The Catch-A-Wave Theory of Adaptability: Core Competencies for Developing Gifted Behaviors in the Second Machine Age of Technology

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Abstract

In this article, I describe a series of Five Core Competencies that gifted education specialists should consider integrating into their teaching to respond to the many changes that are taking place in technology, work, and career preparation. Although the focus of this theory is on high- level jobs usually pursued by college graduates and advanced degree students, this work also has relevance for the general-education community because future employment at all levels will require various degrees of proficiency in the Core Competencies discussed below. Students who will pursue college degrees and professional level jobs will need to attain advanced levels of these skills, have the opportunity to explore a wide range of skills, and be able to learn them more rapidly. Students should be placed in learning situations that require the adaptability that is the theme of this article so that they will learn to apply the skills in ways that will lead to success in job-transformational situations. Leadership and advanced-level positions require high levels of both performance and flexibility in the competencies that will be discussed below._The Catch-A-Wave Theory of Adaptability will be introduced with the presentation of background information and a rationale for the theory. The theory itself along with the five Core Competencies included in the theory will follow and then be supplemented with a section that provides strategies and resources for developing those competencies.

It is not the strongest that survives, nor the most intelligent.
It is the one that is most adaptable to change.
Those that have learned to collaborate and improve will prevail.

Charles Darwin
(Author of Origin of Species in the Struggle for Life (1859))

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Part I. Background and underlying rationale

The job market in industrialized countries around the world is changing, with profound implications for instruction in our general-education classrooms and in programs designed to develop gifted behaviors and high levels of talents in our most advanced students. The Organization for Economic Cooperation and Development published a recent study (OECD, 2019) concluding that today's educators are lagging in preparing students for tomorrow's jobs. The 41-nation study found that students' career aspirations do not reflect the dramatic technological and social changes transforming the workplace. In fact, teenagers' "dream jobs" today are nearly identical to those in 2000. Many of these jobs, however, are at risk of being eliminated or dramatically transformed, placing many individuals at a disadvantage in the rapidly evolving job market and shifting economy. For example, according to a recent survey of economists, business and industry leaders, and human resource specialists, 47% of U. S. jobs at all levels are at risk for elimination in the next two decades (Singapore Ministry of Education, 2018). Further, the report pointed out that only 40% of employers believe that new college graduates are adequately prepared for the future workforce, as they have not learned advanced technology skills and the so called "soft skills" necessary for jobs in the future.

In a comprehensive Rand Report (Zaber et al., 2019) describe employers' difficulty in finding employees with the skills necessary for the 21st century work force. They conclude that a majority of today's curricula (including college and university level courses) are almost totally inadequate for meeting the needs of the rapidly changing job market. They further emphasized that the term "workforce preparation" doesn't apply only to routine job preparation, but also includes the education of persons for the highest-level positions in all career categories and professions.

The purpose of this article is to address a mainly ignored new challenge that will have an important impact on gifted education programs, general education, and college and university curricula around the world. The Industrial Revolution created the world's first machine age and the advent of computers resulted in what is now referred to as the First Information Age. Artificial Intelligence (AI), the ability of computer systems to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages, has now ushered in what is being called The Second Machine Age (Brynjolfsson & McAffee, 2016).

The rationale for the viewpoint offered here is compelling. The Industrial Revolution, and even the First Machine Age, influenced occupations that were mostly routine and carried out by people who possessed either physical strength or the easily taught skills needed to perform them. The types of college-dependent occupations and careers to which many high ability students aspire (doctors, lawyers, architects, engineers, writers, etc.) were thought to be "safe" from being taken over by machines. Brynjolfsson and McAffee (2016) and Frey (2019) provide examples of how AI has now made dramatic changes even in the most advanced level professions. For example, in the legal profession, a new software program can analyze an infinite number of court cases on a given issue, tease out precedents, formulate arguments, and draft briefs at a pace no human could ever hope to match (Levy & Murnane, 2004). In the field of medicine and health care, psychotherapists are providing telehealth services, and surgical robots that can be controlled from far-away places are now being used to treat a variety of conditions (Autor, 2010). Their use has resulted in less pain and infection, faster recovery periods, and a reduction in scars. Furthermore, new tele-ultrasound systems in radiology at major medical facilities enable hand-held devices to capture and transmit real-time medical diagnosis and treatment information that will reduce the need for local facilities and technicians (Rimm, 2011). Artificial Intelligence applications to creative writing and journalism now allow sports writers, for example, to enter a series of facts about a given game or event into Google's Watson Authoring Program and receive a fairly accurate completed first draft of an article for the writer (IBM Watson, n.d.). The advent of AI has even resulted in people working in the creative design of technology to face new challenges.

Computer Vision Software (Computer Vision, n. d.), for example, is a discipline within artificial intelligence and an application that allows a computer to see and understand what it is seeing. This application allows designers to generate HTML code directly from a hand-drawn image. These recent and exciting advances in technology should provide a_wake-up call and a challenge to rethink both general and gifted education in ways_that enable students to be more mentally agile and adaptable to the ongoing and inevitable future developments in technology.

