Tracing the Origins of Cognitive Apprenticeship:

An intellectual genealogy

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1. Introduction

As part of the Next Generation Science Standards released in 2013, the current science curricula should engage students in the engineering practices of real engineers.¹ This can be seen as a part of the larger movement to create more authentic learning in science classrooms to bolster the interest and achievement of students. As early as 1983, the National Commission of Excellence in Education’s report, *A Nation at Risk*, pushed to involve scientists and working professionals in the educational policy decisions being made to further the advancement of American education.² The educational climate in the post war and Cold War era of the United States can be characterized by a shift towards international competition in the STEM fields.³ Due to the new threat of both nuclear arms and cutting edge space technology, STEM education and national security became intrinsically linked in the discussions of the federal government. The US government enlisted the help of professional communities of scientists to redirect curriculum to produce more and higher quality scientists and engineers. These scientists created lessons, videos, laboratory experiments and worksheets with more attention to the rigor of these exercise using their experiences as practicing professionals.⁴ After the Cold War and into the era of No Child Left Behind, educational policy became more focused on closing the achievement gap.⁵ The educational practice of scaffolding became commonplace as a way to elevate all students. Practices such as

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⁵ For an analysis of the strategies used in closing the achievement gap and data analysis on their effects see Haycock, Kati. "Closing the achievement gap." *Educational leadership* 58, no. 6 (2001): 6-11.
“scaffolding” and “modeling” derived from Allan Collins’ work in cognitive apprenticeship. These practices are centered on the idea of situated learning and authentic practice.

In 1987, Allan Collins published a technical paper outlining a theoretical framework he titled cognitive apprenticeship that dealt with learning in the context of authentic practices, coaching, and modeling. As an educational idea the tenets of cognitive apprenticeship had a long history and changed names many times mostly due to changes in political tides within educational policy. Other researchers have termed similar ideas such as “communities of practice,” and some call these ideas “situated learning.” Regardless of the name given to this idea, it is possible to find evidence of the same principles moving back through the different eras of American education.

Cognitive apprenticeship is a modern theoretical framework that draws many of its tenets from previously conducted research. However, there is little information about the evolution of these ideas and how they contributed to the development of cognitive apprenticeship. The literature surrounding this topic can be classified into two generalized areas. The first category consists of historical literature that traces the intellectual origins of an idea. The second category consists of works that study the different histories relating to the core ideas of cognitive apprenticeship such as modeling, coaching, scaffolding, articulation, reflection and exploration. In the first category are historians like John Rudolph who wrote about the origins and implementation of the “scientific method” in American schools where he traced the stepwise evolution of modern concept in science pedagogy back to its origination with Dewey. Also, in the first category are historians such as Pamela Long who traced the modern concept of “intellectual property” and its evolution from the first

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emergence of the idea starting in the 12th century. William Reese wrote about the origins of progressive education in America by situating the changes in the larger humanitarian movement and examining the social changes that allowed this movement to grow. In the second category are historians like John Rudolph who wrote extensively about the development of both the new science curriculums of the Biological Science Curriculum Study (BSCS) and Physical Science Study Committee (PSSC) curriculums coordinated by the National Science Foundation (NSF) which explicitly focused on science as inquiry.

Sevan Terzian’s research into the role of talent searches and science fairs helps to illuminate the historical aspect of exploration where students were encouraged to conduct their own scientific experiments in an effort to increase the scientific manpower in the United States. Rebecca Lowen examined the evolution of university physics departments from purely academic to grant funded and research driven guided by the needs of industry, which showed changes in ideas relating to exploration and the sources of coaching in higher education laboratories.

Finally, Michael Ackerman wrote about the beginnings of scaffolding through the use of aptitude testing to help teach students of differing abilities. The current literature focuses on different aspects of cognitive apprenticeship but does not ultimately connect the threads into the theoretical framework. By situating my work in the overlap of intellectual origin studies and histories of the different tenets of cognitive apprenticeship, I hope to be able to trace the intellectual origins of cognitive apprenticeship.

