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11. AFFORDANCES IN SCHOOL SCIENCE RESEARCH

Narratives from Two Singapore Specialized Science School Students

INTRODUCTION

This chapter examines narratives written by two former students of a Singapore specialized science and mathematics school, Frontier Science High School, FSHS, (a pseudonym). In addition to the core subject-based curriculum, the school offers a complementary science and mathematics curriculum to develop students' research, innovation, and enterprising capacities over the six years of schooling. The courses offered in this program include research methodology and independent science research in which students learn to write research reports and carry out science research work mentored by school teachers with research experience, and/or scientists in external science research laboratories and universities. At the time when the former students were at the school, the complementary curriculum was implemented every Wednesday of the school week. The students were co-mentored by a chemistry teacher at the school and a doctoral level polytechnic (vocational tertiary institution) lecturer on an organic chemistry synthesis project. The lecturer conceptualized the project and came to the school every Wednesday to work with the students in the school chemistry laboratory and served as their research mentor, coach, and facilitator. The students learned organic synthesis research techniques and chemistry concepts undergirding the synthesis process that were typically taught to college level chemistry majors and graduate students. At the end of the project, the students presented a poster of the research findings at a national science symposium.

While student participation in science research was popular in FSHS, such opportunities were not prevalent in mainstream schools as prerequisite factors such as curriculum flexibility, availability of resources such as time, facilities, money, and expertise, and students with appropriate aptitude to do science research may be limited. Student participation in science research, however, has increasingly become a highlight of high-performing schools' branding in Singapore. This practice suggests that gifted students posses the ability and interest to acquire the knowledge, social, and disciplinary practice of the scientific enterprise. It also shows that this differentiated curriculum for the gifted and academically talented students provides an avenue for students' potential to be stretched in areas beyond academic learning. As recently featured in a local newspaper, students in some high-performing schools had reportedly coauthored peer-reviewed scientific publications with their

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collaborators including teacher mentors and scientists. Nonetheless, insights on the affordances present and emergent from the process of student participating in science research and effects they have on the lives of students is limited in the existing science education literature.

In this chapter, the theoretical construct "affordance" is used to examine two students' narratives of their past experiences participating in science research as middle school students. In particular, this chapter will unpack the affordances existent in making such opportunities available to them and emergent in the process of doing science research. In what follows, the theoretical concepts of "affordances" will be discussed and the ideas will be applied to analyze the narratives of their past experiences and how they shaped their current and future decisions. The affordances were complex and not always apparent to the students, or mentors at the time they worked collaboratively on scientific research. In addition, the findings will be discussed to illuminate the nested, interwoven, and sequential qualities of affordances.

AFFORDANCES

Affordance, a concept coined by perceptual psychologist James J. Gibson (1979) in his seminal book *The Ecological Approach to Visual Perception*, refers to an *action possibility* available to an individual in an environment. According to Gibson, there are three fundamental properties of an affordance. First, an affordance exists relative to the action capabilities of a particular actor. It is not a property of the experience of the actor. Second, the existence of an affordance is independent of the actor's ability to perceive it. Third, an affordance does not change as the needs and goals of the actor change. The second and third points suggest the invariance of affordance (McGrenere & Ho, 2000). In other words, the affordance exists whether or not the actor's experience and culture allows him or her to identify it. It is the ability to perceive the affordance that is experience and culture dependent. As such, the actor will need to exercise discretion in making judgment based upon the perceived information (McGrenere & Ho, 2000).

The dialectism in objectivity and subjectivity is played out as affordances are existent independent of its value, meaning, or interpretation and yet, an individual has to be present as an actor to make a direct perception and pick up the necessary information that specifies the affordance. In Gibson's view, being able to pick up the information is independent of the actor's experience, knowledge, culture, or ability to perceive something, but clearly, an individual is a frame of reference and is involved in the characterization of the existence of the affordance.

Donald Norman (1988), however, described 'affordance' differently in his book *The Psychology of Everyday Things*. The dialectism is played out in the relationship between the object and the actor acting on the object. In his definition, affordances are both actual and perceived properties. In his view, the perceived properties may not actually exist. Suggestions or clues on the use of properties can be present and affordances may be dependent on the experience, knowledge, or culture of the actor.