Wireless technology has revolutionized the world, and now even the most remote areas on earth have access to resources that affect their economy, education, health care, communication, and social and cultural contexts. These technologies are already enabling people around the globe to access resources with the potential to create a brighter future in even the remote corners of the earth. A major mission of education at all levels, therefore, should be to equip young people with the Learning-How-To-Learn Skills as described in the Core Competencies in Part III of this paper. Teachers, administrators, and policy makers who fail to learn these skills themselves and create opportunities for students to learn how to gain advanced skills, are placing the future relevance of our educational institutions at all levels in jeopardy.

Although nearly two decades have elapsed since the turn of the 21st Century, the American approach to education, training, and workforce development still largely operates on a 20th century model. Workforce preparation, a linear pipeline from K–12 education to possible college and career options, is similar to what it was several decades ago – high school, college, in some cases graduate or professional school, and then on to a job. Labor-market policies designed for the Industrial Age prevail, and the information that flows between members of the current and future workforce, education and training institutions, and employers have not kept pace with the revolutionary changes taking place in society.

Recognizing the value of interdisciplinary collaboration and systems thinking, RAND Corporation researchers (Zaber et al., 2019) conducted a study to develop a systems-level, unrestricted brainstorming approach to conceptualizing and visualizing a 21st-century U.S. workforce development and employment system. This report is the first step in moving the United States to a system that accounts for workers' needs for lifelong learning, employers' continuously changing workforce requirements, rapid and often disruptive changes in technology, and the ever-evolving nature of work. These changing career conditions should be of interest to educators, business leaders, policymakers, researchers, and other stakeholders who are engaged in issues relating to workforce preparation, career education, and any of the new certificate programs being developed for training that relates to the future of work. The following theory provides a framework for educators in gifted and talented programs to help their students develop these skills.

In a recent report published by the Organization for Economic Cooperation (OECD) and Development entitled Schools of the Future (OCED, 2019 the authors recommend the following eight high-quality learning experiences to prepare students for what they call the Fourth Industrial Revolution:

1. Global citizenship skills: Include content that focuses on building awareness about the wider world, sustainability, and playing an active role in the global community.
2. Innovation and creativity skills: Include content that fosters skills required for innovation, including complex problem-solving, analytical thinking, creativity and systems analysis.
3. Technology skills: Include content that is based on developing digital skills, including programming, digital responsibility, and the use of technology.
4. Interpersonal skills: Include content that focuses on emotional intelligence, including empathy, cooperation, negotiation, leadership, and social awareness.
5. Personalized and self-paced learning: Move from a system where learning is standardized, to one based on the diverse individual needs of each learner, and flexible enough to enable each learner to progress at their own pace.
6. Accessible and inclusive learning: Move from a system where learning is confined to those with access to school buildings to one in which everyone has access to learning and is therefore inclusive.
7. Problem-based and collaborative learning: Move from process-based to project- and problem-based content delivery, requiring peer collaboration and more closely mirroring the future of work.
8. Lifelong and student-driven learning: Move from a system where learning and skill acquisition decrease over one's lifespan to one where everyone continuously improves on existing skills and acquires new ones based on their individual needs. (pp. 7–8).

Although it is difficult to make predictions about good education for the future, the recent worldwide COVID-19 pandemic might actually give us a hint on how the creative use of technology has shown its usefulness and practicality. From preschool to graduate school, online learning experiences were delivered in different ways from traditional schooling and a good deal of the business of the world; in addition, social interactions took place through a variety of on-line web -conferencing programs. But even before this unintended "field test" of alternative resources for the delivery of learning, several vehicles for different learning systems began to make their way into education and the workplace.

Part II. The Catch-A-Wave Theory of Adaptability

The Catch-A-Wave Theory of Adaptability provides a possible foundation for teaching and learning based on emerging technologies. It enumerates an expanded range of competencies required to meet the changing skill requirements for new and evolving careers. Adaptability in the Catch-A-

Wave Theory is the ability to adjust to any given learning or working situation at any given time. Theories are nothing more than systems or sets of ideas intended to explain something, provide a rationale for practices advocated by the theory, and generate research based on those practices. The true value of any theory ultimately rests on its implementation in practical situations; it is hoped that this theory will generate other applications for interested researchers to produce findings that shed light on the value of these ideas. Sternberg (2019), for example, discussed how humans are unique in their high ability to adapt to environments by selecting environments and by making changes that suit their needs. This theory focuses on five sets of Core Competencies specific to adaptability within the skilled job market, along with and the academic and practical resources necessary to inform and guide teachers and students in learning these competencies.

The motivation for the development of this theory has been discussed above. The Catch-A-Wave Theory of Adaptability was designed to address the concerns raised by the studies mentioned above and describes strategies for developing Second Machine Age Core Competencies in K–12 schools and higher education. The name of the theory is a metaphor from the sport of surfing. Catching a wave and riding it well is analogous to the first step in surfing (see Figure 1). But when the wave runs its course or the surfer crashes in a "wipe out," it becomes necessary to paddle back into the surf and catch a new wave.