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Accomplishing these goals required a multifaceted approach. The first step was to construct a “family tree” of the key voices contributing to the idea of cognitive apprenticeship. Starting with Allan Collins, I used his first paper published on cognitive apprenticeship to find the sources of some of his ideas. I moved backwards in this fashion from collaborator to collaborator to establish a lineage for his theory and what other theories either led to or are related to cognitive apprenticeship. Some of Collins’ initial collaborators included John Seely Brown and Paul Duguid who wrote about the social aspects of information sharing and acquisition. To determine the relevance of a source I analyzed the source for keywords relating to cognitive apprenticeship focusing initially on the words used by Collins to describe his framework such as modeling, coaching, scaffolding, articulation, reflection and exploration. I also assessed author’s professional relationship to Collins to determine how closely the idea is related to Collins’ Framework. I also used the date of the article and also the distribution of the article.

My claim is that Allan Collins’ theoretical framework of cognitive apprenticeship has roots that spread beyond the field of traditional education. Collins drew pedagogical methods from a wide range of academic fields that included psychology, anthropology and computer science. By drawing form these diverse backgrounds Collins’ established a framework with applications beyond his initial proposal of using cognitive apprenticeship primarily for the teaching of reading, writing and mathematics from the 1987 technical paper outlining the framework. The diverse background of Collins’ work can help historians of STEM education see that the importance of authentic practice traces its roots outside of traditional science education but actually has a long history as the de facto educational pedagogy of many indigenous peoples. Modern social constructivists prescribe cognitive apprenticeship as a framework to be used in fields like digital learning without recognizing that cognitive

apprenticeship itself draws some of its core tenets from the early work in computerized learning.

2. Description of Cognitive Apprenticeship and Collins

Cognitive apprenticeship is more than just a set of recommendations for teaching practices or a set of guiding ideas to help teachers plan lessons. It is a theoretical framework that establishes the environments for learning including the content being taught, the pedagogical methods employed, the sequencing of learning activities, and the sociology of learning. The entire premise of Collins’ work revolves around the ideas of authentic practice and situated learning. Authentic practice and situated learning refer to a learning environment that mirrors both the content and context of what is being taught. This stems from a philosophical notion that ideas cannot be learned in the abstract but instead are dependent on the setting and environment they are learned in. For example, an engineering student engaged in authentic practice would learn about the different forces being enacted on materials by building actual structures and not by learning their formulas out of context. The claim is that learners gain not only contextual knowledge but also learn the necessary skills if their learning environment mimics the types of situations they would encounter in practice.

Allan Collins is a cognitive psychologist and a foundational member of the field of learning sciences. His, arguably foundational, work in psychology focused on human semantic memory and cognition when he worked with researchers M.R. Quillian and Elizabeth Loftus to develop the theory of semantic networks.¹⁶ Collins’ work with semantic memory led to more work in the field of artificial intelligence where he used discourse analysis to find and implement the pedagogical methods of human tutors in a digital environment. His cognitive

work led to his educational research as he moved to a situated cognition perspective on knowledge and developed the cognitive apprenticeship framework which is outlined in this paper.

This paper focuses mainly on the historical backgrounds of the six pedagogical methods that Collins defines as the core of Cognitive Apprenticeship: coaching, modeling, scaffolding, reflection, articulation, and exploration. These six pedagogical approaches can be subcategorized into three distinct areas. The first group is comprised of modeling, coaching and scaffolding is what Collins considers the core of cognitive apprenticeship. This first group is characterized by the acquisition of skills, both cognitive and metacognitive through the processes of observation and guided practice. The second group is comprised of reflection and articulation. These elements aim to help students center their observations of problem-solving strategies and to help them in accessing their own problem-solving skills. The final group contains only one pedagogical method, exploration. This group focuses on strategies that help learners establish autonomy not just utilizing expert problem-solving skills but also defining the problem that needs to be solved. In the following sections I will trace the lineage of the pedagogical strategies of cognitive apprenticeship in the fields of psychology, anthropology, and computer science. As classrooms move away from primarily brick and mortar institutions and onto the web,

