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Case Studies on the Transfer of Knowledge within the interdisciplinary STEAM curricula construct

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Abstract

Sharing anecdotal case study research documents the vibrancy of personal communication to reveal both spontaneous reactions and profound thinking on the transfer of knowledge in the interdisciplinary STEAM curricula construct. With the growing research and attention to arts-integration and STEAM curricula development, a critical assignment in a graduate course in Arts-integration: Interactive Strategies for (STEAM) teaching and learning required the in-service teachers, who were the students in the course, to be teacher/researchers. In a two-to-three page case study, the students documented evidence of one or two K-12 students' transfer of knowledge between two or more disciplines – science, technology, engineering, math, and the visual arts. The methodology to execute the case study varied among the in-service teachers from surveys to one-on-one interviews to collaborations among teachers. One of the challenges of the assignment, except for a student in a STEAM school, was to investigate an educational initiative that was not actually a part of the design of the classroom or school.

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Keywords

case study, transfer of knowledge, interconnectedness

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Introduction

Sharing anecdotal case study research documents the vibrancy of personal communication to reveal both spontaneous reactions and profound thinking on the transfer of knowledge in the interdisciplinary STEAM curricula construct. With the growing research and attention to arts-integration and STEAM curricula development, a critical assignment in a graduate course in Arts-integration: Interactive Strategies for (STEAM) teaching and learning required the in-service teachers, who were the students in the course, to be teacher/researchers. In a two-to-three page case study, the students documented evidence of one or two K-12 students' transfer of knowledge between two or more disciplines – science, technology, engineering, math, and the visual arts. The methodology to execute the case study varied among the in-service teachers from surveys to one-on-one interviews to collaborations among teachers. One of the challenges of the assignment, except for a student in a STEAM school, was to investigate an educational initiative that was not actually a part of the design of the classroom or school.

Transfer of knowledge is a weighty construct aiming to show the interconnectedness of disciplines for understanding complex issues now and in the future. Synthetic thinking removes a singular focus of one discipline, so that classrooms are enriched by the concepts, methods and approaches of multiple disciplines (Guyotte, Sochacka, Costantino, Walther, Kellam, 2014.) The benefits stemming from the transfer of knowledge support higher order thinking strategies, creativity and the use technology to advance student learning. In the case studies, higher level questioning strategies were embedded in the conversations. The teachers' probing questions utilized vocabulary words/verbs, evident in Bloom's hierarchy of strategies, such as explore, convince, conceptualize, compare, invent, modify, generate, and justify to delve into the students' thinking process. The interpersonal relationships between some of the students and the teacher eased the dynamic during the case study observation and discussion.

Encapsulating evidence of the transfer of knowledge in case studies K-12 classroom environments is described below and organized chronologically from elementary to middle to high school learners.

- ❖ A second grade classroom created a lava tube using a thick clear test tube, vegetable oil, water, a pipette, and two fizzer tablets. The observational study had the teacher/observer ask pointed questions to one student about possible relationships between what he had learned in science, technology, reading, and engineering, art or math. The student promptly answers he only knows about science and math; the science part is that oil is hydrophobic, that it repels water. The teacher and the student agree on the chemical notation for nitrogen. The student fills the test tube with water asking for the exact amount of millimeters needed. The teacher inquires which subjects in school has he been using in this experiment, the student answers math. The fizzer tablets that needed to be dropped into the test tubes come in several different colors which prompts the teacher to question if the colors relate to another subject area in school. The student makes the careful observation that the bubbles from the fizzer tablets are making pockets of air breaking through the oil and rising to the top of the tube. Witnessing this movement, the student suggests the tube might explode then calmed by the teacher, says the swirling color in the test tube looks like a lava lamp. When asked, the student feels that engineers make lava lamps and the project has a possible science