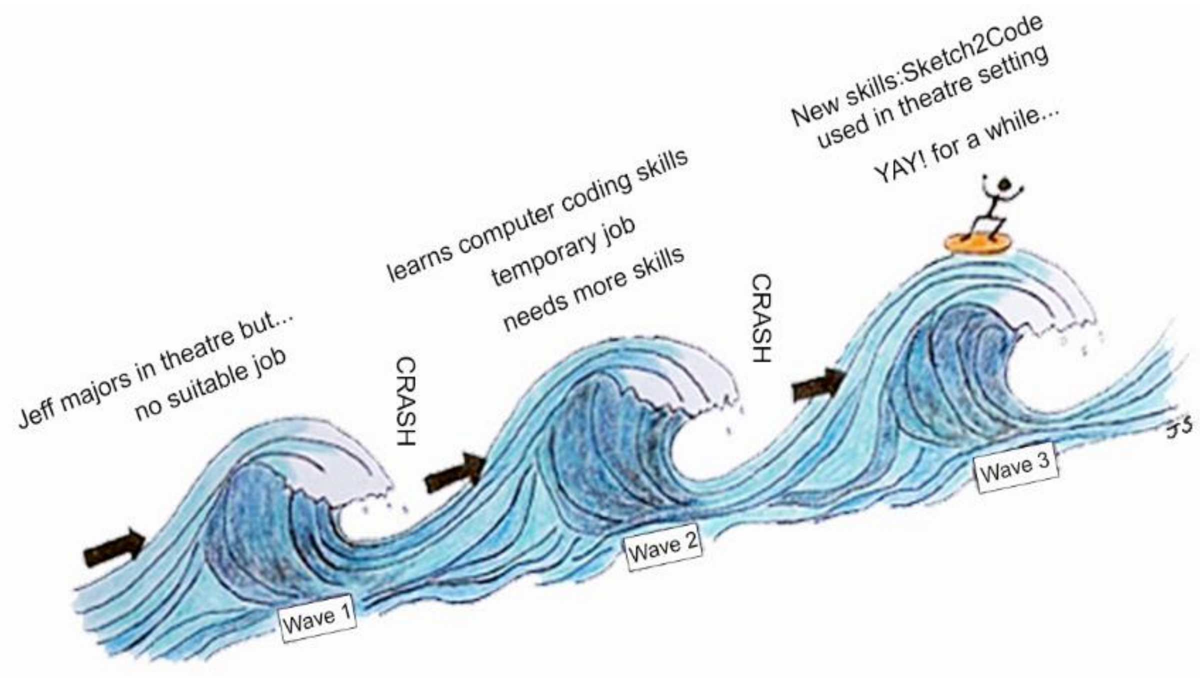

Figure 1: Figural representation of the Catch-A-Wave Theory of Adaptability.

The theory can be described quite simply: learners must not only acquire knowledge and skills, they must also learn how to acquire new knowledge and skills, continuously and independently, and to flexibly adjust their goals flexibly as opportunities arise and falter. The Catch-A-Wave Theory of Adaptability rests on an important distinction between two sources for the acquisition of knowledge and skills. It is generally agreed that a strong knowledge background in basic concepts within a given field of interest and study, research methods in that field, and application options and opportunities in that field are necessary for understanding and making contributions to a field (Renzulli, 1982; 2016). The old cliché, "You can't be analytic or creative with an empty head," emphasizes this point. The first source of knowledge, "To-Be-Presented" knowledge, is that which drives traditional teaching practices, textbooks, and standardized curriculum; and these approaches have certainly demonstrated their value in preparing young people with basic knowledge for advancement in both schooling and the job market. But today's technology-driven world, with its instant access to information, has made another kind of information acquisition readily accessible for learning and problem solving.

This second approach to the acquisition of knowledge focuses on what is immediately relevant to a given challenge or project upon which one is working. This type of information can be labeled "Just-In-Time" (JIT) knowledge (as distinct from To-Be-Presented knowledge), and although determining the relevance of found JIT knowledge is dependent on an understanding of the basics, the ability to determine what you need to know and where to find it are necessary skills for developing the Core Competencies discussed below. Thus, learning-how-to-learn skills for acquiring JIT knowledge might be the most important basic skill needed in developing adaptability necessary for 21st Century learners at all levels. These skills are exactly what researchers and innovative practicing professionals have employed for years. Unfortunately, many, if not most schools (including colleges and universities), continue to place major focus on acquisition of To-Be-Presented knowledge using didactic and prescriptive approaches to instruction (Brynjolfsson & McAffee, 2016; Frey, 2019).

The underlying idea of the Catch-A-Wave Theory of Adaptability is perhaps best understood through an example. Jeff, a college graduate who majored in theater, found that opportunities for work in this area were few and far between, even for a graduate from one of America's best fine arts universities. In other words, he crashed on his first wave and needed to catch another wave to continue to advance in his career. He decided to take a course in computer coding and quickly obtained a position that employed his new technological skills in the entertainment sector. The position didn't last long because of the need for more sophisticated technology, so he had to swim out again and catch another wave. This wave required advanced training in a program called Sketch2Code, which uses artificial intelligence to convert hand-written drawings into working HTML prototypes. Designers share ideas through the Internet on a whiteboard, and each person's contributions and changes are shown instantly in their browser. Armed with these advanced new skills, Jeff immediately landed a new job. In other words, when the first wave he was riding crashed, he "swam out" by learning new skills and then caught a new wave so he could continue to be productive in his field. He will undoubtedly need to continue this process as new changes in technology continue to emerge at a rapidly growing pace. Jeff explained how he manages his constant upskilling as follows, "For example, if I wanted to learn how to integrate remote data into a software application, I would try to create a small tool that fetched the latest tweets from <https://twitter.com> and displayed them. After completing that activity, I would likely see what the next incremental step would be, and I could plan a small project to get me there" (personal communication). While it is difficult to determine how long a wave will last, an understanding of the data associated with job information in one's respective career areas is essential for all aspiring professionals. Burning Glass Technologies (2019) is a useful source for following career changes and developments in several fields.