Collins’ work has found an increasing amount of traction in the field of e-learning. The rising number of virtual laboratory spaces being utilized by educators means that researchers are working to find strategies to makes these activities more effective. Cognitive apprenticeship has also found a home in teacher preparation programs to help preservice teachers transition in their roles from students to teachers through observation and inclusion into the community of practice. Educators in the STEM fields find Collins’ framework to be significant because of its focus on knowledge as well as skills. By using cognitive
apprenticeship science educators are not just preparing their students with the content knowledge to become a successful scientist but also the requisite skills to function as a working scientist. Cognitive apprenticeship blends both formal and informal learning in an effort to provide a comprehensive education.

3. Psychology

In 1958, the behavioral psychologist B.F. Skinner published an article titled “Reinforcement Today” in the journal American Psychologist which was also cited by Manzo. In this article, Skinner described his work with teaching a pigeon to bowl on a miniature wooden bowling alley. He was sure to mention that the work in training the pigeon was not groundbreaking, as similar work had been done by himself and other researchers. He made note that behaviorism had not found the academic presence he thought it deserved. He felt that researchers were more interested in maintaining behaviors and not concerned enough with the creation of desired behaviors. Skinner used classroom behaviors as an example of a scenario where the methods of behaviorism could be employed to improve student engagement and behavior though the use of positive reinforcement. In Skinner’s paper, he specifically used the example of changing the behavior of a classroom at the time of dismissal but did note that these principles could be applied to any behavior in a classroom, especially learning. Manzo summarized his use of Skinner’s behaviorism as “The opportunity to exchange information and get corrective feedback.” Skinner’s use of positive reinforcement with the goal of increasing a desired behavior can be seen as a rudimentary approach to Collins’ pedagogical style of coaching. Both methods centered on the use of teacher feedback towards a student to improve the actions of that student whether in regard to

behavior with the case of Skinner or learning processes in the case of Collins. The majority of
the psychological foundations found in Collins’ framework are based in cognitive psychology
not behaviorism as cited with Manzo’s link to Skinner, however, I think that it is important to
show that cognitive apprenticeship was not necessarily tethered to a rigid academic ideology
but was goal oriented and worked to find ideas and strategies which helped to resolve an
issue not further one specific field’s academic agenda.

Collins’ work finds an academic link to Albert Bandura, a cognitive psychologist and
one of the most cited psychologists of all time. The citation was a book chapter authored by
Bandura in 1964\textsuperscript{19} which itself was based on a paper written for the Nebraska Symposium on
Motivation in 1962\textsuperscript{20}. Bandura’s work was a criticism of behaviorist theories and their inability
to replicate learning in natural environments. Bandura believed that imitative behavior was
the key to creating learning processes in natural settings through the use of social interaction.
Bandura’s references to imitative learning can be seen in the pedagogical method of
modeling in Collins’ framework, as Bandura’s participants were able to demonstrate increased
learning processes by imitating an expert model for a given task.

In 1968, Anthony Manzo wrote his dissertation titled “Improving Reading
Comprehension through Reciprocal Questioning\textsuperscript{21}.” Manzo’s work cited researchers Bandura
and Skinner In his research Manzo implemented a strategy called reciprocal questioning in which
the students and teachers read a text selection. The student then asked the teacher as many
questions as they can think of about the short selection. The teacher then in turn asked the
student to answer questions without looking at the text. If the student was not able to answer
the question the teacher asked either prompting questions or directed the student to consult
specific areas of the text. This process continued for each sentence in a text selection with the

\textsuperscript{19} Bandura, Albert “Social learning through imitation” \textit{Educational Psychology} by E.b. Page (1964): 274-285
\textsuperscript{20} Bandura, Albert. “Social learning through imitation.” (1962).
\textsuperscript{21} Manzo, A.V. (1968) Improving Reading Comprehension Through Reciprocal Questioning (Doctoral
dissertation). Retrieved from \url{http://search.proquest.com/docview/30237}
student being encouraged to imitate the questioning style of the teacher. The level of questioning used by the teacher also increased as the group moved through the text building off the previous questions. The process of reciprocal questioning outlined by Manzo illustrated all three aspects of the first group of Collins’ cognitive apprenticeship methods two decades later. By having the teacher ask the student questions, the student has a model on which they can base their own questioning, an example of modeling. Coaching can be seen in Manzo’s work through the teacher’s feedback during the students’ round of questioning the teacher. By building the subsequent rounds of questioning off of the vocabulary learned in the previous rounds, reciprocal questioning comprised what Collins would later refer to as scaffolding.

