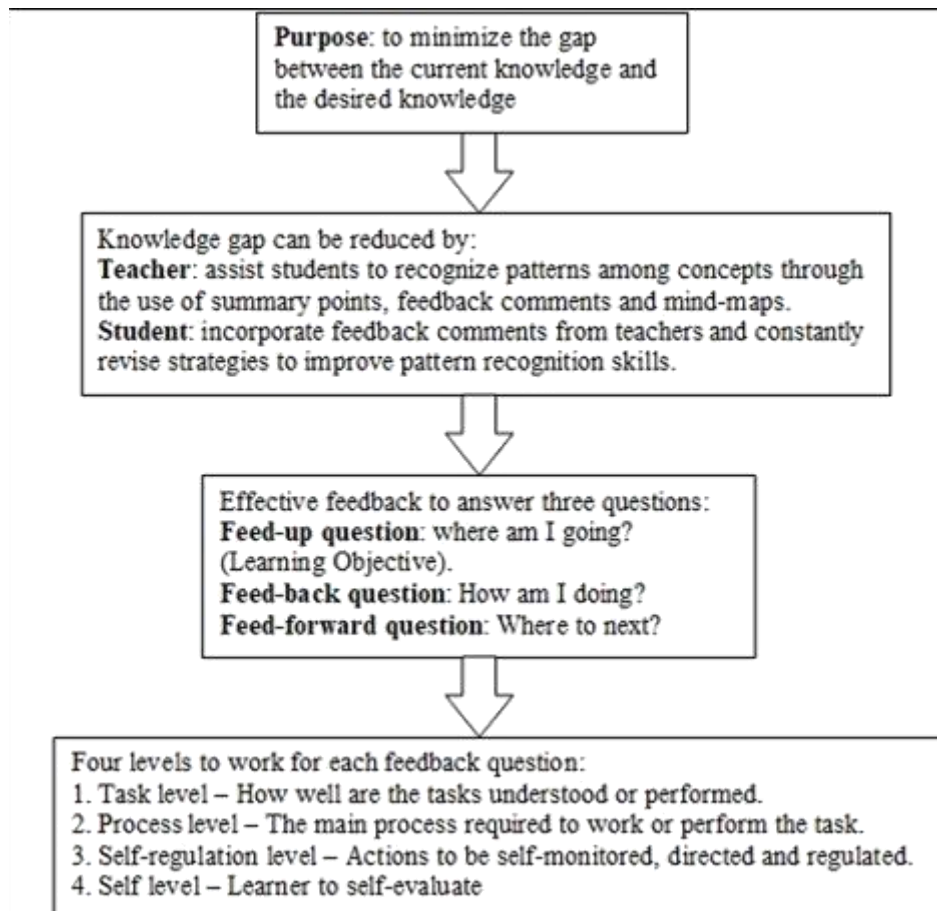


Figure 5: A feedback model to improve the learning and teaching of CPR
[source: Hattie & Timperley (2007), pg.87; Yusoff, 2013]

4. Teaching Process Model for Teaching and Learning of CPR

With the discussions on the concepts and application of the six SoL principles, a proper teaching framework must be developed as a guideline for teachers. Figure 6 presents the proposed teaching process model by incorporating the SoL principles at different stages of the model for teachers to plan and teach CPR.