Part III. Core Competencies for Adaptable Learning

The elimination of jobs at all levels and the uncontested recognition of major changes that will be required to perform effectively in higher level careers have thus become the focus of this theory. *Five* **Core Competencies** *or general areas of proficiency are critical for preparing young people to successfully make decisions about career choice and for preparing them for the inevitable job market changes that will define all future high-level professions and careers.* There is no particular order of importance in the list of Core Competencies either across the competencies or within each competency. The Core Competencies are as follows:

- Higher Level Analytic Thinking Skills
- ***Creativity Skills***[1]
- Basic Investigative Research Skills
- Executive Function Skills
- Learning-How-To-Learn Skills in Technology

[1] Creativity Skills are sometimes considered as part of Higher Level Thinking Skills but treated as a separate category here because of the predominant emphasis being placed on them in high level career paths. The same argument could be made for Executive Function Skills. In the model developed here, the first category focuses on Higher Level *Analytic* Skills.

A figural representation of the five Core Competencies is presented in Figure 2. This figure is purposefully designed to emphasize the interaction between and among these five competencies. In other words, no single competency will equip a person to progress in his or her career path or to seek new career options; all will be required, and they will need to be fluently used together. It is important to reflect on the overlap among the skills. For example, creativity shares some of the skills for higher-level analytic thinking, investigative research skills, and executive functions.

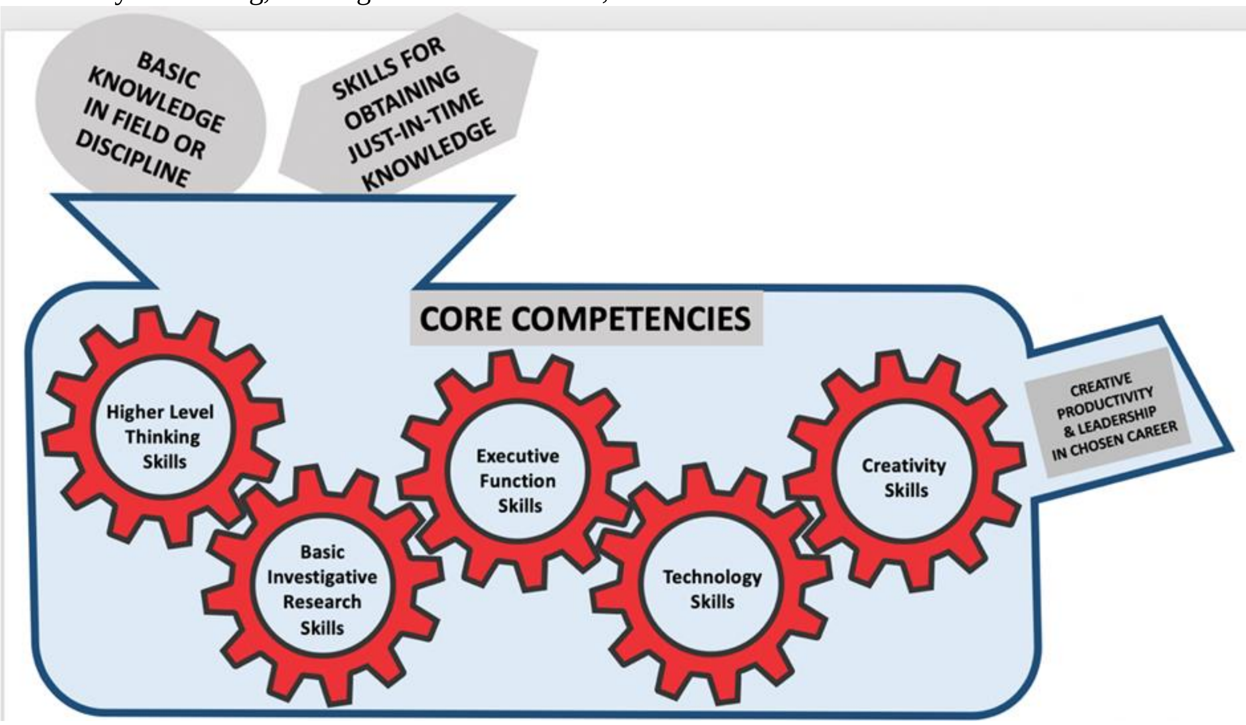

Figure 2: ***Core Competencies for the Catch-A-Wave Theory of Adaptability.***

The Core Competencies are discussed in greater detail below and should be considered priorities in designing programs for high ability and talented youth, as for well as other students with high aspirations and goals for future engaging and challenging work. Some of these ***competencies*** are already well known to many educators but are included here to call attention to the overall or "big picture" of what the adaptability theory is all about. Teachers must understand how to find the resources and practical implementation strategies to guide students in acquiring the five Core Competencies described below.