Diving deeper into the realm of cognitive psychology, Flower and Hayes wrote about the rhetorical problem solving in writing in 1980. In their study Flower and Hayes collected data from two different groups of writers. The first was a novice group of college students who had sought help at the college writing center and a group of expert writers and teachers of writing who had attended a year-long writing fellowship. The two groups were assigned the task of writing a response to the prompt “write about your job for the readers of Seventeen magazine, 13-14 year-old girls”. As the participants from the two groups wrote, they were instructed to audibly voice every thought that went through their head as they were composing their response. The protocols created by combining the transcript of the think-aloud and the writing were analyzed for goals created by the participants. Flowers and Hayes sorted these goals into one of four categories: audience, self, text, and meaning. It was found that the expert writers not only had more goals in their protocols but they also had more of their goals directed towards the audience. The outcome of this study was used to show that

expert writers were able to create a more cohesive product by voicing and then answering a larger number and range of problems. This study also implied that novice writers struggled with their writing more than experts because they were not reflecting on the problem to see the different problems that needed to be solved. In their work it is possible to see the foundations for some of the pedagogical methods in cognitive apprenticeship. Flower and Hayes explored the ability of writers to express the problem they were trying to solve which is very similar to Collins’ method of articulation. They also concluded that students who were poor writers most often did not develop their argument or their knowledge of the problem effectively before writing which would mean the students were lacking what Collins would refer to as reflection.

Collins drew from the work of Marlene Scardamalia, Carl Bereiter, and Rosanne Steinbach who studied the reflective process in writing\textsuperscript{24}. Scardamalia et al. cited the work of Linda Flower and John Hayes in their work with middle school students focused on the use of modeling and think-alouds to teaching the process of reflection during writing exercises. In 1984, Scardamalia et al., used modeling frequently in the study using both the instructor as the model as well as students modeling for other students. In the planning stages of the writing process, instructors stood in front of the group and recited their thoughts about how they were planning their essays. If they became stuck during the modeling phase of the experiment, the “experts” in the student groups had access to cue cards that were comprised of different categories of sentence starters written to mimic the language of an instructor. An example of a cue card would be a sentence starter such as: “An important thought that I haven’t considered yet is…”\textsuperscript{25} After the public demonstration of the thought process by an expert, the students would spend time individually planning their own essays using the


strategies they had observed in the earlier part of the lesson. Collins drew directly from their approach to modeling citing it as an example of effective modeling in the theoretical framework.

Much of the work from which Collins’ drew inspiration has a background in the field of psychology, specifically in field of cognitive psychology. In his paper Collins, cited the work of Annemarie Palincsar and Ann Brown from 1984 which is inspired by the work of Anthony Manzo on reciprocal learning in 1968. Palincar and Brown studied the reading comprehension skills of seventh grade students and found that the method of reciprocal teaching showed statistical improvement over the standard teaching practice. In their study Palinscar and Brown implemented their strategy of reciprocal teaching in an experimental group of six students. These students worked with a teacher to read a passage and then alternated acting as the dialogue leader. As a part of their role as dialogue leader the students would have to ask questions “that a teacher might ask” and assume the role of the expert in the group. Initially, the students struggled to identify as the leader in the dialogue and the teachers acted like guides by using different prompting questions and offering sentence/topic starters to the struggling students. As the intervention progressed, the students’ role as dialogue leader became more pronounced and they began to paraphrase and summarize information without scaffolding or prompting. This pedagogical method was a blend of coaching and modeling where the adult acted as a model for the readers as well as guiding them through the complex sections of the text.

