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Using the Kolb Cycle to Enhance Undergraduate Research Experiences

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Using the Kolb Cycle to Enhance Undergraduate Research Experiences – a Work in Progress

Abstract

Much work has been done to assist engineering faculty in higher education as they work to enhance their classroom teaching. While some of this work might be applicable to faculty leading undergraduate research teams, it is unclear which "enhanced teaching methods" might apply in this research setting. Kolb's cycle is a method that has been used widely in pedagogical work. This current effort is intended to provide a method to facilitate its use with undergraduate research teams. The Kolb cycle represents a set of four learning activity categories where, if the full slate of these activities is engaged, learning is enhanced. In addition, previous researchers have created a Kolb Learning Style (KLS) instrument that can identify which of the four Kolb categories a student prefers. The process for this current research entails listing the research tasks, identifying the extent to which each task falls into a Kolb category and then attempting to align the Kolb categories of the research tasks with the students' KLS. This is done by altering the *process* used to accomplish some of the research tasks, not by altering the task itself. The impact of this alignment of research tasks with KLS was assessed qualitatively through discussions with the student researchers. The result, while only qualitative in this initial research study, is positive. The students definitively indicated that the alignment enhanced their research experience in terms of efficiency, effectiveness and satisfaction of the research work.

Background

In 2020 approximately 4 million bachelor's degrees were given in the US [1] across all academic disciplines. According to the Council on Undergraduate Research, only 28% of undergrads engage in research [3]. However, within 10 years, approximately 40% of former undergraduate students enter graduate programs [2] where research capability and experience is often critical to success. One study indicates that 29% of undergrads do not choose to participate in research because they simply are not interested in research [3]. Possibly if research projects could be tailored to be more attractive to undergraduate students, more students would take advantage of these research opportunities. In addition, for the 29% of undergrads that take the opportunity to work on a research team, utilizing the knowledge in pedagogical advancements to enhance those research experiences could have a significant impact on those students.

The Kolb model is characterized by a cycle that begins with Concrete Experience (CE), proceeds with Reflective Observation (RO) and Abstract -Conceptualization (AC), and ends, before restarting, with Active Experimentation (AE) (see Figure 1). Educational environments that incorporate all four parts or categories of the cycle have been shown to span the spectrum of student learning styles more fully, and in general to enhance the overall learning experience [4-7]. The educational enhancement method has been used in many contexts including experimentally based classes and engineering education in general [10,11]. Many times, the Kolb model can be used to enhance an educational experience by making sure all 4 parts of the cycle are included. For example, if a learning experience does not have a hands-on, kinesthetic component, adding that component will ensure the "Concrete Experience" part of the cycle is addressed. In addition, previous researchers have created an instrument that can provide a Kolb Learning Style (KLS) for a student [8]. This KLS indicates which of the 4 Kolb categories (CE, RO, AC or AE) a student prefers to engage with. This is quantified in a 2D spectrum where the instrument provides a student's preference for either AE or RO and then for either CE or AC.

In the summer of 2022, an engineering research project was undertaken by two undergraduate students, a professor and a mentor who is a senior-level practicing engineer. The research project focused on development of a strategy to inform engineering designers of the benefits, or drawbacks, of engaging in either digital prototyping or physical prototyping (or both). The project was funded by industry and the college. The project ran for a ten-week summer session, but then continued after that in a less aggressive manner. That prototyping oriented research project functions as the testbed for the Kolb Method research reported on here. The initial idea for this Kolb Method work was highlighted as part of an overall presentation on the prototyping research at the ASME annual conference in November of 2022 [9].

Research Objective and Research Question

In this current work, a process is provided that allows the Kolb cycle to be applied to an undergraduate research project, with the goal of improving the research team's experience in various ways. In addition, the improved research environment may cause other students to become interested in pursuing undergraduate research in their future.

Research questions:
Can we use the Kolb cycle and Kolb Learning Styles (KLS) to enhance an undergraduate research experience?