The most fundamental difference between Gibson's and Norman's ideas is that the former emphasized action possibility while the latter underscored that an action possibility is conveyed or made visible to the actor by having some perceptual information that specifies the affordance and allows it to be directly perceived (McGrenere & Ho, 2000). Another difference is that Norman implied the manipulability of the environment while Gibson did not. Norman also suggested that the existence of affordance is dichotomous; but rather, some grey areas exist due to different interpretations (McGrenere & Ho, 2000).

In extending Gibson's and Norman's ideas, Gaver (1991) distinguished affordances from the perceptual information that specifies affordances. In his framework, *false affordance* (Gibson's idea of 'misinformation') exists when the actor perceives the information about the affordance which does not exist. When the perceptual information is not present and there is no affordance, the actor makes a *correct rejection* that the affordance does not exist. *Hidden affordance* exists when the perceptual information is not there but the affordance is present. Last, when the perceptual information is present with the affordance, *perceptible affordance* exists. In Norman's term, the false affordance and perceptible affordance are "perceived/ apparent affordances". This type of affordance is perceived to exist whether or not the affordance exists or not.

The concept of affordance continues to evolve and efforts have been made to clarify the concept. Reed (1996) argued that affordances are resources in the environment or properties that might be exploitable. Chemro (2003) argued that affordances are relations between particular aspects of the actor and particular aspects of situations. He argued that affordances are not always properties but are about *placing features*—that is, seeing that the situation allows for certain activity—and they are not always in the environment but features of whole situations. Michaels (2003) provided six definitions of affordances summarized as follows: (a) Affordances are the actions that are goal-directed and encapsulates intention, (b) Affordances are multidimensional compounds of properties that are measurement-based, descriptive, or conceptual, (c) Affordances are not arbitrary actions, (d) Affordances exist independently of perception—they do not disappear when they are not perceived and taken advantage of, (e) Affordances are specified by the information and may be perceived as some action engaged in by the perceiver-actor and not others, and (f) Affordances entail an effectivity (Shaw, Turvey, & Mace, 1982)—properties that allow them to make use of affordances—for its actualization but not its existence (Turvey, 1992).

Other forms of affordances have also been discussed. McGrenere and Ho (2000) argued that Gibson had implied that affordance could be nested when an action possibility is composed of one or more action possibilities. Gibson had suggested an environment composed of nested objected and about nesting information that specifies information. McGrenere and Ho thus introduced the term *nested* *affordances* (p. 2). Gaver addressed the issue of complex affordances by coining the term *sequential affordances* to refer to situations in which the action on a perceptible affordance invokes other information that indicates new affordances that emerge over time.

While the concept of affordance is currently applied in the literature on human-computer interaction (HCI) to understand how designs may be improved to enhance the usability and usefulness of a product by creating affordances of possibilities for action, this concept is applied to a different context to analyze how gifted and academically talented students perceive information about their science research experiences. Through examining the complexity of the affordances, nested and sequential affordances are discussed. In addition, one more form of affordance is identified and interwoven from the analysis of the findings. While the idea of usefulness—meaning to contain the right functions for users to perform their work with efficiency and attain their goals—and usability—to mean clearly designing information to enhance the design—is used in product design in HCI community, the concept has been imported here to analyze the usefulness of doing science research and the usability of such affordances on their lives. The findings of this study will allude to the apparent and non-apparent benefits and limitations of science research so school administrators and teachers who want students to embark on science research may be informed about the possible effects it can have on students.

THE DATA

About the Mentees and Mentor

Grace (a pseudonym) was matriculated into FSHS in 2005 as a female 7th grader and Mary (a pseudonym) was matriculated into FSHS as a female 9th grader. At the time Grace and Mary embarked on their first science research project together, they were third and fourth year (Grades 9 and 10) students at the school. They were inspired by the strong research culture in the school and decided to take up the projects mostly offered to fifth year (Grade 11) students at the school.

At FSHS, Grace took courses in English, Chinese, Mathematics, Physics, Biology, Chemistry, Music, and Geography. At the end of Grade 10, she decided to leave for a mainstream high school and continued to study Physics and Chemistry in that school. Grace remained highly interested in science research and embarked on a new project at the high school under the supervision of a schoolteacher. Currently, she is a final year undergraduate at a local university and is majoring in Physics. Mary joined the specialized school as a 9th grader and then decided to continue her high school education at a junior college. She studied Mathematics, Physics, Biology, Chemistry, and other subjects at FSHS but disliked the Humanities. After the chemistry project, she embarked on another in bioengineering. Mary has recently graduated from a U.S. university and has found interest in computer science—a subject not offered at

FSHS and high schools. During one of the summers, she worked as a research intern at a university laboratory analyzing statistical data of volcano samples.