component. The teacher asks the student to freely associate what the blue or red pattern reminds him of from previous readings. The student replies that the blue looks like fish and the red could be blood cells and the lamp is technology. This one-on-one teacher/student interaction continued with the teacher inquiry how light can be an enhanced teaching tool. The student explains that if the light is below zero degrees Fahrenheit, it has a fifty percent chance of burning in motion. This light force creates the movement in the lava lamp and the flashlight makes enough heat for there to be movement in the test tube. The teacher's deliberate questioning asks how the student could see an enlarged view of the light movement; he responded through a microscope. A final question, asked this time by the student, was if a force made up of heat light energy can create slow moving motion and be called a light force? The teacher answers in the affirmative. Reading is included as a resource for learning facts in the elementary grades. The teacher's astute and targeted questioning strategies advanced the students and the readers' understanding of cross/disciplinary thinking.

- ❖ In a third grade classroom, an egg drop challenge considered the transfer of knowledge between math, science and literacy (a non-STEAM discipline). How to protect an egg from cracking when dropped from different heights? The third graders virtually tested their design. A student, identified for the gifted and talented program, made inferences a technique learned in a language arts class to relate the engineering cyclical process – ask, imagine, plan, create, improve to the project. The language arts class incorporated non-fiction reading to link with the STEAM project. After the teacher's conversation with the student on the importance of the egg holder, filler, and parachute in the experiment, the teacher recalled that the student's use of a parachute to have the egg float down to earth and not break indicated the student's transfer of knowledge from physical science to engineering. The parachute made the egg container drop slowly from the ladder revealing an understanding of the forces of motion and that objects in contact with each other exert force on each other. The student needed to calculate the budgeted costs involved in the experiment; she understood that the computer calculated the total cost of the project not taking into account the already purchased costs of the experimental materials. The teacher who observed and engaged with the student felt that the student used adaptive reasoning, strategic competence and a conceptual understanding of the problem. The aligned rubric for this class project assessed students' abilities to make a claim about potential engineering steps to complete the project, show evidence to support each claim and the need to test a design. The teacher's adept use of pedagogical language was the key to identifying key components to the interdisciplinary lesson.

- ❖ A third grade student, who was in the teacher/researcher's class last year, was chosen for the observation because of her attention to details, reading ability above grade level and is a high achiever in mathematics. The teacher/researcher observed the student in an in-class science lesson focusing on engineering and the engineering process of ask, imagine, plan, create, and improve. The science project was to create a bird feeder where squirrels would not eat all the bird food during the winter months; the storyline and challenge is from the book *Those Darn Squirrels* by Adam Rubin. For the squirrel-proof bird feeder the observed female student drafted a very detailed design, then constructed the bird feeder with a cone shape unlike the rectangular and cylindrical shaped bird feeders in the book's illustrations. When asked why she used a cone she responded by saying the squirrels will have nothing to grab onto and with the sloped sides to the cone the squirrel would fall off the feeder. She had openings in the bird feeder for a bird to fit but not a squirrel. The teacher

asked if a perch should be included the student responded no because then the squirrel might grab onto it and get inside the feeder. In construction, the student used a circular base for her cone since the rest of the shape would be circular. She traced the circle from an available circular shaped object in the room but then realized she needed a larger hole for the bird so she found a larger circle shape to trace. The student used her aesthetic understanding from the book's illustrations, imagined and constructed an alternative shape for the feeder, embedded real world knowledge of squirrels' behavior as well as measured and estimated sizes from the entrance to the feeder. Each of these actions reflect on the integration of science, technology, engineering, art, and math. At the early elementary level, STEAM is introduced through the curricula construct of 'Making and Tinkering' (Heroman, 2017) where real world artifacts are the catalyst in interdisciplinary teaching and learning. The student's decision-making in the maker-space/STEAM bird feeder illuminated the engineering process along with the student's creativity.