Sub questions:

- *Can we alter the process of certain research tasks to move their Kolb designation?*
- *If the Kolb designation of the research tasks is more aligned with the students' KLS, will the students see this as an enhancement of the research experience in terms of efficiency, effectiveness and satisfaction?*

Research Process

This Kolb Cycle oriented research follows a step-by-step process:

1- Students on the research team take the KLS instrument to identify their KLS [8].
2- The research team lists the tasks needed for their research process.
3- Each task from step 2 is mapped onto the 2-D Kolb plot through consensus of the research team.
4- Both the research tasks and the KLS for the students are plotted on the 2-D Kolb plot.
5- A center of gravity (CG) is calculated for both the research tasks and the KLSs of the students. These 2 CGs are plotted on the same Kolb plot.
6- The set R of research tasks furthest from the KLS CG is identified as tasks to move in order to more closely align the research task CG to the KLS CG.

7- For each task in R, the process by which the task is accomplished is altered to move it closer to the KLS CG, thereby achieving the goal stated in the previous step.
8- Assessment is accomplished by obtaining feedback from the students on their perspectives related to the altered process for accomplishing the research tasks.

The first stage of the process asks members of the research team to complete an instrument that identifies their preferred KLS. The background and development for the KLS can be found in [8]. The instrument based on that work is in Appendix 1. This Kolb learning style (KLS) is a combination of different pairs of the four Kolb cycle activity categories (see Fig 1). The instrument provides ranked learning preferences as either more oriented toward CE or AC and either toward AE or RO. The learning preference can therefore be mapped as a two-dimensional (2-D) vector that has, on the horizontal axis, AE as "-1" and RO as "+1" and on the vertical axis has AC as "-1" and CE as "+1". Figure 1 (from [4]) shows this 2-D space.