By examining the roots in psychology from which Collins draws his pedagogical methods it is possible to see a general pattern emerge. The large majority of psychological studies that are connected to Collins fall into the first grouping of his pedagogical strategies revolving around the acquisition of skills. When drawing from the field of psychology

Collins tends to focus on work which studies the use of experts to transfer their knowledge to a group of novices. This could be done through a teacher modeling their thought process for their students, scaffolding like a student being challenged to read progressively harder texts, or coaching in the case of a teacher giving positive reinforcement to a class. The outlier from this grouping would be the work of Flower and Hayes which are focused on the internalization of the skills placing their work in the second grouping of Collins’ framework. The academic genealogy of Collins theoretical framework of cognitive apprenticeship can be shown to have a strong link to the field of cognitive psychology.

4. Anthropology

The earliest purely anthropological source linked to Collins’ work in cognitive apprenticeship comes from British anthologist Raymond Firth\(^\text{27}\) who can be connected to Collins through Jean Lave. Firth spent a year living among the native Polynesians in the mid-1930s. During his time living among the people he was described the educational system in which the tribal children were raised. In contrast to the traditional European style of formalized schooling the native Polynesians were educated in a much less formalized manner with focus of their instruction being on practical skills for dealing with actual situations likely to arise in daily life. In Tikopia a child was most likely educated by a close family member usually one of their uncles. If the uncle was skilled in a particular trade or field then the boy would become a part of that field as well. The uncle acted like a master for the boy to model his behavior after. In the example of an uncle who was a fisherman the boy would travel with the uncle and learn how to find secret fishing spots and learn navigational techniques for traveling the waters. All of this knowledge was passed down through observation and feedback from the

\(^{27}\) Firth, Raymond. *We the Tikopia. A sociological study of kinship in primitive Polynesia.* Routledge, 2013.
expert. This shows examples of Collins’ methods of both modeling and coaching. The uncle acts as both the model and the coach showing the boy how to complete tasks and also giving advice and corrections on the boy’s own attempts at the task.

Collins’ framework also find connections to traditional anthropology by way of anthropologist Meyers Fortes, found through the link to Jean Lave, who published a study of the Tallensi African tribesman in Ghana in 1938. In his section about the educational practices of the Tallensi, Fortes describes a system of communal education lacking a specific structure where the children acquire the skills of the community based on their level of physical and mental development and not on their numerical age. The system Fortes describes bears a striking resemblance to the pedagogical strategy of scaffolding described in Collins’ framework. The level of guidance and the requisite skills of the Tallensi are adapted to the level which best fits at their stage of development. As described by Collins scaffolding can be defined as an expert tailoring the lesson to fit the developmental needs of the learner. In this way the Tallensi allow the children to begin to take on new tasks and responsibilities based on the skills and motivations of the learners. Infants are allowed to crawl as they please and are not helped to walk until they begin to walk on their own at which time some of the children will help steady them until they are able to balance more readily on their own. This individual progression of skills can be seen across development of the Tallensi children not just in their physical development but also the development of skills such as archery, farming, and cooking. As the children grow older they are given more duties such as tending the livestock, but with these new responsibilities also come new opportunities. In one example a child in charge of his father’s livestock goes on strike in order to force his father to buy him a loincloth for the local celebration and the father relents. This also displays the basic principles of scaffolding by allowing the child more and more autonomy as a farmer to the point where his labor transitions from a chore to

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a prototypical job. The education of the Tallensi children also demonstrates concepts relating to Collins’ modeling. When the children began to learn a new skill there was no formalized manner for them to do so. Instead they would begin to interact with an adult who was participating in the task. The children would observe the adult and begin to mimic what they observed as stated by Fortes’. “It works through the situation, which is a bit of the social reality shared by adult and child alike.”