- **Higher Level Analytic Thinking Skills (The Traditional Goals of Gifted Education):**
  Critical Thinking, Problem Solving, Decision Making, Analysis, Synthesis, Evaluation.

This category of Core Competencies is well known to gifted-education specialists and persons interested in infusing more thinking skills into the regular curriculum. A number of authors have helpful information, and research relating to this competency that can guide teachers and other professionals in selecting relevant skills for their classrooms (Bloom, 1956; Halpern, 1996, 1998; Sternberg, 1996). Practical teaching resources are listed in Appendix A: Resources for Teaching Core Competencies.

- ***Creativity Skills:***
  Curiosity, Brainstorming, Substituting, Questioning, Reframing, Imagining, Modifying, Combining, Adapting, Eliminating, Reversing, Magnifying, Minifying, Putting to Another Use.

This set of skills is also fairly well known to gifted-education specialists. Vast numbers of books and articles have been devoted to studying just about every aspect of both the research and theoretical nature of creativity and on the practical strategies for creativity training for young people (e.g., Kaufman & Beghetto, 2009; Kaufman & Sternberg, 2019; Renzulli & de Wet, 2010). Although creativity is almost always included alongside Higher Level Thinking Skills, it is regarded as a separate set of major ***Core Competencies*** because of the overwhelming emphasis that all writers on this topic and almost all employers have placed on the importance of creativity for the promotion of the kinds of career-related adaptability that is the focus of this article. Practical teaching resources can be found in Appendix A.

- **Basic Investigative Research Skills**
  Developing a Hypothesis or Research Question, Reviewing Relevant Research, Planning and Scheduling, Finding or Developing Data Gathering Instruments or Techniques, Organizing and Classifying Information. Analyzing Data, Drawing Conclusions, Writing Reports and Communicating Results

Most teachers have had a course that covers the basic concepts and procedures for conducting the research skills listed above. This set of Core Competencies is essentially how most people in the sciences go about creating new knowledge, and even people in other areas such as business, entrepreneurship, public service, and the arts follow similar patterns to develop new ideas, products, services, and forms of entertainment. These skills obviously differ in sophistication by age levels, backgrounds and experiences in selected areas of study, as well as the tools and resources are at the disposal of investigators. This Core Competency is listed separately from the more general Higher Level Thinking Skills because of the applied nature of these skills; one can use analytical skills to compare and contrast two readings or objects in an isolated practice scenario, but investigative research, even at a junior level, involves putting the more abstract skills to work together. General information for professionals on topics related to investigative research skills can be found in Borg and Gall, (2018), Efron and Ravid, (2019), and Plano-Clark and Creswell, (2015). Some excellent materials that teachers can use to develop these skills in young people are listed in Appendix A.

- **Executive Function Skills:**
  Action Orientation, Realistic Self-Assessment, Optimism, Social Interaction, Awareness of the Needs of Others, Altruistic Leadership.

Executive functions are the skills needed to successfully execute the skills of higher-level thinking, creativity, and research in school and in the careers that are an outcome of our education system. These important skills, listed in greater detail in Figure 3 below, are sometimes referred to as the “Soft Skills.” They have been widely discussed in publications in recent years, because of a growing concern about the important role they play for career development and professional growth in today’s rapidly changing job market. These skills are also sometimes labeled as “co-cognitive skills” because they are not intended to replace the traditional cognitive skills described above as higher-level thinking skills or creativity. Rather, they are intended to enhance traditionally labeled thinking skills such as knowledge acquisition, comprehension, analysis, synthesis, and evaluation. The acquisition of these traditional or “hard skills” is usually documented by report cards, college transcripts, and formal tests (IQ, State Achievement Tests, SAT, GRE, LSAT, etc.), and include the kinds of information that employers evaluate in ensuring that prospective employees have the technical skills to pursue a particular job or career competently.

However, it is the “soft skills” that enable a collaborative and altruistic work environment (Seligman, 1990)). The Executive Functions detailed in Figure 3 are not as easily or objectively identified. Their value has rapidly grown in importance as more and more employers also look for information about whether or not prospective employees bring imagination, creativity, innovation, and effective leadership to their organization. They seek these kinds of leadership skills to fulfil positions that will grow their organizations, businesses, government or non-profit agencies, and groups promoting commercial products, ideas, beliefs, values, or other fundamental principles of their organizations. Among the five categories of ***Core Competencies*** discussed in this article, the Executive Function skills are best acquired through work on projects and any other activities that require teamwork, collaboration, the application of knowledge and thinking skills, and the pursuit of a product or outcome that has an impact on a targeted audience.

Two major books in this area (Hoerr, 2016; Seligman, 1990) provide a general introduction, orientation, and numerous references to the many studies that have been conducted on executive functions. Seligman offers many techniques to develop optimism and the other types of personal skills listed above that contribute to engagement in one's work, working effectively with others, and developing meaningful life skills. Hoerr's work is designed to help students develop attributes that aren't typically measured on standardized tests, but that help students develop self-control, see the world through others' perspectives, recognize and appreciate human differences, and prepare themselves for a future education and career in which the only constant is change.