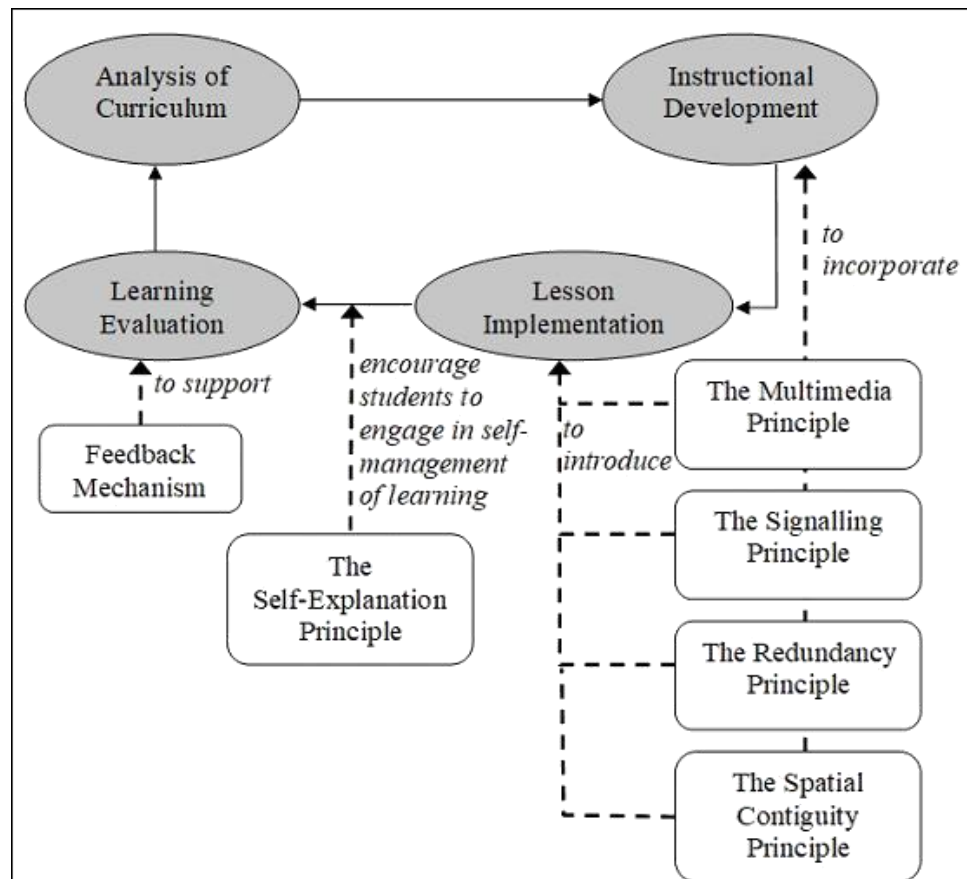


Figure 6: A teaching process model for CPR that incorporates SoL principles

In the typical teaching process model, the teacher first needs to analyse and understand the academic requirement of the stated curriculum. This is followed by the development of instructional materials. After which, the lesson is delivered (implemented) and finally evaluated for effectiveness. The teaching process model in figure 6 is modified from the ADDIE model, which is generic enough to be used for almost any type and level of curriculum design and development (DeBell, 2020).

During the instructional development phase, the four SoL principles of multimedia, signalling, redundancy, and spatial contiguity should be incorporated into the crafting of the lesson materials. These four principles also serve as the guiding principles during the lesson implementation stage, where the teacher uses the four principles to deliver the lessons, such as providing for appropriate signals during the presentation or reducing the use of unnecessary contents in the power-point slides. With these four guiding SoL principles, the CPR contents are created and lessons delivered with optimal lesson experience and minimal extraneous processing (Mayer, 2008).

After the lessons are delivered, students are encouraged to engage in self-management of their learning, such as try to explain the concept of CPR to themselves, or to identify connections among concepts through the use of CPR (Ceballos *et al.*, 2020). At the learning evaluation phase, the teacher needs to engage in two forms of feedback. One, to provide feedback comments to the students with regards to their learning progress. Two, to evaluate the effectiveness of the lessons that have been delivered. This will not only enhance the learning experiences of the students but also improve the quality of future lessons (Yusoff, 2013).

5. Implications

There are two implications to the above discussions. The first implication is that with the introduction of the SoL principles into the curriculum to teach CPR, students will spend more time working on self-explanation and self-regulated learning (Sim & Kucinski, 2020). Learning takes on a different form, where students create their own knowledge through recognition of patterns and engage in deeper learning. The second implication is that the teacher will take on a different role in and outside of the classroom. Instead of being the traditional knowledge provider, the teacher becomes the mentor (or even becomes the learner) and students are there to share their knowledge. The teaching time is reduced without compromising the quality of teaching, and more time is reserved for peer discussions and small group feedback conferences.