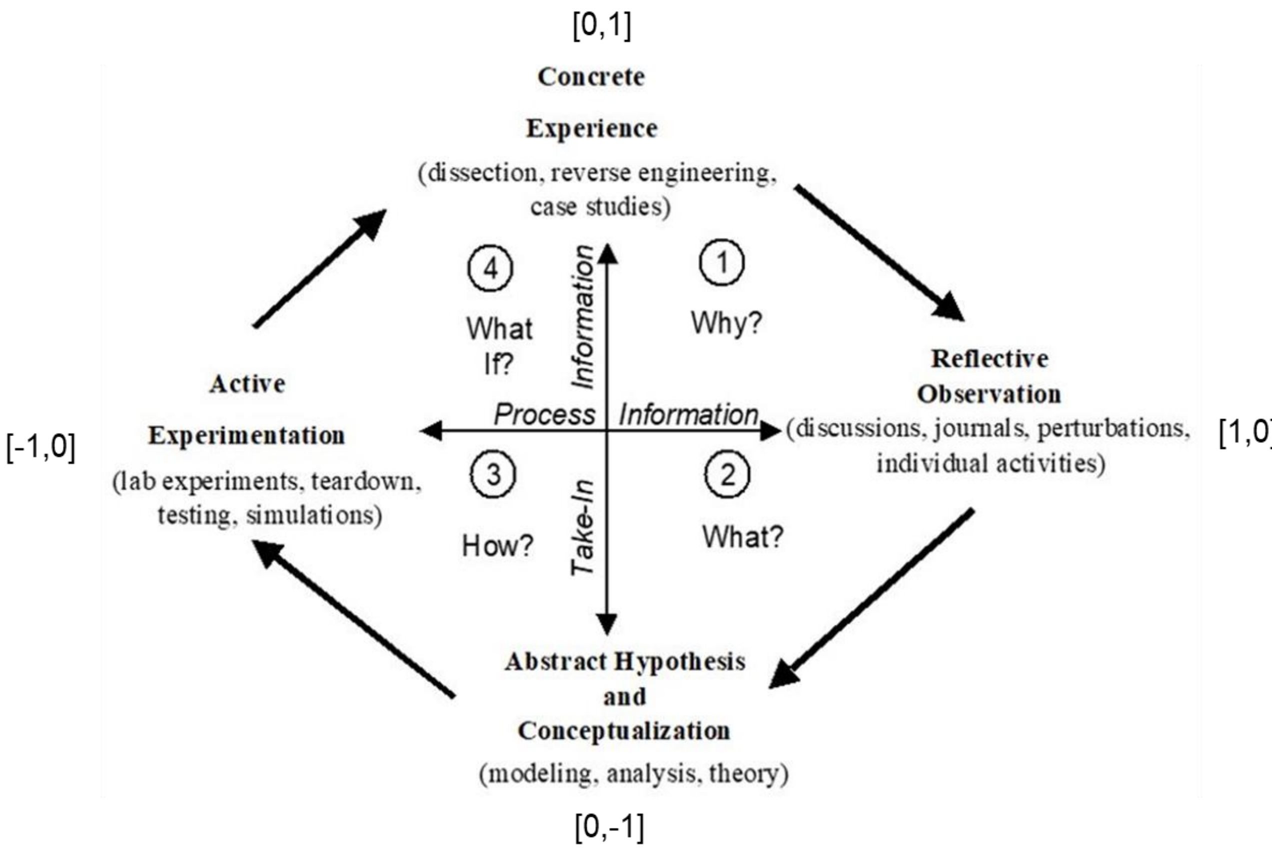

Figure 1. 2-D Vector Space for Kolb

Next, activities are identified that must be completed in the process of the research. Each of these tasks are rated in terms of how they are oriented toward CE or AC and toward AE or RO. For example, if creating a prototype is a task in the research process, that task might be given a vector (-0.5, 0.8); meaning that the task leans toward AE over RO with a strength of 0.5 and aligns with CE over AC with an even stronger measure of 0.8. This Kolb categorization for each research step or task is done in a group format, where the group needs to come to consensus on the task's rating from -1 to 1 for AC vs. CE and similarly -1 to 1 for AE vs. RO. This creates a 2-D vector location for each research activity that can be plotted on an axis with the four Kolb categories as horizontal and vertical axis as shown in Figure 1.

A description of the 4 different Kolb cycle categories is used to assist in giving each research task a 2-D vector position by the group. The description is shown in Figure 2. Once all the different research tasks have been associated with a 2-D Kolb vector, each task is plotted on a 2-D graph with AE – RO being the horizontal axis and AC – CE being the vertical axis as shown in Figure 3. Each research task is represented by a box that contains the task's description.