The mentor was a chemistry teacher at the school when she co-supervised Grace and Mary on the organic synthesis project with a polytechnic lecturer who has a doctorate degree in chemistry. During her chemistry honors year in the university, she had done research in organometallic synthesis and hence, was able to advise students on the research when the co-supervisor was not available. Currently, she is an Assistant Professor and conducts research in science education and teaches chemistry preservice teachers. Through analyzing her students' retrospective accounts of their science research experiences she had gained deeper insights into how such an informal curricular experience for her students had shaped their lives many years later.

The School Context

As compared to other Singapore mainstream schools, Frontier Science High School, FSHS, was unique in many ways. First, it was an independent school which did not follow the national curriculum. Second, as opposed to having a typical five-day teaching week, every Wednesday (at that time when Grace and Mary were students at the school) was devoted to informal curriculum programs including student independent research. On Wednesdays, Grace and Mary would meet their mentor in the school's chemistry laboratory and work for as long as six hours. This laboratory was atypical of most school laboratory as the infrastructure and layout mimics that of university chemistry research laboratories. There were three rows of at least five fume hoods each such that students were assigned a permanent working space, which allowed students to run overnight experiments. Nested within the laboratory was an instrument room equipped with ultraviolet spectrometers and other analytical instruments. Other apparatus not found in typical schools included the vacuum line, vacuum pump, and rotary evaporators used for filtration, purification, and extraction work. The mentor would demonstrate and coach Grace and Mary in setting up the apparatus for organic synthesis, purification, and analysis work. She also taught them how to keep records of scientific data. More importantly, she would teach them organic chemistry concepts and skills that were not taught in the formal curriculum as the students did not learn organic chemistry until their fifth year at the school. Grace and Mary would also do occasional follow up and preparation work on other weekdays if needed.

Narratives

According to Connelly and Clandinin (1988), experiences is the primary actor of education central to the understanding of what schools mean to those who spend a major part of their lives there. The narratives presented here display what the students went through, thought, and felt rather than what they did so that we could gain insights into what they lived through, construed their learning experience, and how those earlier experiences shaped their current higher education decisions. The narratives contained voices of their recollections and reflections on what they liked, disliked, learned, and did not learn in their science research work. Thus, the narratives were developmental and process-oriented, emphasizing the past, present, and future as a continuum and whole in (re)constructing meaning and understanding through story-telling about themselves (Connelly & Clandinin, 1988). Their education was a narrative of experience that developed the individual's capacity to handle their life matter in and outside the school. Narratives thus, helped to recover meanings of ideas people had in order to understand their impact on the curricular experience of these students beyond the school. The hidden curriculum—things which were taught but not intentionally planned for—may be illuminated.

Two separate narratives written by Grace and Mary are presented. Grace's narrative illuminated her informed understanding of science while Mary's narrative illuminated her additional understanding about her own niche and interests after participating in science research. Interestingly, both of them have now realized that that a career in science research involving synthesis work is not for them. When the first author contacted them to write the narratives on their reflections and recollections of the school and science research experience, and how the research experience had shaped their university major and career choice, they were not told how the narratives would be analyzed and what theoretical lens would be applied. The first author had decided to keep the narratives separate from the analysis so that Grace's and Mary's voices are clearly heard and uninterrupted by the analysis that follows.

Analysis

A mix of prescriptive and emergent codes was used to analyze the data. Using the concepts of affordances described earlier, prescriptive codes such as "perception of affordance", "manipulation of environment", "availability of resources, placing features", "multidimensionality of affordance", "nested affordance", "sequential affordance", and "relations between aspects of the actors and situations" were used. The two sets of narratives were coded separately using these codes. Nonetheless, other emergent codes were also identified in the process of reading the narratives. For example, "interwoven affordance" was derived as a code when Grace mentioned that she had learned from other mentors present in the laboratory. Grace's and Mary's realization that they would not want to pursue a career in science research was coded as "making more informed choices".

The process of coding was reiterative as the first narrative was reread and recoded from the beginning of the narrative as new codes were identified. The process was repeated with the second narrative. When new codes were identified in the second narrative, the first narrative was recoded again. The codes that were related were grouped together into categories. For example, the codes “nested affordance”, “multidimensionality of affordance”, and “interwoven affordance” were grouped together as a category to illustrate the multi-faceted nature of affordance which enriched the science research experience for students.