Douglass Price-Williams, William Gordon, and Manuel Ramirez who studied the learning styles of Mexican potters. The group conducted an experiment to test whether the skills taught to young boys for use in pottery making would translate into an early conceptual understanding of volume, weight, and conservation of mass. They did this by administering a Piagetian test for conservation to two groups of children, one group who came from a family if potters and a second group whose family did not have a background in pottery. A significantly higher number of potters’ children showed conservation skills compared to children from homes that did not work as potters. Price-Williams et al., concluded that “manipulation may be a prior and necessary prerequisite in the attainment of conservation”. The fact that the children of potters were able to first learn about conservation with simple examples such as pottery clay demonstrates a primitive example of, what Collins would term, scaffolding where the children gain knowledge about more difficult topics by first understanding simpler concepts such as molding pots versus conservation of matter. An argument could also be made that the leap from pottery to conservation of matter is similar to what Collins refers to as exploration. This leap demonstrates exploration in that the examiners are “fading the problem-setting” by moving away from the familiar structures of

pottery and towards more complex ideas like physics.

The work of Douglass Price-Williams, William Gordon, and Manuel Ramirez and their study of Mexican potters inspired a paper by Patricia Greenfield in 1977 which studied the work of weavers in southern Mexico\footnote{Greenfield, Patricia Marks, and C. P. Childs. "Weaving, color terms and pattern representation: Cultural influences and cognitive development among the Zinacantecos of Southern Mexico." \textit{Teramerica Journal of Psychology} 11 (1977): 23-48.}. Greenfield’s work examined the generalizability of pattern weaving skills to more general pattern continuation skills by having a group of children with diverse ages and levels of schooling create patterns by placing multi-colored sticks in a wooden frame. The children were asked to recreate familiar and unfamiliar patterns using the sticks as well as continue a new pattern that had been started by the instructor. She found evidence that the development of pattern representation skills fostered the development of more universal skills. The system in which the weavers learn their skills is an example of Collins’ pedagogical method of scaffolding. In the Zinaconteco tribes the women teach the children to weave by first boiling threads and dyeing wool, they then graduate to weaving followed by warp-winding and finally spinning these steps are seen by the women as a progression from the easiest skills to the most difficult.

Douglass Price-Williams, William Gordon, and Manuel Ramirez and their study their study of Mexican potters was also cited by anthropologist Jean Lave. Collins’ closest direct link to anthropology comes through the work of Jean Lave and his study of tailors in West Africa\footnote{Lave, Jean. "Cognitive Consequences Of Traditional Apprenticeship Training In West Africa." Anthropology & Education Quarterly 8, no. 3 (1977): 177-180.}. Lave was not a pure anthropologist but crafted his work in the hybrid field of psychological anthropology. His work studies the cultural and societal influences on the transfer or learning. In the late 1970s Lave conducted an ethnographic study as well as a more formal experiment exploring the link between arithmetic skills and the medieval apprenticeship learning system utilized by tailors in West Africa. Lave wanted to challenge the notion that formalized schooling played a unique role in learning and instead prove that a less formal
system such as apprenticeship could lead to “acquisition of general cognitive skills, although skill acquisition might have different sequence and rate characteristics than skill acquisition in school”\textsuperscript{34}. In his study, Lave constructed a set of 32 hypothetical tailoring problems requiring elementary knowledge of arithmetic to solve. These problems were administered to a group of tailors which included masters, apprentices and a wide range of schooling histories. The tailors were sorted into groups based on the amount of formal schooling they had received. In analyzing the data Lave found that while formal schooling benefited students in solving unfamiliar problems the apprenticeship model was beneficial in the development of general problem-solving skills. Lave concluded that the two types of schooling did not work against each other and that the best results were found when the two types of schooling were used together. Through these studies Lave was able to establish that training through traditional apprenticeships aided in the development of general problem-solving skills thus establishing a theoretical basis for the guided learning model advocated in Collins framework.