A. Action Orientation Goal setting Decision Making Networking Organization Perseverance & Persistence Time Management Delegation of Responsibilities Focus Attention to Details Creativity•	**B. Realistic Self-Assessment** Appraisal of Personal Strengths and Weaknesses Confidence in Leadership Skills Willingness to Accept and Act Upon Constructive Feedback Optimism Self-Management Self-Motivation Sense of Humor
C. Social Interaction Listening Written, Verbal, and Non -Verbal communication Friendliness Respect for the Opinions of Others Cooperation and Collaboration	**D. Awareness of the Needs of Others** Empathy Tolerance Generosity Kindness Patience Calmness Trust
E. Altruistic Leadership Teamwork Positive Reinforcement Recognition of Other's Strengths Negotiation and Mediation Openness to Idea Exchange	
• Creativity is treated as a major Core Competency category in this article, but it also used in the Executive Function Taxonomy when the Taxonomy but is used for other purposes.	

Figure 3: Taxonomy of Executive Function Skills.

- Learning-How-To-Learn Skills in Technology:
  Identify Trustworthy and Useful Information, Selectively Manage Overabundant Information, Organizing, Classifying, and Evaluating Information, Use Relevant Information to Advance One's Work, Communicating Information Effectively, Planning One's Own Learning by Setting Reasonable and Incremental Goals, and Conceiving and Carrying Out Self-Driven, Hands-On Projects That Operationalize Those Goals

Most of the early work on learning-how-to-learn skills focused on the acquisition, storage, and retrieval of knowledge with resulting lists of skills that include reading, note taking, outlining, summarizing, and related skills such as underlining, highlighting, creating note cards, and using graphic organizers. The advent of the Internet and the Second Machine Age have radically improved the speed and efficiency for acquiring the Information-Age skills necessary for young people to learn new material quickly and easily. The new kind of learning-how-to-learn, however, is not a one-shot phenomenon. Rather, it requires a lifelong learning frame of mind that can adapt to and keep pace with the never-ending changes in technology. The works of Brynjolfsson and McAfee (2016) and Frey (2019) are comprehensive overviews that contain numerous references for persons who want to delve deeper in the dynamic changes taking place in technology and the impact technology is having and will continue to have on all levels of education institutions. Because of the importance of upskilling in this a particular category of learning, the practical resources for teachers in Appendix A have been supplemented with numerous web sites on coding in Appendix B.

Teaching technology skills is a relatively new addition to general-education teachers' repertoires of responsibilities. More attention is given to this Core Competency because of the critical role that technology plays in the Adaptability theory and the necessary how-to resources that teachers need in order to pursue this topic with their students. Some of the references listed in Appendix B have been included in the recommendations for both teachers and students because of their general treatment of the topic and the practical information necessary to acquiring skills in technology.

Although some educators have included technological skills? (in their programs for many years, one type of technological skill that is fairly new for most general educators is programming or coding. These logical thinking skills allow a programmer to use code to convert human ideas into instructions that a computer can understand (International Society for Technology in Education and the Computer Science Teachers Association, 2011). Even in work that does not involve coding, an understanding of how a computer "thinks" with code may help users of technology to understand how their devices function, which in turn should enable them to solve related problems.

Professions that require coding skills are prevalent across industries and are expected to become more common in the future (Burning Glass Technologies, 2019). Coding, or programming, requires clearly defining the problem at hand, knowing what types of actions the computer can take, and correctly writing or arranging instructions (the "code") that tell the computer to do those actions. Other transferable and "soft" skills can also be developed by learning to code. For example, coding is usually an iterative process, as programmers develop a partial solution, get feedback from users (or from their own examination of the output), and then revise the program or continue to build extensions of it. Iteration is a key part of all complex investigations, creative endeavors, and problem-solving processes. It requires patience, frustration tolerance, and acceptance of critical feedback. Learning to code is one way that children can learn these soft skills (Popat & Starkey, 2019; Strawhacker & Bers, 2019).

How Children Learn Coding Skills

When learning to code, students typically learn to use simplified, visual programming tools that allow them to build programs with pre-made blocks of codes that can be stacked together to form a sequence of instructions. Some toys have even been developed for very young children that enable them to code without a screen by physically arranging objects or by pushing directional buttons that are used to create a sequence of movement directions. For primary-grade children, Scratch (<https://scratch.mit.edu>) is an example of a computer-based programming tool that uses blocks of different colors and shapes that represent different types of functions. Older children and teenagers can learn to use professional, text-based programming languages in a game-like environment on sites like https://code.org.

Once children understand that the computer will follow their written instructions, they can begin to apply that knowledge to higher-level processes. Even beginning coders can animate, solve puzzles, and create interactive games once they learn the basic commands. These coding experiences also involve the logical thinking and problem-solving process discussed above in the Core Competency section on thinking skills; and when students embark on an innovative project such as designing a new video game, they also must employ many of the previously discussed creativity skills. Coding also helps to develop some of the executive-function skills mentioned above such as perseverance and time management, as well as collaboration and cooperation when students are coding in groups (Popat & Starkey, 2019; Strawhacker & Bers, 2019).