- ❖ A fourth grade student was observed in order to understand how connections were made between two different classes, math and science. Though the researcher could only observe the student in the math class she was teaching, the student and teacher had a conversation about his science class; the teacher had spoken with the science teacher about the objectives of the science class. The science class centered on watching the growth of a plant indicated in part by the size of its leaves. The students needed to examine the nature of the dirt where the plants were growing, the amount of sunlight needed for the plants' growth, and charting the temperatures over a week. There clearly were numerous variables in this experiment on plant growth but the central idea was to see if the growth of the squash plant was related to temperature. The student had to keep a journal with a table on the plant's growth. In math class the student was learning about rounding numbers which piqued his interest in watching the weather channel and apps in following the weekly temperature. When asked by the teacher how many hot or cool days there were during the week, the student could respond with rounded numbers in recalling the temperatures and indicated his understanding of the precision needed in rounding numbers. The teacher/ researcher could hear and see first-hand in a one-on-one conversation with the student how the student was linking his science and math content learning in reading and understanding temperature readings. Through intentional and pointed questioning the teacher was able to recognize a transfer of knowledge between measurement and observational learning. Though there were numerous variables in the science class related to plant growth, the student's observation of temperature limned both math and science disciplines. Running records of teacher/student conversations and/or a student's portfolio of drawings and notes can reflect learning over time.

- ❖ Two accelerated sixth grade math students were interviewed by the math teacher. Working carefully with the students' schedules, the teacher researcher interview focused on science, math and art classes. The teacher asked pointed questions such as was there anything you learned in science that could connect with what you have learned in math. Both students connected how positive and negative integers reminded them that the number of protons, neutrons and electrons in an atom affect its positive or negative charge. The range of what is positive or negative conceptually overlapped in the students' learning in math and science. The teacher deepened the question asking if there was anything in science that helped them in the math class. The science class had a tennis ball hanging from the ceiling and the students said that helped them see different perspectives to a problem. The teacher recognized the use of varying perspectives as a problem-

solving strategy. The questioning then continued asking if the students saw a connection between math and the visual arts. It appears the students answered quickly that they both use graphics and scales to measure objects. One of the students referenced the Fibonacci sequence and angles of the lines and the curves and how much space a shape takes up. The student's answer perhaps needed further explanation on what he meant exactly in visualizing the Fibonacci sequence. Affective learning became apparent in one student's response in saying art helps him focus. The teacher summarized her transfer of knowledge interview with the two students seeing a need to further understand creativity. Her choice of students and proactive questioning allowed for an open conversation with astute learners.

- ❖ The sixth grade special education teacher observed a sixth grader who is a second language learner, in two subject areas, math and science. Before the teacher began the interview, she was reflectively pondering if the sixth grader would recognize what is a transfer of knowledge. The selected student was chosen because he is highly motivated, works well independently and in groups when he is the leader. The student does well in math and is eager to participate in class unlike his behavior in science class. The math lesson had the students label the coordinates and connect the points to create a polygon. Then the students were to draw a polygon with specific vertices using the graph table that was projected on the board and to find its perimeter. The recorded interview questions asked the student about his feeling towards math, he responded by saying math and science have some of the same things. The student, as the teacher knew, was referring to a recent science test where students had to find the combination of measurements within a diagram of beakers. The student also referred to using liters in both classes. The teacher inquired about the use of graphs and points in a polygon and if they are used in both subjects? The student adamantly said yes that graphs and grams are in both subjects. The teacher attempted to link the art class with the math class looking at shapes and angles but the student did not respond to the possible content overlap. Rewording the questions on the similarities between two different academic disciplines, like science and math, by the teacher during the student interview provoked more incisive answers from the student than the initial questioning. It appears that this student was interested in seeing common learning areas only between math and science.

