Final Project Narrative:

How to Solve a Rubik's Cube

Sarah Strong

Faculty of Education, Wilfrid Laurier University

EU 503: Learning Theories

[REDACTED]

December 7, 2024

Final Project Narrative:

How to Solve a Rubik's Cube

Introduction

In *Range: Why Generalists Triumph in a Specialized World*, David Epstein discusses the value of maintaining broad skills and interdisciplinary thinking in a world that increasingly demands hyper-specialization. He states, "Specialization is obvious: keep going straight. Breadth is trickier to grow" (Epstein, 2019, p. 206). For this project, I applied one field of specialized knowledge, learning theories, to another field of specialized knowledge, solving Rubik's Cubes.

There are thousands of Rubik's Cube tutorials on the Internet and in print. However, they are rarely written by educators, let alone an educator who engages in self-driven professional development in learning theories and is also a competitive Rubik's solver with a strong foundation of the theory behind the Rubik's cube. For this project, I have created a Rubik's Cube tutorial that incorporates relevant ideas from cognitivism, constructivism, connectivism, and motivation theories. I also applied developmental theories from pedagogy and andragogy to differentiate it for learners of different ages. I have created a unique product that only someone like me could create.

Cognitivism

In cognitivism-based learning theories, learning is considered to be the memorization of information. One of the major concepts of cognitivism is Vygotsky's concept of the **Zone of Proximal Development** (ZPD). The ZPD is the "area of knowledge beyond what an individual currently has but is capable of apprehending"

(Stevens-Fulbrook, 2020). *Scaffolding* is a key strategy for effectively targeting a learner's ZPD. My tutorial is separated into nine steps, each with one clear objective. Within each step, the information is presented through a self-paced slideshow with one main idea per slide. The information builds slowly to prevent learners from trying to learn too much all at once or learning something that is not within their ZPD yet.

Another major concept from cognitivism learning theories is Sweller's **Cognitive Load Theory (CLT).** CLT provides us with crucial information about how learning works from a cognitive perspective. First, in order to learn information, the information needs to be placed into our long-term memory. However, information needs to be processed in our working memory before it is transferred into our long-term memory. Our long-term memory is practically infinite, but our working memory can only hold several chunks of information at a time (Garnett, 2020). The information (i.e. load) in our working memory can be categorized into three types of loads: intrinsic load, extraneous load, and germane load. Intrinsic load is imposed by the inherent difficulty of the information, extraneous load is imposed by distractions that do not aid learning, and germane load is imposed by the processing of the information (Garnett, 2020). Applying CLT helps prevent cognitive overload, the state in which a learner is overwhelmed by excessive information in their working memory. This can be accomplished by mitigating extraneous load within our control and ensuring that the intrinsic and germane load is not overwhelming for the learner (Ashman, 2023). This explains why scaffolding is an effective teaching strategy. It also encourages us to avoid excessive front-loading and keep information relevant. In my tutorial, I gradually release information on an as-needed basis. For example, I only introduce the notation when it is needed for a specific algorithm. Many tutorials front-load all the notation at the very beginning, which unnecessarily imposes germane load. I also avoid presenting confounding information as much as possible. Many tutorials state near the beginning that there are six centers, twelve edges, and eight corners on the cube. This can give a false impression that the numbers six, twelve, and eight are important and that there might be some math involved, which could increase anxiety. In my tutorial, I simply show where the centers, edges, and corners are; the learner can choose to count them if they wish.

Constructivism

In the constructivist learning theories, learning involves creating new knowledge from existing knowledge. Cognitive constructivism builds on the ideas from cognitivism by incorporating the learner's prior knowledge. In order for information to be easily retrievable from long-term memory, it needs to be attached to a *schema*, a term coined by Piaget (Stevens-Fulbrook, 2020). A schema is a category of information decided by the learner. When learning new information, the learner can either assimilate the information by creating a new schema or accommodate the information by using existing schemata (the plural of schema). Using as few schemata as possible reduces germane load and can help prevent cognitive overload (Stevens-Fulbrook, 2020). I put care into designing my method so that prior knowledge outside the tutorial is used when it is appropriate to do so. For example, I refer to the middle horizontal slice as the "equator" even though it is typically called the "middle slice" or the "E slice". I also use the terms "good edge", "good corner", "bad edge", and "bad corner" even though these are terms that are typically only used in advanced methods, including blindfolded solving methods. When I present information that likely does not fit into a learner's existing schema, I build it onto an existing concept from earlier in the tutorial if possible. I introduce only four distinct algorithms and show how to mirror and invert them to create new algorithms. In the last step, I show how to combine two previous algorithms to solve the last few pieces, whereas most tutorials introduce one or two new algorithms for this step.