NARRATIVES FROM THE STUDENTS

Grace’s Narrative

The school. It helped that Frontier Science High School is an independent school, meaning that the school is given autonomy in planning its own curriculum. I learned interesting content, which I would not be able to learn in a mainstream school. At that school, students could pick and choose electives for themselves. This way, we were given partial autonomy in deciding what we learn. Thus, in some areas, we got a chance to learn only what we want to learn and we will enjoy learning. Furthermore, the small class size compared to other schools promoted greater interaction and encouraged more discussion. More questions were raised and our quality of learning was raised to a higher level.

The research culture at FSHS was very strong. The school provided many platforms that promoted the exchange of research ideas such as the annual research congress. I found it really interesting to be given the chance to get to know more about research in other areas. It helped that the research facilities in FSHS were quite advanced, and this made it possible for us to do most parts of the research experiments in the school.

Science research experience. Research trained me to be creative and innovative when looking for alternatives. For example, there was once when my mentor modified a pipette so it could function as a spoon. I also learned to be more independent in thinking and doing my work. This was because in a laboratory, the mentors would not always be present and we had to make decisions on our own. In contrast, there was much more hand holding in the classroom, since the teacher was always present during lesson time.

It also helped that the teachers in charge of science research in FSHS and my teacher-in-charge for the research project were very helpful in taking us for Research Methodology Modules (RMMs). I had a better understanding of the research process as a result. It also helped that my mentor would give us work and checked our work regularly. This was important because I was new to the subject area and made conceptual mistakes very easily. By checking my work, any mistake made could be corrected early.

Whenever new procedures were introduced, my mentor was always there to supervise and correct any mistakes made while I was carrying out the experimental procedure. This way, I was more likely to master the procedure after a few tries. Besides, she was patient in explaining how different instruments worked. Furthermore, the mentor prompted me on what I could research on in my spare time and it had enriched my theoretical understanding.

It was good that the mentor and teacher-in-charge gave us extra theory lessons and lent us some resources that we need. This was because we did not have any prior knowledge in organic chemistry. They were also very patient in clarifying any doubts we have and gave us questions to think about. I benefitted more from the questions given by the mentors because they made me more aware of the areas I should be thinking about while doing the research project. However, I felt that it would have been better if, the mentor shared some of the challenges faced in her past research experiences at the beginning of the project and how she overcame them, so I that I would be mentally prepared about what I am in for.

While doing the project, there were a few other research groups in the same laboratory. I learnt quite a bit when the mentor from another group taught us relevant concepts once in a while. Thus, I realized that the laboratory was also a place for learning, and it was not just a place to carry out experiments.

I feel that I will learn more if I have a greater understanding of the different methods used to purify compounds obtained from different reactions. I remember various methods used, like recrystallization and column chromatography. At that time, I did not think about factors, which affect the purification method used. It also did not help that I did not think very critically at that time. Perhaps, the mentor could ask even more questions to push me to think at a higher level, and after that, have a discussion about the questions raised.

I saw the relevance of classroom learning and was more appreciative of the concepts learned in school. In the classroom, we just learned concepts, but hardly knew what the concepts were used for. By applying the concepts to the experiment, we saw how the knowledge learnt in school could be applied. For example, I appreciated how the varying polarities of different organic substances could affect the choice of eluent used in column chromatography. The experience had redefined the purpose of learning science for me. We did not learn science just because it was interesting. Rather, we learned it so that we would be able to have the necessary knowledge to carry out science research in future.

Also, the research experience allowed me to see how various fields of science came together. Even though the project was in the field of organic chemistry, I saw some applications of physical chemistry as well. This was unlike classroom learning where we isolated different fields of science and did not think about how the various fields could be integrated.

At the same time, the experience redefined my perception of science. In the classroom, I used to see myself as a person trying to absorb as much knowledge as I could. I did not appreciate science as a subject of inquiry. During the project experience, a number of questions were raised. These questions prompted me to think at a higher level. After the experience, I started to appreciate science as a subject of inquiry. Besides, the research project I undertook was not graded. Thus, I did not feel pressured during the experience and I saw the project as an opportunity to make mistakes and learn from them. Further, the research experience gave me a glimpse of what I could expect to do in my career if I chose a science discipline in the university.