The unifying theme of the anthropologically based sources that Collins draws from is the idea of individualized guided learning focused on the acquisition of usable skills. In the examples drawn from the informal educational practices, the pedagogical methods of modeling, scaffolding and coaching become apparent. In the tribal societies like the Tallensi and the Tikopia, the children learn skills through the observation of skilled adults which Collins would define as modeling. The Mexican crafters as well as the Tallensi scaffold their instruction of the children, starting them on easier patterns and skills and advancing them as they master the easier skills. The oldest examples that can be linked to Collins are merely observations about the educational practices of tribal groups. These authors catalog the actions of these tribal groups and often note the stark contrast when compared to traditional western education, specifically formalized schooling. As we move closer in time to Collins’

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\textsuperscript{34} Lave, Jean. "Cognitive Consequences Of Traditional Apprenticeship Training In West Africa." Anthropology & Education Quarterly 8, no. 3 (1977): 178
work we see these informal educational practices transition from a curiosity written in an anthropologist’s account of preliterate tribes to valued system of education that researchers seek to gain understanding from in order to potentially improve the educational practices of their own cultures. Through these examples it is possible to track the evolution of scaffolding and modeling from Collins’ modern framework back to the traditional informal educational practices observed in tribal members.

5. Computer Programming

In 1976, Papert conducted a case study on the interactions of a child with a graphical computer program.\textsuperscript{35} This study focused on finding the best strategies to use when engaging a student’s learning through a computer. Papert’s group at MIT AI-LOGO lab studied the interactions between a second-grade girl and a computerized talking turtle. The girl used computer commands to direct the turtle to draw different pictures. Papert described his interactions with the girl and the different approaches he used to direct her towards completing the task. The dialogic approach which Papert described is very similar to what Collins would call coaching. The instructor was providing specific feedback to a student to aid the student in learning the process. An earlier internal memo of Papert’s talks about the goals of his research group at MIT. In this document Papert boldly claims that their main goal for educational technology was to “give children a mathematical experience more like an engineer’s than like a bookkeeper’s.\textsuperscript{36} In this memo Papert outlined the importance of a “purposeful constructive attitude” which means that students should only give up on a problem when it is unfixable not merely because a part of the process when wrong. This is a


\textsuperscript{36} Papert, Seymour, Uses of Technology to Enhance Education, MIT AI Lab. LOGO Memo 8, June 1973. Retrieved from: https://dspace.mit.edu/handle/1721.1/6213#files-area
concrete example of what Collins refers to as reflection. The student must understand their own problem-solving system in order to determine if the problem is unfixable or if they only made a procedural error.

Collins’ conception of cognitive apprenticeship originated beyond the traditional background of psychology, human development and educational theory when drawing inspiration for cognitive apprenticeship through his use of ideas from the field of computer programming and digital computing. The first link that can be drawn directly between cognitive apprenticeship and computing is through the work of Richard Burton, John Brown, and Gerhard Fischer who developed the idea of Increasingly Complex Microworlds (ICM) initially in 1978 but expanded upon in 1984. Burton et al. cited multiple works of Seymour Papert who also wrote specifically about microworlds but also the effect of technology on student learning as well as an earlier work begun by Gerhard Fischer in his 1977 dissertation. Burton et al. wrote about the use of skiing as a model for scaffolding instruction through the creation of microworlds and manipulations of the environment to aid in learning a skill. The initial metaphor used to explain how to increase the complexity of the microworlds was the instruction of downhill skiing. They described how a skiing instructor could use the environment to aid the student in learning to ski such as ending the lesson on an uphill section of course so that stopping would be easier because it would naturally slow the skier down without input. Burton et al., also wrote about fostering exploration in learners. The example used in regard to skiing was that the development of safety bindings “the catastrophic consequences of wrong behavior” allowed for learners to take “an active approach to mastering” a new skill. They focused on how this related to the use of the

UNDO button in a computerized learning environment to reduce the risk involved in making errors but the principle is easily generalized to any learned task. The paper also focused on the importance of coaching in the acquisition of a new skill. In the skiing metaphor a coach helps students learn where their weight is so that they can contextualize what it means to put their weight forward. The work of Burton et al., touches on three of Collins’ pedagogical methods: coaching, scaffolding and exploration. The work was focused specifically on the instruction of students in a computerized environment but the learning in general. principles advocated are easily transferable to the field of learning in general.