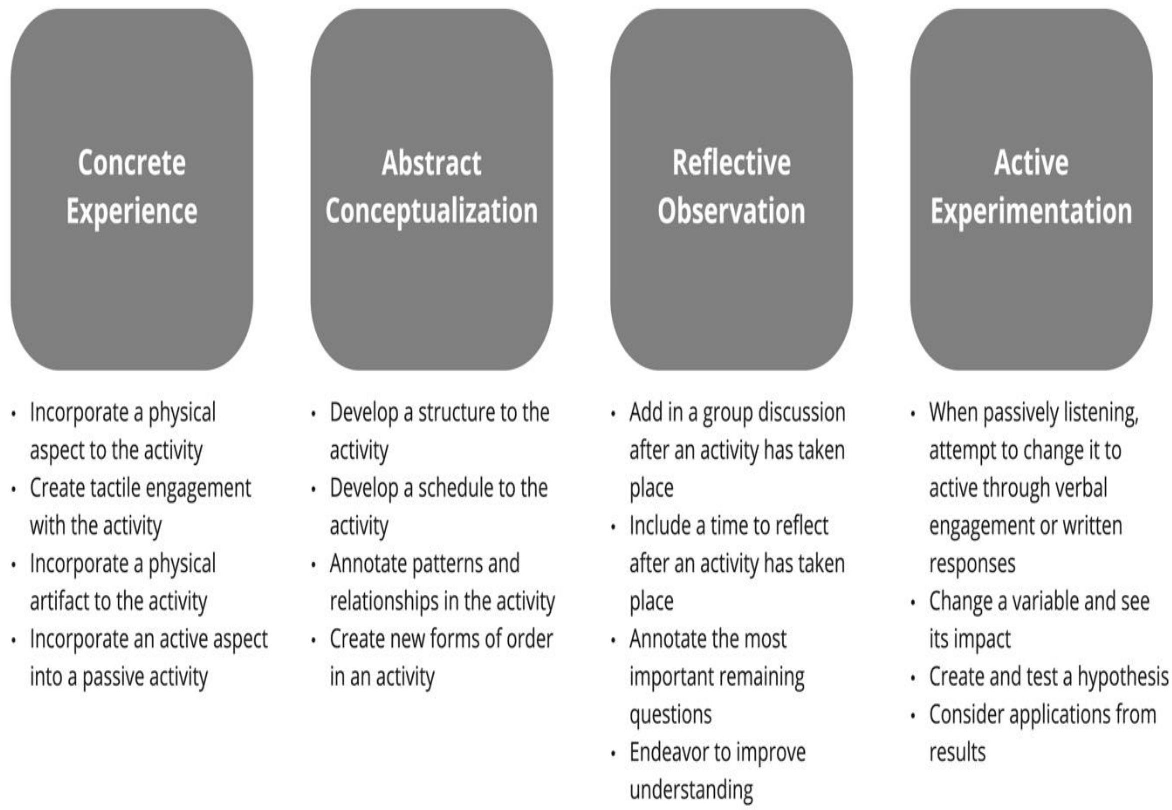

Figure 2. Descriptions of Kolb types used to Give Research Activities a Kolb Plot Location

This research into the Kolb alignment process was implemented part way through the team's actual research program, so the research tasks were coded as either GREEN – meaning tasks that had already been accomplished, YELLOW – meaning tasks that were in process or RED – meaning tasks that have not yet been started. Placement of the research tasks on the 2-D axis can therefore be seen in Figure 3 as the different green, yellow and red boxes. The amount of time spent on a task is also included in the graph represented by the size of the box for the task. The exact description of the task is not readable in Figure 3 as that information is not relevant to this study. The location, color and box size provide the Kolb-related information of the tasks.