If I could do the project again, I will check out books in the school library or in the university library. Even though I had access to the university library at that time, I did not think about making use of the resources there. My main source of information, whenever I needed help with theoretical knowledge, was the Internet. However, I did not find the Internet very useful, because many of the underlying theories were rather specific and information on the internet was rather general.

How the experience affected my university major and career choice. I felt that the research experience has provided many learning opportunities. Besides learning more technical knowledge, I also picked up life skills like perseverance and creativity. Thus, I will certainly want to do the honors year project in university, if my grades allow me to do so.

A few years after the project, I started thinking about my career and university options. I thought about my research experience, and felt that I will not want to do research involving chemical reactions all my life. I was sure about the reason behind my career decision. Thus, I would say that the experience allows me to make an informed decision about my career choice.

It also helped that the teacher-in-charge of the project shared about happenings in actual research laboratories, for example, possible conflict between different project groups. This has allowed me to make a more informed choice about going into research as a career.

Mary's Narrative

The school. FSHS was a young school, so there were many things to figure out for both the staff and the students. FSHS taught me to step out of my comfort zone. I had been a fairly good student in my previous secondary school. Some subjects came naturally to me, and hard work usually allowed me to do well at those which I was not naturally good at. That all changed in FSHS. I struggled a lot with Physics, and for two years it seemed that my best efforts could only yield disappointing results. Things got better after we studied Calculus. I eventually did figure Physics out, but I felt that I had never worked so hard at something.

Science research experience. My first experience with research was a project on organic chemistry. I worked with a fellow student. Since it was our first time doing research, we had a lot of guidance from the mentor who explained how to perform the steps first before we did them ourselves. I had not taken any organic chemistry classes at that point, so I felt that I did not do much critical thinking, but the experience was useful in preparing me for what to expect in future projects.

One of my more memorable research experiences was at an external research institute. I had a very dedicated supervisor who knew how to strike a balance between teaching and letting me figure things out myself. She also let me learn protocols which were not related to my project. I got to watch her dissect lab rats. It was more difficult that I thought, since the rats were able to sense when one was about to kill them and kept lashing out and biting.

A good supervisor is of course the most important thing to the research experience. I was lucky enough to get good supervisors most of the time, who took the time to explain things and think of projects which I could reasonably work on myself with a little guidance.

One thing I regret not knowing before I started research was computer programming. This is becoming a very crucial skill for anyone to know, especially those working in science. If I had known computer programming, there were some projects which I could have done differently, such as writing a physical model to simulate flowing through a micro fluidic device instead of running many actual experiments which were few and delayed due to problems with the equipment. After taking a computer science class in college, subsequent research supervisors have asked me to write programs for various reasons, and I felt that I did a lot more than with previous experiences.

How the experience affected my university major and career choice. After I graduated from high school, there was quite a wait before I entered college. I was not sure what to study yet. I knew it would be something to do with science and engineering. I thought about doing Physics, but I did not have spectacular experiences at the Physics labs in school. The theory made sense, but I strongly disliked the practicals. It took me another year of Physics in college to admit it, but I was not at all interested in experimental Physics and I was bad at it. Reluctantly, since I had invested a lot of time and energy into it, I dropped the idea of doing Physics major in college.

The previous summer at my university, I did an internship studying cryptography. It was a good experience. I had to learn computer programming language myself to write a program to attach a cipher. I also had to read up on cryptography and number theory, which I knew almost nothing about. Luckily, my supervisor was very patient and pointed out what I should know for the purpose of my internship. I decided that programming would be something I could see myself doing in the future, and decided to major in computer science.

I have always known that I wanted to do science, because I enjoyed the science classes in high school, but not so much the humanities ones. Some of my classmates from FSHS realized that math and science was not for them, and decided to pursue university degrees not related to these fields. I felt quite uncomfortable watching them, as I thought that it might be quite sad to have invested four years studying all the tough classes in math and science, and then do something completely unrelated to it. At the same time, that made me realized that I should be careful when choosing a career path as it was better to change directions than continue in a field I did not like. I was not sure which branch of science I would end up in. They were all quite interesting and useful, so I studied Math, Physics, Chemistry, and Biology until the end of Junior College. I decided in High school that I liked Physics and Chemistry best. I did a research project in Chemistry, then one in Bioengineering, and participated in Chemistry and Physics Olympiad. I thought they were quite fun and a good introduction to research within those fields, but I wasn't sure if I wanted to continue in the fields for the rest of my life.