- ❖ Three eighth grade students in an accelerated math class who are now studying geometry, were asked if anything they had learned in the math class had something in common with another class they were taking in school. One student promptly answered social studies because in history we learned the Chinese people had developed their own mathematical systems. Another student suggested that the Created by Design class is about making things using the process by having the right measurements in order to do the math to problem-solve to achieve the correct results. The third student sees mathematics in every subject such as learning about the gravitational pull of planets in science. The student who spoke about the social studies linkage also offered that in science there was a lot of scaling. The teacher continued the questioning, inquiring if skills they are using in math class can explain phenomena in science? In math you learn to understand the equation and why the equation exists was the response by one student. Extending the conversation to include the content area of art, the student who mentioning the Creating by Design class and its relation to math saw that math and art use graphs that helps one see the scale/dimensions of objects. The student who saw the connection to social studies and another country's system of mathematics found that art assisted in focusing in math. The teacher notes that this student is frequently doodling

in class; the teacher recognizes the importance of transformative approaches to problem-solving and therefore encouraged the student's doodling. Though it was challenging to arrange a time during the school day for questioning of the three students, it enabled the teacher to clearly identify the students' abilities to transfer skills amongst disciplines. The energetic math teacher understands and welcomes the responsibility to engage students in creative thinking processes. He notes that attention to the ability to engage the students' creative minds is possible by generating an organic relationship of integrated learning and holistic engagement.

- ❖ A questionnaire designed by the high school special education math teacher, formed the framework for a case study of two students in a math class. The questionnaire asked students to find the total area of a house of specific dimensions and then on a graph plane create an image with ten points and identify the coordinate pair (x,y) for each point. The students needed to convert measurements of ten meters into centimeters. The teacher asked very directly if the questions could be related to other subject areas than math. After the conversation began between the teacher and one student, the student said, of course math but other subjects could be science and art. This student had created buildings in science using technology. In typing class she made a google sheet and graphed squares. The second student responded to the teacher saying that art could be integrated into all parts of the assignment. Descriptions of specific aspects of the content area of art were not forthcoming by this student. The second student did say graphing is like an art, a science and a technology. The teacher conducting the conversational interview for the case study reflectively stated that some people make immediate connections while others take their time. The factor of time in identifying transfer of knowledge between subject areas may be a critical factor in research with larger populations. The teacher/researcher underscored the need for art in the interdisciplinary construct of STEAM.

- ❖ A ninth grade math teacher emphasizes that student success is built on perseverance, creativity and critical thinking. The case study focuses on the transfer of knowledge between math, chemistry and biology by one student. The student notes that math learning builds on itself so that learning from one year paves the way for learning the next year. The idea of direct variation was the center of the lesson. How does a taxi determine what to bill a customer, is it based on time, distance and/or rate of travel? The student was able to make predictions that the longer the drive is, the more expensive it is, and how much the ride would cost. The teacher noted a connection to science in the student's answer. He could generate a scatter plot looking at kinetic and potential energy and plot the findings, in this case, of stretched rubber bands. The students working in the lab with the data collection using technology. The student remembered how to organize data and the difference between independent and dependent variables and could create a meaningful graph. During another meeting with the teacher, the student asked about direct variation for a science topic, alligator growth and the passage of time which provoked unprompted questions on direct variation. The meaningful conversation continued with the student asking about postal rates based on distance, weight and cost. The student has taken the teacher's ideas on success to heart with his self-generated questions on direct variation based on the world around him (Quigley and Herro, 2019). The teacher chose well in her selection of a student for the case study. Her professional but cordial rapport with the student allowed for an open discussion over time.