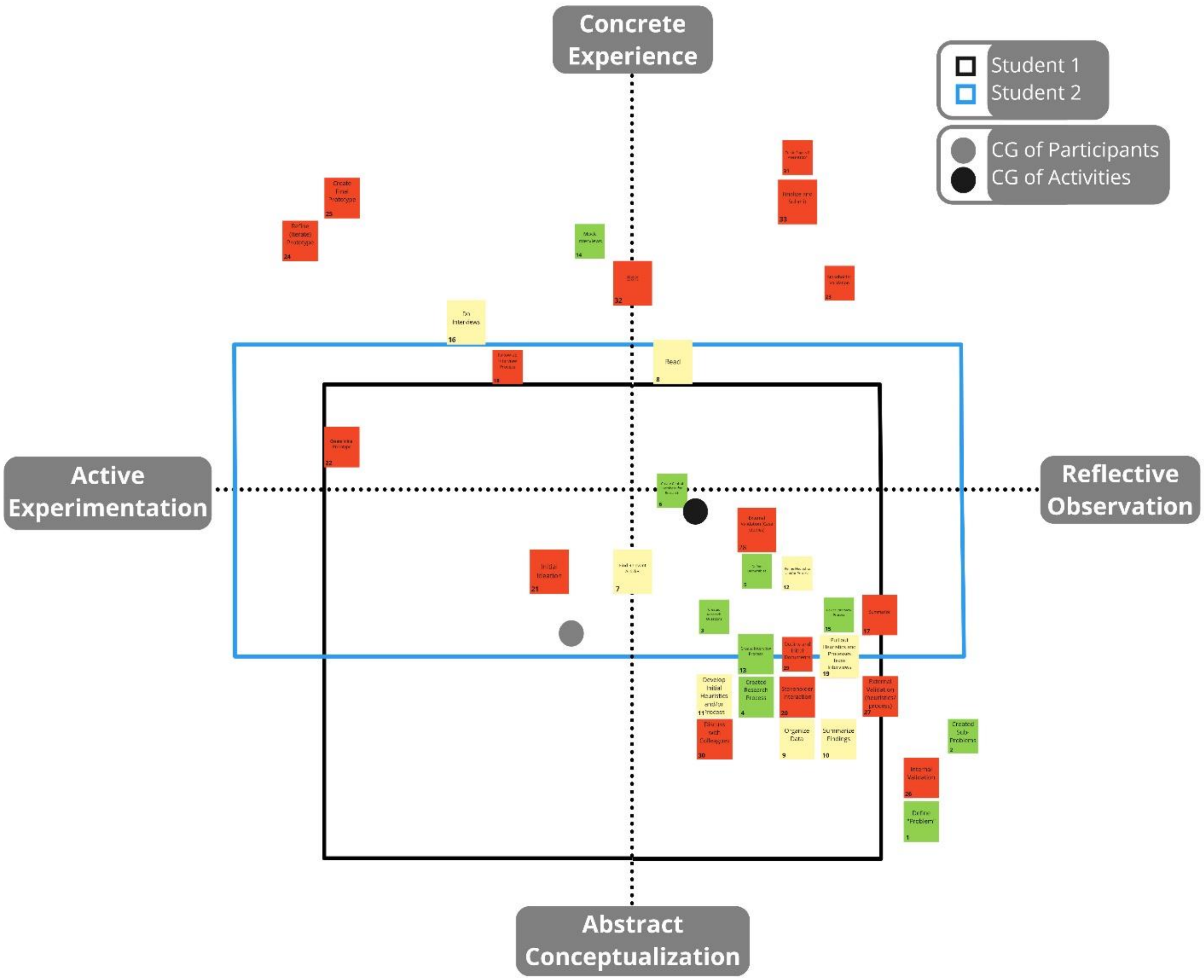

Figure 3. Research Activities Plotted on their Kolb Plot Location

As mentioned, the students on the research team each take a short survey that defines their KLS [8]. That KLS is quantified as a strength of preference for each of the four Kolb categories. This can be indicated on the same 2-D plot that shows the how the research tasks fit within the four Kolb categories. In the present work there are two students on the research team, and their individual KLS preferences are shown in Figure 3 by the black and blue rectangles, respectively. These rectangles were fabricated using the student's KLS scores. Dots have also been placed within the rectangles, representing the different center of gravity (CG) measures which are calculated below. It is helpful to think of the rectangles as showing a gradient of confidence and comfortability where the further out activities lie from the CG of the students, the more they are outside the students' preferred characteristics of the Kolb categories.

The KLS Instrument [8] shown in Appendix 1 asks the students to rank each of five different responses to a statement from 1 to 4. Each response correlates with one of the four Kolb categories. Once the individual scores are summed, the maximum possible total score in a specific Kolb category is 20, and the minimum is 5. The plot shown in Figure 3 uses axes that range from -1 to +1 in both the horizontal and vertical directions. In order to normalize the KLS instrument values to fit within the range, each one is therefore divide by 20. This provides the height and width of the different rectangles on Figure 3.

The plot with the research activities and the KLS can be studied to show how the KLS for the students aligns with the correlation between the research tasks and the four Kolb categories. This provides a graphical representation of how the research tasks align with KLS preferences for the students on the research team. The potential utility of this work is to provide insight into how research tasks might be altered to align them more closely with KLS of the students. As this alignment increases, the quality of the research experience is hypothesized to increase as well. Examples of how the tasks can be altered to improve this alignment are given later in the paper. Specifically, a center of gravity (CG) can be computed for the research tasks in the 2-D plane of the 4 Kolb categories. In a similar manner a CG can also be computed for the research team's combined, averaged KLS. To calculate the CG of the students' KLS, the average is taken between each participant's normalized KLS values represented by their rectangles on the plot. For example, student 2 scored (normalized) 0.8 in RO and 0.95 in AE, while student 1 scored 0.66 in RO and 0.75 in AE. The average in the x-axis would be:

$$Student\ KLS\ CG\ \ x-axis\ coordinate = \frac{(0.8-0.95)+(0.6-0.75)}{2} = -0.15$$

A similar calculation is done for the y-coordinate. These calculations provide a CG of (-0.15, -0.30) as shown as a gray dot in Figure 3.