As part of his 1977 dissertation, Fischer’s work centered upon the idea of cognitive efficiency in regard to the understanding and writing of programs. Fischer was concerned with the development of microworlds and the setting of top-level goals as a way to facilitate the change in prospective from computational efficiency to cognitive efficiency. By creating a series of increasingly complex learning environments, Fischer scaffolded the students’ learning by planning a system that would decrease the assistance from a simple goal up to the top-level goal. This is a clear representation of scaffolding in that a student is given the support structures needed to complete simpler tasks and these supports are slowly removed as the student progresses towards the goal, in Fischer’s this is done through the manipulation of the environment or “microworld”. This work is a very early look into the foundations of human-computer interaction.

Collins also links to computerized learning through two works of John Seely Brown in 1985. The first is a paper written about the shifting paradigm for the use of computers in education. In this paper Brown argued that for computers to be an effective mode of instruction they must not only focus on teaching a process but “record, represent and

cognition: Its development in social context 1984): 143
communicate that underlying process. Also, in 1985, Brown published an article that discussed many of the possible impacts of the increased use of computer technology in classrooms. A big portion of both articles centered on the goal of not only having computers mirror the process to the students but more importantly have the students reflect on the processes of their learning. The use of a computer to communicate the process of a student’s learning back to that student is what Collins refers to as reflection in his framework. By being able to see their learning process through the computer, students are able to determine the “features of expert and student performance” which is a key component to reflective practice.

From the work done in early educational technology and computer programming, the common themes that emerge regarding pedagogy seem to be centered on the notions of scaffolding, coaching and also reflection. Burton et al. describe the use of feedback from a computer as a form of coaching as well as the tailoring of digital environments as a form of scaffolding. Both Brown and Papert draw from the idea of reflective practice as an important part of skill acquisition. They both focus on how computers can provide the necessary information to students in order for that student to recognize their own internal process. Some of Collins’ pedagogical practices prescribed in cognitive apprenticeship can trace their origins to some of the early work being done in educational technology and the emerging field of computer programing.

6. Conclusion

The work of Allan Collins on the theoretical framework of cognitive apprenticeship can be shown to draw from a diverse background of academic traditions. Unsurprisingly, Collins drew heavily from the work of other cognitive psychologists due to cognitive apprenticeships strong alignment to problem solving, critical thinking and creativity which are the core principles of cognitive psychology. These psychologists could ultimately trace their academic lineage to the work of Jean Piaget. What is actually surprising is to find that Collins also can trace the lineage of cognitive apprenticeship to two fields that exists outside of the field of psychology. It was unexpected to find cognitive psychologists that cited work of anthropologists and computer scientists, usually cognitive psychology is a field that is cited by other fields to justify the methods being used to instruct in a specific manner. The history of Collins’ work shows that the opposite relation occurs in cognitive apprenticeship where the pedagogical methods are co-opted from practices already occurring and reframing them in the field of cognitive psychology.

Some of Collins’ fundamental ideas about cognitive apprenticeship came from the field of anthropology. By working in the lineage of Raymond Firth who posited that socialization practices of tribal groups were forms of education, Collins allowed the framework to free itself from the restrictions of traditional formalized schooling and draw from a much wider range of pedagogical techniques. While ideas like scaffolding and modeling can be seen in cognitive psychology, they were also uniquely presented in the medieval apprenticeship model people like Jean Lave and Patricia Greenfield.

Moving even further way from the humanities, Collins used the work of early computer scientists to draw ideas for his pedagogical methods. The early work by Seymour Papert at MIT showed how the cognitive processes of learners were being modeled and expanded through the use of computers. These early experiments into educational technology gave Collins a background into the pedagogical process of reflection and
articulation.

By sketching out the academic lineage of Allan Collins in the three fields of psychology, anthropology and computer science it is possible to show how the evolution of ideas from different academic fields can coalesce to create a novel approach to teaching mathematics, reading and writing. It is this diverse background that has allowed cognitive apprenticeship to find footholds in educational practices outside of those three core topics.