6. Recommendations

The author would like to make two recommendations based on the above discussions of ideas. First, teachers need to be aware of the various SoL principles and to make a conscious effort to incorporate them into the CPR lesson contents and delivery. It is recommended that teachers be sent for training so that they know how to use the SoL principles and also be aware of the importance of CPR in academic success. When considering the professional upgrading of the teachers, management should consider budgeting for SoL and CPR related courses.

Second, there needs to be close monitoring by the school management to ensure the proper implementation of the SoL principles in the teaching of CPR. It is recommended that a checklist be created for teachers to periodically check off the list of components that have been incorporated into the lesson materials and lesson delivery. The action points will serve not only as intermediate reminders for the teachers to implement the SoL principles but also for the management to carry out monitoring and performance evaluation.

7. Conclusions

The purpose of this research paper is to discuss the applications of the science of learning principles to support the teaching and learning of cognitive pattern recognition. Six science of learning principles have been identified and their relevance to cognitive pattern recognition was discussed. The next segment of the article presents a series of ideas on how each science of learning principle can be used to teach or learn cognitive pattern recognition. Two of the suggestions include the use of the signalling principle for teachers to properly segregate their materials with headings and sub-headings, and to highlight important words or formulas; and the use of a feedback mechanism for students to engage in reflections of their own learning for knowledge creation. A teaching process model for cognitive pattern recognition is then modified and developed using the ADDIE model, and the six science of learning principles are incorporated into the model. The model serves as a guiding framework for teachers and school administrators to use in curriculum planning, development, and implementation. The paper concludes with brief discussions about the implications and recommendations from the author.

8. Declaration of Interest Statement

The author declares that there is no relevant financial or non-financial competing interest in this study.

References

- [1] Akcay, H. (2017). Constructing Concept Maps to Encourage Meaningful Learning in Science Classroom. *Education*, 138(1), 9–16.
- [2] Astrid, A., Amrina, R.D., Desvitasari, D., Fitriani, U. & Shahab, A. (2019). The Power of