In order to compute the CG for the tasks, once the students have organized their project into specific tasks and the tasks have been ranked according to the Kolb categories, the next step is to assign a weight scale to each task from 1 to 3. This score represents the time taken to complete the activity with 1 as low, 2 as medium, and 3 as high. This is represented in Figure 3 by the size of the task's box. This allows the activities that have taken more of the project duration to impact the location of the CG to a greater degree. The equation to calculate the CG is as follows:

$$Task\ CG\ \ x-axis\ coordinate = \left(\sum_{n=1}^{N}(W_n x_n)\right) / \sum_{n=1}^{N}(W_n)$$

Where n= task number, N= total number of tasks, W_n = Weight of task n and X_n= x-coordinate of the nth task. This step needs to be repeated for the y-axis as well. These calculations lead to a CG of (0.15,-.05) as the CG of the tasks. This is shown as the black dot in Figure 3.

The goal then is to change certain process parameters in some yellow or red tasks to more closely align the CG for the tasks with the CG for the KLS of the students. Note that the idea is not to add or remove research tasks, but to change the manner in which the research tasks are accomplished to improve the CG alignment. In this manner, certain tasks can be modified to intentionally move the black dot toward the gray dot.

As stated, the way to move the Kolb assignment for a research task is by changing the method or process details for how that task is being accomplished. This can take form in many ways. A task such as “individually ideate and down select,” can be moved on the Kolb 2-D plot by simply changing how the task is carried out. For example, if a student’s KLS maps toward the Abstract Conceptualization KLS category over the Concrete Experience category, they will likely prefer a less structured approach to some tasks. Some aspects of ideation and the down select process may be too structured and could be reformatted to require a less step-by-step approach to better align with that specific KLS. Providing more flexibility in the specific ideation method’s instructions and replacing a step-by-step down select process with a more conceptual approach would move the task’s box down toward “AC on the 2-D Kolb plot. Of course, this means that the task CG moves slightly downward in Figure 3.

A similar approach to alter a research task’s process can be used to move a task’s horizontal location on the plot. Often incorporating a hands-on aspect to a task can move the task’s box to the left (i.e. toward Active Experimentation). Active Experimentation can also be increased through a process where independent variables are perturbed and the impact on dependent variables is seen. As an example in the opposite direction, creating a process that requires identification of root causes or anticipating future impacts can move the GC dot to the right (i.e. toward Reflective Observation). An important issue to consider is whether it is beneficial to move <u>every</u> task into the comfortable KLS range of the students. Of course, this may not be possible, especially if the students working together do not have similar KLS. In addition, it might be a helpful growth process for students to engage outside of their preferred KLS range. It does seem reasonable however to attempt move the CG of the research tasks closer to the aggregate CG of the students’ KLS, anticipating that this will enhance the research experience overall.

Research Results

By changing the process used to accomplish certain research tasks this current work has shown that moving the tasks’ CG toward the average of the students’ KLS CG was a helpful way to improve the research team’s efficiency and effectiveness for this project. Not only did it help the students to work in their respective areas more productively, but it also allowed for the students to take into account what their colleagues are proficient at and use that information to assign task leaders to “best fit” tasks. This process allows any given research project to be better tailored to the participants, while still allowing room for them to grow in tasks that require a KLS outside of their preferred, or comfort, zone.

As an example of the alignment of tasks to a student leader for that task, consider the situation where student 1 had a higher RO score than student 2. Both students are working on a task to “Create Heuristics and Processes from Interviews”. That task is a more RO oriented task, so the leadership of that task was given to the student #1.

As a second example, an early task in the research was a literature review. Initially, both students began by independently researching and taking notes. The task of summarizing the literature review articles is a task that is deep in the lower right of the KLS graph in Figure 3; meaning it is strongly weighted toward both RO and toward AC. After beginning the task working individually, the students had the idea of centralizing the data and creating a joint database where they did research working side by side. In addition to combining the research summaries, they worked on these summaries in the same room and discussed these summaries as they worked. This meant that they had successfully shifted a mainly strong RO and AC task closer to the CG of their comfort zones. Discussing and then co-writing summaries of the literature made the task move toward both AE and CE. Not only did this make the research process more efficient and effective, but also boosted team morale and improved rapport, thus encouraging the students to do more background literature review.