Another concept from cognitive constructivism is **experience first, formalize later** (EFFL). EFFL involves gaining an intuitive understanding of a concept before rote memorizing the remaining details (Stecher et al., 2023). I apply EFFL by providing *Pause and Think* opportunities when the information that I am about to present could be reasonably figured out by the learner if they pause and play around with their cube. For example, a recurring concept in the tutorial is to *take out a piece you have already solved and put it back in differently*. Most tutorials jump right to presenting the formal algorithm without helping the learner understand why and how it works. When I provide an algorithm, I show a few moves at a time and describe in layperson's terms what it is accomplishing.

Bruner played a significant role in the development of cognitive constructivism and social constructivism. In his book *The Process of Education*, he writes, "We begin with the hypothesis that any subject can be taught effectively in some intellectually honest form to any child at any stage of development" (Bruner, 1963, p. 33). He pioneered the **Spiral Curriculum**, which refers to structuring material so that topics are regularly revisited, typically with increased difficulty or sophistication each revisit. Although it is meant to be applied throughout a child's entire schooling, it can also be applied on a much smaller scale, as I did in my tutorial. The notation is re-introduced with increased complexity each revisit. When I first introduce notation I provide the names of three faces and the meaning of one symbol, and the algorithms I demonstrate them with are only three moves long. As the learner progresses through the tutorial, the algorithms get longer and more notation is introduced on an as-needed basis. Although algorithms naturally get longer in later steps of solving the cube in any method, the minimalism of the notation is a deliberate effort on my part. Many tutorials introduce more notation than needed, including slice moves and rotations along the x- and y-plane. Although these are good to know for those who later choose to pursue speedcubing, a beginner does not need to know this information to solve the cube. Another way I applied spiralling is through the construction of my four main algorithms. The very first algorithm, named the *Flick*, is three moves long. There are several three- or four-move algorithms that essentially accomplish the same thing, but I chose the Flick because my third algorithm, named the *Sune*, begins with the same three moves. Furthermore, the last step in the tutorial does not require any new algorithms but rather an understanding of how the Sune can be looked at from another perspective to solve different pieces.

Connectivism and Digital Learning

In connectivism-based learning theories, knowledge is created to fit reality. The way learners visualize the cube, recognize patterns, and follow pieces around will be unique to them. To aid this learning, I embedded interactive visualizing tools using an app called Twisty Player. Learners can click on the cube in the tool and drag it around to view it from different angles. When a tool is used to demonstrate an algorithm, the user can interact with it through the control panel. I configured each tool to show only relevant pieces to reduce extraneous cognitive load.

Pedagogy and Andragogy

Not only did I apply learning theories when I was creating my tutorial, but I also applied developmental concepts from pedagogy and andragogy. One of the main themes I followed was *understanding before memorizing*. This is a particularly important concept in adult learning, and it can be effective for children too. The tutorial starts with disassembling the cube and putting it back together. This helps the learner recognize the three types of pieces and how they interact. Many tutorials state that the centers do not move, but then they do not explain why. By disassembling the cube first, learners can discover on their own that the centers do not move because they are physically attached together. Many tutorials also provide algorithms with little to no explanation of how they work. Some tutorials provide analogies as memory aids, such as a dog (an edge piece) trying to find its tail (a corner piece), but these do not improve understanding. I agree with Bruner that anything can be taught effectively with intellectual honesty to any child. I designed my method to include algorithms that are explainable by following the movement of a specific piece or group of pieces. Each of my three algorithms for solving the last layer does not break up the existing pieces; they merely take them out of their correct spots and put them back in differently. One of my innovations is to have learners tape these pieces together to track them and make sure they do not break up. I came up with this idea when I broke my 7x7x7 cube and needed to reassemble it – I used scotch tape to keep the pieces in place while I was working on the pieces around it. Although my method has only four distinct algorithms, I show how to transform any algorithm by mirroring it or inverting it, allowing the learner to have a stronger foundation of how algorithms can be manipulated. Many tutorials like to show shortcuts because they feel faster than their longer counterparts, but I have a zero-shortcut policy since it encourages memorizing without understanding. There is a scenario in which the Flick is used two times in a row, resulting in a few moves cancelling out. Instead of showing the cancellation, I show the full version and point out that although we could cancel some of the moves, we should practice without the cancellation at first.