Resources for teachers

Resources for helping teachers get started with coding in the classroom abound. For example, Free Code Camp (https://www.freecodecamp.org) has curated hundreds of resources that students might use to develop advanced technology skills. The host website of the “Hour of Code”, http://www.code.org/, offers brief introductions to block-based and text-based coding that are tailored to different ages and interests. For teachers who want to begin coding lessons, one reference that is helpful is Common Sense Education (https://www.commonsense.org/education). This organization curates and creates materials to help educators identify and make use of the best educational technology tools, including tools for teaching coding. They also offer helpful guides, such as their Get Started with Coding tip sheet (Common Sense Media, 2017).

Another useful resource that guides teacher instruction in technology is a series of columns that Del Siegle, Professor of Educational Psychology at the University of Connecticut, has contributed to *Gifted Child Today* magazine for many years. Each column provides detailed descriptions on how to teach a specific topic in technology. Examples of topics covered in this series are Student Animated Projects in Technology, Using Virtual and Augmented Reality to Enhance Student Learning, and Drawing Pictures with Big Data.

The pedagogy for developing adaptability skills

Any discussion of developing advanced level skills should also consider the pedagogy that will most effectively prepare young people to pursue these skills. The 21st Century thinking skills movement (National Research Council, 2012; Prensky, 2008) has certainly called attention to the importance of higher-level thinking skills, creativity, and collaboration. It is important, however, to examine teaching strategies for infusing these skills into the curriculum that differ qualitatively from the prescribed and presented pedagogy that has dominated the content-based and standards- driven curriculum. In other words, canned worksheets on thinking skills or didactic lectures are not the best way to teach the Core Competencies, especially since the several competencies are highly interactive and therefore require a more holistic approach. Learning the skills discussed in this article should be embedded in creative–productive endeavors rather than simply presented and assessed sequentially, as one might with arithmetic (Renzulli, 1982). Creative productivity is defined as “the development of original ideas, products, artistic expressions, and areas of knowledge that are purposefully designed to have an impact on one or more target audiences.”

At the risk of over- simplifying the “learn by doing” work of John Dewey (1910, 1963) and other “hands-on” learning theorists such as the pedagogy developed by F. Paul Brandwein’s (1955) to guide young science students, it is recommended that an individual investigative project or a group project-based learning approach be the major way that we present opportunities for the Core Competencies. These skills are most effectively learned and used in real-life learning situations rather than through formal instruction (Renzulli, 1982). Real-life learning situations are similar to tasks presented in project-based learning; however, their focus is on accommodating student interests, encouraging creative outcomes, and applying knowledge and thinking skills to problems that meet the following four requirements:

1. Personalization of Interest. Students have some choice in selecting and pursuing the problem because of a personal or even passionate interest in the topic;
2. Use of Authentic Methodology. Students go about investigating the topic or solving the problem using the methods of a practicing professional, even if this methodology is at a more junior level than that of adult scientists, writers, film makers, etc.;
3. There is No Existing Solution or “Right” Answer. Students simply do not “find out” what is already known, but rather use existing knowledge, information, and core skills to form their own hypotheses or their desire to create something new. (e.g., a new story, poem, playground design, or a study that examines the amount of pollution in a local pond or river); and,
4. Student Products Are Designed to Have an Impact on Selected Audiences Other Than or in Addition to the Teacher. The raison d'être for all creative work throughout history has been to have an impact on one or more desired audiences, whether that audience be one child who is

being bullied in school or all of the persons attending a conference on environmental protection.

Efforts to promote the manifestation of adaptability in young people should be based on the modus operandi of a creative practicing professional and guided by the above four requirements of what makes a problem real as detailed in the Enrichment Triad Model (Renzulli, 1976). In other words, experiences should be provided that that encourage young people to think, feel, and do things like the practicing professional.

Conclusion and implications

What implications do all of the remarkable changes in technology, global economic conditions, and workplace and career planning have for the education system? While we should continue to use a good deal of the content that currently comprises the standards- driven curriculum followed by schools, colleges, and universities, a major related goal of our education system should be instilling the adaptability skills necessary for lifelong learning and frequent and flexible upskilling. This change will not take place overnight, but as it begins to evolve, it will certainly diminish the endless criticisms about our schools being stuck in an Industrial Revolution orientation for the educational preparation of our young people. Maria Montessori once said, “Teachers are the unacknowledged legislators of the world.” As we begin to think about preparing our most able young people for a creative and productive future, it is time for educators at all levels to initiate the inevitable changes that are necessary to fulfill Montessori’s vision.

While forecasting the future is always a risky business, bold steps to prepare students for a future of fast and effective reskilling are clearly indicated by the conditions that have created the Second Machine Age (Brynjolfsson & McAfee, 2016). The brightest minds need to develop groundbreaking solutions for teaching the five Core Competencies discussed above so that we can push the boundaries of career development at all levels of the occupation continuum. This theory may be ambitious, but we need to build an education system that moves beyond the Industrial model. Based on both what current information tells us about the kind of education system we must create and the technology that is now available to build such a system, the future can be full of creative opportunities for everyone.

References

Autor, D. (2010). *The polarization of job opportunities in the U. S. labor market: Implications for employment and earnings.* Brookings Institute. https://www.brookings.edu/research/the-polarization-of-job-opportunities-in-the-u-s-labor-market-implications-for-employment-and-earnings/

Bloom, B. S. (Ed.). (1956). *Taxonomy of educational objectives: Handbook 1, cognitive domain.* Longman.