- Questioning: Teacher's Questioning Strategies in the EFL Classrooms. *Indonesian Research Journal in Education*. 3(1), 91-106. doi: 10.22437/irje.v3i1.6601.
- [3] Barkman, R.C. (2018). *See the World Through Patterns*. Retrieved from Psychology Today: <https://www.psychologytoday.com/intl/blog/singular-perspective/201801/see-the-world-through-patterns>
- [4] Britannica (1998). Cross-fertilization. Encyclopædia Britannica. Retrieved from <https://www.britannica.com/science/cross-fertilization>
- [5] Ceballos, M., Camara, J. A., & Taylor, R. T. (2020). Science of Learning Principles That Support Learning to Read: How Are They Represented in Undergraduate Reading Course Textbooks and Syllabi? *Journal of Alternative Perspectives in the Social Sciences*, 10(3), 451-482.
- [6] Chamberland, M. & Mamede, S. (2015). Self-Explanation, An Instructional Strategy to Foster Clinical Reasoning in Medical Students. *Health Professions Education*, 1(1), 24-33, <https://doi.org/10.1016/j.hpe.2015.11.005>.
- [7] Claessens, A. & Engel, M. (2013). How Important Was Where You Start? Early Mathematics Knowledge and Later School Success. *Teachers College Record*. 115(6), 1-29. Retrieved from <http://www.tcrecord.org/Content.asp?ContentId=16980>
- [8] Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Mahwah, NJ: Erlbaum.
- [9] DeBell, A. (2020). What is the ADDIE Model of Instructional Design? Retrieved from <https://waterbearlearning.com/addie-model-instructional-design/>
- [10] Du, K.-L & Swamy, M.N.s. (2014). Associative Memory Networks. In *Neural Networks and Statistical Learning* (pp. 187-214). https://doi.org/10.1007/978-1-4471-5571-3_7.
- [11] Erlauer, L. (2003). *The Brain-Compatible Classroom: Using What We Know about Learning to Improve Teaching*. ASCD.
- [12] Fiorella, L. & Mayer, R. E. (2016). Eight ways to promote generative learning. *Educational Psychology Review*, 28(4), 717-741.
- [13] Gordon, I. E. (2004). *Theories of Visual Perception (1st Ed.)*. Psychology Press. <https://doi.org/10.4324/9780203502259>
- [14] Griffin, T.D., Wiley, J., & Thiede, K. W. (2008). Individual differences, rereading, and self-explanation: Concurrent processing and cue validity as constraints on metacomprehension accuracy. *Memory and Cognition*, 36(1), 93-103.
- [15] Gurney, K. (1997). *An introduction to neural networks*. University College London Press Limited.
- [16] Hattie, J. (1999). Influences on student learning. *Inaugural lecture given on August, 2, 1999*. Retrieved from <http://www.education.auckland.ac.nz/webdav/site/education/shared/hattie/docs/influences-on-student-learning.pdf>
- [17] Hattie, J. (2009). *Visible learning: A synthesis of over 800 metaanalyses relating to achievement*. New York, NY: Routledge
- [18] Hattie, J. & Timperley, H. (2007). The power of feedback. *Review of Educational Research*, 77(1), 81-122.
- [19] Hounsell, D. (2003). Student feedback, learning and development. *Higher Education and the Lifecourse*. Buckingham: SRHE & Open University Press. 67-78.
- [20] Jawabri, K.H. & Sharma, S. (2020). *Physiology, Cerebral Cortex Functions*. StatPearls Publishing. Retrieved from <https://www.ncbi.nlm.nih.gov/books/NBK538496/>
- [21] Johns Hopkins University (2020). *What is the Science of Learning?* Retrieved from