My tutorial fully aligns with **Universal Design for Learning** (UDL) and **Differentiated Instruction** (DI). UDL is a framework for making learning accessible to all learners and DI are the instructional strategies to meet individual learners' needs (Novak & Couros 2022). All the design choices I have discussed so far are grounded in UDL and DI. Furthermore, the tutorial is written at a fifth-grade reading level to help make it accessible to young learners, learners with reading challenges, and learners whose first language is not English. Each page has a header with a colour-coded indicator of what type of information the page has. The second step, *The White Cross*, offers two different approaches: a step-by-step process aimed at young learners and a self-driven process aimed at teenagers and adult learners. Although I encourage all learners to understand before memorizing, the *Pause and Think* pages are suggestions, not requirements. I believe that autonomy is important in self-driven learning and am okay with learners jumping right to the answers if they wish.

Motivation Theories

In Ryan and Deci's **Self-Deterministic Theory** (SDT), learners are motivated when the following three needs are met: autonomy, competence, and relatedness (Ryan & Deci, 2000). Although my method does not offer many choices beyond how to solve the white cross, learners have autonomy over their pacing since each step is presented as a self-paced slideshow for learners to go through at their own pace and revisit as needed. I designed my tutorial to minimize the possibility of being overwhelmed or confused. The information is gradually introduced in small chunks and is connected to prior knowledge whenever possible. This allows the learner to feel competent throughout the tutorial. The one aspect of SDT that I did not incorporate is relatedness, the need to feel connected to others and experience a sense of belonging. A digital tool simply cannot replace human interaction in an authentic way. Nevertheless, I believe I incorporated other aspects of SDT as best as I could.

Conclusion

This was a fun and challenging project. Although it was tremendously time-consuming, it was well worth it. It allowed me to think more deeply about learning theories and pedagogy beyond my teachable subjects. Happy cubing!

References

Ashman, G. (2023). *A little guide for teachers: Cognitive load theory*. SAGE Publications Ltd.

Bruner, J. S. (1963). *The process of education*. Vintage Books.

Epstein, D. (2019). *Range: Why generalists triumph in a specialized world*. Riverhead Books.

Garnett, S. (2020). *Cognitive load theory: A handbook for teachers*. Crown House Publishing.

Novak, K., & Couros, G. (2022). *UDL NOW!: A teacher's guide to applying universal design for learning*. CAST Professional Publishing.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68–78. https://doi.org/10.1037//0003-066x.55.1.68

Stecher, S., Wilcox, L., & Gallas, L. (2023). *Experience first, formalize later. Mathematics teacher: Learning and teaching PK-12, 116*(7), 520–528. https://doi.org/10.5951/mtlt.2022.0178

Stevens-Fulbrook, P. (2020). *Vygotsky, Piaget and Bloom: The definitive guide to their educational theories with examples of how they can be applied*. Teacher of Sci.

Additional References

Bridges, M. W., DiPietro, M., Lovett, M., Norman, M. K., & Ambrose, S. A. (2023). *How learning works: Eight research-based principles for smart teaching*. Jossey-Bass.

Cozolino, L., & Sprokay, S. (2006). Neuroscience and adult learning. *New directions for adult and continuing education*, *2006*(110), 11–19. https://doi.org/10.1002/ace.214

Didau, D., & Rose, N. (2016). *What every teacher needs to know about psychology*. John Catt Educational Ltd.

Feldon, D. F. (2007). Cognitive load and classroom teaching: The double-edged sword of automaticity. *Educational Psychologist*, *42*(3), 123–137. https://doi.org/10.1080/00461520701416173

Lang, J. M. (2021). *Small teaching: Everyday lessons from the science of learning*. Jossey-Bass, a Wiley imprint.

Oakley, B. A., & Schewe, O. (2021). *Learn like a pro: Science-based tools to become better at anything*. St. Martin's Essentials.

Weinstein, Y., Sumeracki, M., & Caviglioli, O. (2019). *Understanding how we learn: A visual guide*. Routledge.

Willingham, D. T. (2021). *Why don't students like school?: A cognitive scientist answers questions about how the mind works and what it means for the classroom*. Jossey-Bass.