After high school, the most natural thing was to try to get an internship related to Physics research to see if it was something I would want to do for a career. I knew from my experiences doing research in high school, that research in a field and studying it in high school were two very different things. Unfortunately, I found that I did not enjoy experimental Physics research, nor did I enjoy any of the experimental physics classes in college. I did another internship during the summer between by freshman and sophomore year in high school, this time in cryptography. I had just taken an introductory computer science class, and this internship made use of what I had learnt in math and computer science. I found that I enjoyed what I was doing, and decided to switch to math and computer science (CS) instead. I would most likely do something related to CS in my future career, since these are subjects, which are useful in many technical jobs, and something I enjoy.

FSHS has done a good job in preparing me for science classes in college, though I wish it could have been more emphatic in teaching how to write math proofs, and offering computer-programming classes. I did not know how to do either when I first started college, so it was quite a steep learning curve. However, all FSHS students are used to steep learning curves, so I was prepared for the amount of effort and work needed.

DISCUSSION

The affordances available to these two students were situated and not generic to all students in other Singapore schools. As Grace had mentioned, the school had partial autonomy in deciding what the students learn as opposed to mainstream schools, which follows more closely to the national curriculum. Situated affordances made available by having the science research program in the school, the necessary physical, human, and monetary resources including access to university libraries (due to the school's affiliation), and students' autonomy to decide their research topics and elective subjects. As Grace mentioned, the research facilities were advanced allowing most of the research experiments to be done in-school without having to travel to external research institutes. This gave them the flexibility to continue with their experiments even on non-designated research days. Being a boarding school, students who stayed in the hostels could also continue with their research later into the evenings.

The science research has provided opportunities for affordances to be acknowledged, generated, and engaged through several conduits. For example, affordances were provided by the human resource (mentors) to Grace and Mary as they learned to represent chemical molecules using symbols. This is a technique and language universally understood and used by chemists to communicate ideas about the reactions, reacting species, reaction sites, and reaction conditions. As such, affordances were provided by the introduction of conceptual entities and operations of discipline through the process of scientific discourses.

Affordances were made available to Grace and Mary by virtue of their participation in the social practice of science in a setting, which underscores the important status of science. The fact that science is one of the two core disciplines in the school, most students like Grace and Mary took up science related projects aligned to the school's niche. Grace recognized the availability of platforms such as the annual research congress where students showcased their work and presented their findings like research scientists. The resources including advanced research facilities were affordances, which Grace thought had allowed them to do most of their research in school and at ease. Nonetheless, the affordances existed even if she had not recognized them.

To use the affordance present, students need to be able to recognize its presence. The role of perceiving affordance is that such perception can set up action systems to act, direct attention to appropriate action-guiding information, and so on. Perceiving affordances is more than just perceiving relations. It involves making sense of the information and deliberating on issues in making independent decisions. As Grace noted, there was less handholding in the laboratory than classroom. What Grace and Mary had undergone was similar to that of what scientists do in real science laboratories. They had to make decisions without instructions or adequate information from existing literature as scientific research papers did not always provide all the details.

Affordances do not arise as a consequence of mental operations alone but from the action-related properties of the practice that may or may not be perceived. In the process of carrying out the experiments and making scientific records, they encountered and engaged gestures, facial expressions, and body language that provided information to each actor. The information, in turn, shaped their action, self-perception, knowledge-building, understanding of the practice of science—how theories may be applied and changed through the process of negotiation and gathering empirical data.

Affordances are action-permitting and the action is goal-directed; it entails intention and identification of information and a lawful relation between the information and the control of actions (Michaels, 2003). Mary commented that she had a supervisor who guided her and at the same time, allowed her to figure out things by herself. This afforded her the space and agency in decision-making. Grace talked about learning to be creative and innovative from this experience. She saw her mentor converted a pipette into a tool with spoon-like features. This was, to her, a valuable lesson in showing how one can be creative and innovative in the laboratory and address one's situated needs. As mentioned by Turvey (1992), the affordances are complemented by the effectivities of the actor to bring it to actualization. In this case, the mentor had perceived the possibility of using a pipette as a spoon and had effectively manipulated it to be used as one. Her mentor knew that a pipette was manipulatable through identifying its features that could be changed into a "spoon". In emplacing spoon-like features on the pipette and adapting it to her own needs, she had generated affordances for herself (to get the object out of a narrow neck vessel) and her students who learned how the object may be modified for other uses. The actor who adapts it for use thus subjected the perceived possibility of what a pipette may be used for to interpretations. Thus, science research could expose students to the idea that science and scientific practice is not rigid and fixed but adaptable to suit the situation.