Similarly, the students were able to transform another mainly strong RO and AC task into a more balanced and centered task. The task in question involves the interview process. Normally, interviewers tirelessly take notes on all the interviewee's responses to the questions posed, which is how the team began the interview process. However, after only two interviews they asked the interviewee for permission to record the sessions. What this allowed them to do was focus more on the interviewee and allow them to center their attention toward moving the conversation to even more thought-provoking places where they would be able to extract heuristics (a goal of the research project). They realized that if they spent too much time and effort focusing on essentially scribing the responses without sorting what was important information and what was not, they would burnout, waste time and possibly risk losing crucial insights. The sessions that were recorded allowed them to take brief notes during the interview, but not worry about missing any crucial data, as they could later return to and review the recorded session in a more relaxed manner. This moved the task slightly toward AE as they were "experimenting" with routing the conversation in different directions to uncover critical data from the interviewee. Although it was not a large alteration in the task's process, it resulted in a small movement in the CG of the tasks and was recognized as a positive alteration in our extraction of data and heuristics.

These two examples involved moving tasks from the RO and AC corner (lower right corner of Figure 3) and closer to the CG of our students' KLS. For this specific research project, a majority of the research tasks were in the RO and AC area, but this likely varies project to project. Overall, the examples provided, and other efforts that were accomplished to move the project task CG toward the student KLS CG did help the small team's efficiency, effectiveness, and morale. Students commented that putting them in leadership of a task that is close to their KLS helped with both efficiency and morale. Furthermore, they said this redistribution of leadership on tasks did not impact the overall sharing of the workload. Finally, the students said that the increase in efficiency that the revision of tasks caused made the work more enjoyable.

Conclusions and Future Work

This work takes a pedagogically oriented tool called the Kolb Cycle and uses it to enhance an undergraduate student research project. Students are provided with their Kolb Learning Style (KLS) from a previously published instrument. This KLS describes how students prefer to interact with a learning situation, in this case a research project. Tasks for the research project are rated in terms of how they align with each of the four Kolb Cycle categories. The research experience is enhanced by altering the manner in which certain tasks in the research process are accomplished in order to increase the task's alignment with the students KLS. Initial assessment of the process indicates that this adjustment of task process does increase efficiency, effectiveness and satisfaction with the research process.

In the future, increased clarity in how tasks are assigned their place on the Kolb chart should be addressed. Also, an experiment with a control and experimental group (respectively not using and using the process) combined with quantitative assessment of the outcome should be pursued. A sample size that can create a statistically significant difference between control and experimental groups, resulting in the determination of a p-value that can verify the validity or invalidity of the research hypothesis, will be needed. To do this will likely require at least 20 data points. Implementing this process across additional research groups would also determine the applicability of the idea in different contexts.

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Appendix 1 – Kolb Learning Style Instrument

Kolb Learning Inventory, Quick Activity

4= most like you, 1= least like you… rank each response.

1. When I learn:

___ I like to deal with my feelings. (CE) ___ I like to think about ideas. (AC)

___ I like to be doing things. (AE) ___ I like to watch and listen. (RO)

2. I learn best when:

___ I listen and watch carefully. (RO) ___ I rely on logical thinking. (AC)

___ I trust my hunches and feelings. (CE) ___ I work hard to get things done. (AE)

3. When I am learning:

___ I tend to reason things out.(AC) ___ I am responsible about things. (AE)

___ I am quiet and reserved. (RO) ___ I have strong feelings & reactions. (CE)

4. I learn by:

___ feeling. (CE) ___ doing. (AE)

___ watching. (RO) ___ thinking. (AC)

5. When I learn:

___ I get involved. (CE) ___ I like to observe. (RO)

___ I evaluate things. (AC) ___ I like to be active. (AE)

AE- Active Experimentation Score: ______

RO- Reflective Observation Score: ______

CE- Concrete Experience Score: _______

AC- Abstract Conceptualization Score: ______