- <http://scienceoflearning.jhu.edu/science-to-practice/resources/what-is-the-science-of-learning>
- [22] Jozwik, S.L., Cuenca-Carlino, Y., Mustian, A.L., & Douglas, K.H. (2019). Evaluating self-regulated strategy development reading-comprehension intervention for emerging bilingual students with learning disabilities. *Preventing School Failure: Alternative Education for Children and Youth*, 63(2), 121-132. doi: 10.1080/1045988X.2018.1523126
- [23] Kemp, A. W. (1999). Neural networks for pattern recognition / pattern recognition and neural networks / elements of pattern theory. *Biometrics*, 55(1), 328. Retrieved from <https://search-proquest-com.proxy.lib.sg/scholarly-journals/neural-networks-pattern-recognition-elements/docview/221670817/se-2?accountid=12691>
- [24] Kristoffersen, M. B., Franzke, A. W., van der Sluis, C. K., Murgia, A., & Bongers, R. M. (2019). The Effect of Feedback During Training Sessions on Learning Pattern Recognition-Based Prosthesis Control. *IEEE transactions on neural systems and rehabilitation engineering : a publication of the IEEE Engineering in Medicine and Biology Society*, 27(10), 2087–2096. <https://doi.org/10.1109/TNSRE.2019.2929917>
- [25] Liljedahl, P. (2004). Repeating pattern or number pattern: The distinction is blurred. *Focus on Learning Problems in Mathematics*, 26(3), 24–42.
- [26] Long, M., Blankenburg, R. & Butani, L. (2015). Questioning as a Teaching Tool. *Pediatrics*. 135(3). doi: 10.1542/peds.2014-3285.
- [27] Ling & Loh. (2020). Relationship of creativity and critical thinking to pattern recognition among Singapore private school students. *Journal of Educational Research*, 113(1), 59–76. <https://doi.org/10.1080/00220671.2020.1716203>
- [28] Lombardi, M.M. (2007). Authentic Learning for the 21st Century: An Overview. Educause. Retrieved from http://www.lmi.ub.edu/cursos/s21/REPOSITORIO/documents/Lombardi_2007_Authentic_learning.pdf
- [29] Matthews, P., & Rittle-Johnson, B. (2009). In pursuit of knowledge: Comparing self explanations, concepts, and procedures as pedagogical tools. *Journal of Experimental Child Psychology*, 104(1), 1-21.
- [30] Mayer, R. E. (2008). Applying the Science of Learning: Evidence-Based Principles for the Design of Multimedia Instruction. *American Psychologist*, 63(8), 760–769. <https://doi.org/10.1037/0003-066X.63.8.760>
- [31] Mayer, R. E. (2009). Spatial Contiguity Principle. In *Multimedia Learning* (pp. 135-152). Cambridge: Cambridge University Press. Doi: 10.1017/CBO9780511811678.010
- [32] McEldoon, K. L., Durkin, K. L., & Rittle-Johnson, B. (2013). Is self-explanation worth the time? A comparison to additional practice. *British Journal of Educational Psychology*, 83(4), 615-632.
- [33] Moreno, R., & Mayer, R. E. (1999). Cognitive principles of multimedia learning: The role of modality and contiguity. *Journal of educational psychology*, 91(2), 358.
- Miemis, V. (2010). Essential Skills for 21st Century Survival: Part I: *Pattern Recognition*. Retrieved from Emergent by Design: <https://emergentbydesign.com/2010/04/05/essential-skills-for-21st-century-survival-part-i-pattern-recognition/>
- [34] Nuuyoma, V., & Phillipus, S. K. (2020). Nursing students’ perceptions and experiences of concept mapping as a learning tool in a human physiology course. *African Journal of Health Professions Education*, 12(3), 98–102. <https://doi.org/10.7196/AJHPE.2020.v12i3.1330>

- [35] Ohio State University (2018). "This is your brain detecting patterns: It is different from other kinds of learning, study shows." ScienceDaily. Retrieved from www.sciencedaily.com/releases/2018/05/180531114642.htm.
- [36] Pi, Y. G., Liao, W. Z., Liu, M. Y., & Lu, J. P. (2008). Theory of cognitive pattern recognition. In P.-Y. Yin (Ed.), *Pattern recognition techniques, technology and applications*. doi:10.5772/6251. Retrieved from: https://www.intechopen.com/books/pattern_recognition_techniques_technology_and_applications/theory_of_cognitive_pattern_recognition
- [37] Shank, P. (2016). *The Science of Learning*. ATD Press. Retrieved from <https://tdokc.org/resources/Documents/the-science-of-learning-ebook.pdf>
- [38] Sim, F., & Kucinski, N. (2020). Application of Learning Science to Improve Deep Learning in Online Classes. *Academy of Business Research Journal*, 1, 7-20. <https://search-proquest-com.proxy.lib.sg/scholarly-journals/application-learning-science-improve-deep-online/docview/2472179194/se-2?accountid=12691>
- [39] Tovée, M. (1995). Neuronal Processing: How fast is the speed of thought? *Current Biology: CB*. 4. 1125-7. 10.1016/S0960-9822(00)00253-0.
- [40] Vollmeyer, R & Rheinberg, F. (2005). A surprising effect of feedback on learning. *Learning and Instruction*. 15(6), 589-602. doi: 10.1016/j.learninstruc.2005.08.001.
- [41] Wylie, R., & Chi, M. (2014). The Self-Explanation Principle in Multimedia Learning. In R. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (Cambridge Handbooks in Psychology, pp. 413-432). Cambridge: Cambridge University Press. doi:10.1017/CBO9781139547369.021
- [42] Yusoff, M. B. (2013). *Using Feedback to Enhance Learning and Teaching*. Penang, Penang: Centre for Academic Excellence & Student Advisory and Development.