- ❖ Three tenth grade students were closely observed to examine their problem-solving skills in a high school geometry and chemistry class. The teacher created two graphic organizers, one with five ovals with topics from the geometry class; the students had to write down notes or draw pictures what they remembered learning on each topic in each of the ovals. They then had to draw lines between related topics. The other graphic organizer had rounded boxes where the students needed to fill in notes or make drawings on the other subjects they were learning in school as a way to create a web of learning. The students wrote reflections on the overlapping concepts/skills between school subjects. The student that was the main focus of the study completed the first graphic organizer very well; she connected many interrelated topics in geometry such as measuring segments and angles as related to proofs, angles and parallel lines. In the second graphic organizer she made many connections. For instance, she saw relationships between themes and topics in history and literature, the use of observations and recording reactions in psychology and chemistry, and the need to be able to estimate distance in math and drivers' education. She drew similarities between f-stop numbers in a photography course and math discussing the fraction of the opening for light to enter into the camera and fractions in math. These extraordinary answers indicating deep and creative thinking come from an otherwise reticent young female student. (Costantino, Kella, Cramond and Crowder, 2010). The graphic organizers were the prompt for the one-on-one teacher/student conversation revealing numerous cross-disciplinary examples of the transfer of knowledge. The question arises if students are not asked about the transfer of knowledge among subject areas, this ability remains unrecognized and undeveloped.

- ❖ In a high school physics class, eleventh and twelfth grade students were challenged to design and personalize bottle rockets from two liter soda bottles and to create a parabolic flight path. Minimizing air resistance, the height of the rocket and the types of fins for stabilization of the flight path along with the use of appropriate materials for the rocket were central to the design process. The physics teacher consulted with the art teacher so that the shape of the flight path and the rotation of the rocket had an aesthetic component. The focus of the lesson was on parabolic trajectories. The students had to track the path of rocket looking at the shape, symmetry, sound, and movement of the rocket in flight; the second part of the lesson examined the pattern of motion with the class designing a rocket with maximum repeatable wobble. Students were to draw the flight path and to create a 3D model of the flight path. The student in the case study was asked to draw a symmetrical parabola and label the vertex. She was very concerned that the drawing was symmetrical. She was requested to answer what direction and what was the force bringing the rocket down to the earth. Did the rocket momentarily stop moving on the parabolic flight path? She thought and answered the rocket must have stopped in mid-air because it changed direction. The teacher's questions continued, asking what one could infer about the time needed for the rocket to reach its highest point in the trajectory. The student's answer was it is half the flight time. The teacher understood this physics lesson as being augmented by an aesthetic component. The teacher is interested in expanding this lesson next year. The teacher's carefully constructed lesson and aligned questions provided a base line for developing a checklist for understanding about physics with subsequent attention to the aesthetics of flight.

Cyclical Artistic and Scaffolding Engineering Practices

The museum educator Philip Yenamine (2012) developed ‘visual thinking strategies’ that are based on three questions: What is going on in the work of art? What makes you say that? What more can we find? These questions are germane to investigating not only works of art but artifacts and ideas in all disciplines. A discussion employing these questions can generate a plethora of responses. The engineering process cycle of ask, imagine, plan, create, and improve has a similar structure where there are always new approaches and perceptions to solve problems or confront complex issues.

Conclusion

The collected anecdotal case studies provide important insights into the transfer of knowledge from elementary to middle to high school students. There was a concentrated effort by the teacher/ researchers to integrate aesthetics and creativity as essential components to STEAM thinking. Aesthetics and technology perhaps can be understood as the tools in the transfer of knowledge (Blumenthal-Jones, 2012). Meta-cognition, the ability to think about thinking, highlights the fundamental assumptions of the benefits of the transfer of knowledge. When students can recognize the interconnectedness of disciplines, it will ameliorate the conceptual and practical challenges in confronting and comprehending global economic, environmental and humanitarian issues.

Reflecting on the methodology of the above described case studies brings attention to the teacher’s ability to have a laser focus on the goals of the interview. The teacher needs to develop age-appropriate questions, select students where a cordial yet professional relationship exists and to evaluate the appeal of a discussion on the transfer of knowledge. Educators can start to re-examine the antiquated idea that curricula designers align student learning objectives with Career and Workplace Readiness Standards, when the jobs of the future are yet unknowable. A more proactive stance for curricula designers is to create an animated graphic organizer where multiple perspectives in interdisciplinary learning constructs such as STEAM are fluid to reflect the transfer of knowledge in our ever-evolving world.

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