Affordances are multi-dimensional. In doing research, Grace learned to apply concepts she learned in class and changed her perception of science. Drawing upon her knowledge of differences in bond polarities, she understood why various solvents were chosen as eluents in the separation of different organic compounds. Also, she saw how various science disciplines were less segregated than it seemed in the formal curriculum where science was taught as physics, biology, and chemistry. She had also learned from other research group mentors and hence, the learning took place across groups. This reflected the reality in scientific work where scientists and research groups collaborated on projects to support one another rather than work in isolation. This illuminates the interwoven affordances present as mentors in other groups may have relevant knowledge of various projects and may potentially be tapped upon as resources. Grace said that she learned that laboratory was a place for learning and not only for doing science research. This illuminated the nested affordances that different learning settings could offer to people. The university library, which students in this school could access due to its affiliation to the university, was nested within the school space but Grace had not recognized its importance earlier. Instead, she had turned to the Internet, which she eventually found to be limiting. As such, the recognition of affordances required the actors to perceive it; otherwise, its existence would be overlooked. In this case, the perception was aligned to Norman's (1988) idea that it was independent of the students' knowledge of the type of literature that could be found from different resources and experienced from doing literature search. Grace recognized that this experience from doing, listening, and learning had created longer term impact on her life in terms of her choice of career and major in the university. This illustrates that affordances are specified by information and perceived by the actor (Michaels, 2003). In making connections to what she had learned in class, Grace now understood how theoretical concepts could have practical applications. This understanding, she said, had redefined for her the purpose of learning science. Additionally, before her research experience, she learned science by trying to absorb as much information as possible rather than see science as a process of inquiry and that the knowledge is subjected to change. The questions asked during the research provoked her to think more. This was probably why she continued to embark on science projects in the junior college and university.

Interestingly, affordances do not only result in expected outcomes but also incite unexpected outcomes not aligned to the original goals. For example, from her research experience, Grace learned that she did not want to be doing research involving chemical reactions as a career. She was also adverse to the possible politics that could happen in laboratories. The affordance was thus one of action possibility in terms of her career choice and higher education. Similarly to Mary, her earlier exposure to science research made her realize that she disliked practical work, especially in physics. Her exposure to science and research made her rethink her future career and higher degree choices. Later, she found her interest in computer programming which was something she was not taught to do in the school. The unexpected outcomes of providing the science research experience to acquaint students to the practical and discourse of science had inevitably resulted in the students having a clearer idea of their interest and prepare them on what to expect when they do research work in future. This illustrates the sequential nature of affordances as her experience doing science incited her to look for other learning opportunities. Subsequently, she discovered her interest in an area which she had never been exposed to in her 10 years of schooling before college.

CONCLUSION AND IMPLICATIONS

In this chapter, the concept of affordance was applied to unpack the science research experiences of two students who attended a specialized science and mathematics school in Singapore. The findings show that affordances two students had were situated in the school they attended as the resources they had were not available to mainstream schools. The affordances that were available to them had to be perceived, acknowledged, and engaged by them even though they were made available to them through participation in the social practice of science. The affordances were abstract and real in that they arose in mental operations and from action-related properties of the practice of doing science. Finally, the affordances are multi-dimensional; they can be nested in contexts-within-contexts, interwoven, and sequential.

As a final note, let us return to the idea of usefulness and usability—two reasons why HCI communities engaged in the concept of affordance to theorize about the designs of products. The science research experiences were valuable to the students as they gained better understanding of what science was about, better ways to learn science, and about what they enjoyed or disliked doing. The usability—in terms of preparing them for a career in science—however, may be limiting as both students decided that they did not want to do organic chemistry, synthesis work, or to make science research a career. This suggests that while providing science research opportunities to students may provide students with some early exposure to the practices of the discipline, it may not guarantee that students would pursue a career or higher studies in this area. This may be an unexpected outcome of the science research program but it certainly, brings to light that affordances, or perceived possibilities, do not necessarily always lead to expected outcome of invoking more students' interest to become scientists. However, the affordances provided to students through participating in science research may enrich their schooling experience in more ways.

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