Borg, W. R., & Gall, M. D. (2018). *Educational research: An introduction* (5th ed.). Longman.

Brandwein, P. F. (F.P. on p. 15). (1955). The gifted student as future scientist. Harcourt Brace Jovanovich.

Brynjolfsson, E., & McAfee, A. (2016). *The second machine age: Work, progress, and prosperity in a time of brilliant technologies.* W. W. Norton & Company.

Burning Glass Technologies. (2019). *Beyond tech: The rising demand for IT skills in non-tech industries.* https://www.burning-glass.com/wp-content/uploads/BGT_Oracle_BeyondTech_v7.pdf

Computer Vision Software (n. d,) https://onedoor.com/visual-merchandising-platform/analyze/?gclid=EAIaIQobChMIsYefhtOd6wIVGo-GCh3jiwVnEAAYAyAAEgLujvD_BwE#analyzeGallery?utm_medium=cpc&utm_source=google&utm_campaign=Computer%20Vision&utm_term=computer%20vision%20software&utm_org_campaign=Computer%20Vision&utm_org_medium=cpc&utm_org_source=google&utm_rct_campaign=Computer%20Vision&utm_rct_medium=cpc&utm_rct_source=google

Dewey, J. (1910). *How we think*. D. C. Heath and Company.

Dewey, J. (1963). *Experience and education*. Collier Books.

Efron, S. E., & Ravid, R. (2019). *Action research in education: A practical guide* (2nd ed.). The Guilford Press.

Frey, C. B. (2019). *The technology trap: Capital, labor, and power in shaping the age of automation.* Princeton University Press.

Halpern, D. F. (1996). *Thought and knowledge: An introduction to critical thinking* (3rd ed.) Lawrence Erlbaum Associates.

Halpern, D. F. (1998). Teaching critical thinking for transfer across domains: dispositions, skills, structure training, and metacognitive monitoring. *American Psychologist, 53*(4), 449–455. https://doi.org/10.1037/0003-066X.53.4.449

Hoerr, T. R. (2016). *The formative five: Fostering grit, empathy, and other success skills every student needs.* Association for Supervision and Curriculum Development.

IBM. (n.d.). *Learn how to operationalize AI in your business.* https://www.ibm.com/watson?p1=Search&p4=43700050370936614&p5=b&cm_mmc=Search_Google-_-1S_1S-_-WW_NA-_-%2Bibm%20%2Bwatson_b&cm_mmca7=71700000060771770&cm_mmca8=kwd-33133461216&cm_mmca9=EAIaIQobChMI_-XOk-fj6gIVBqSzCh3FgwH2EAAYASAAEgIdBvD_BwE&cm_mmca10=406603549665&cm_mmca11=b&gclid=EAIaIQobChMI_-XOk-fj6gIVBqSzCh3FgwH2EAAYASAAEgIdBvD_BwE&gclsrc=aw.ds

International Society for Technology in Education and the Computer Science Teachers Association. (2011). Operational definition of computational thinking for K-12 education. https://id.iste.org/docs/ct-documents/computational-thinking-operational-definition-flyer.pdf

Kaufman, J. C., & Beghetto, R. A. (2009). Beyond big and little: The four C model of creativity. *Review of General Psychology, 13*(1) 1–12. https://doi.org/10.1037/a0013688

Kaufman, J. C., & Sternberg, R. J. (Eds.) (2019). *Cambridge handbook of creativity* (2nd ed.). Cambridge University Press.

Levy, F., & Murnane, R. J. (2004). *The new division of labor: How computers are creating the next job market.* Princeton University Press.

National Research Council (2012). *Education for life and work: Developing transferable knowledge and skills in the 21st century.* The National Academies Press. https://doi.org/10.17226/13398

Organization for Economic Cooperation and Development. (2019). *Education at a glance 2019: OECD indicators.* OECD Publishing. https://doi.org/10.1787/f8d7880d-en.

Plano-Clark, V. L., & Creswell, J. W. (2015). *Understanding research: A consumer's guide.* Pearson.

Popat, S., & Starkey, L. (2019). Learning to code or coding to learn? A systematic review. *Computers & Education, 128,* 365–376. https://doi.org/10.1016/j.compedu.2018.10.005

Prensky, M. (2008). The role of technology in teaching and the classroom. *Educational Technology, 48*(6), 64–72.

Renzulli, J. S. (1976). The Enrichment Triad Model: A guide for developing defensible programs for the gifted and talented. *Gifted Child Quarterly, 20*(3), 303–326. https://doi.org/10.1177/001698627602000327

Renzulli, J. S. (1982). What makes a problem real: Stalking the elusive meaning of qualitative differences in gifted education. *Gifted Child Quarterly, 26*(4), 147–156. https://doi.org/10.1177/001698628202600401

Renzulli, J. S. (2016). A role of blended knowledge in the development of creative productive giftedness. *International Journal for Talent Development and Creativity, 4*(1), 13–24.

Renzulli, J, S., & de Wet, C. F. (2010). Developing creative productivity in young people through the pursuit if ideal acts of learning. In R. A. Beghetto & J. C. Kaufman (Eds.), *Nurturing Creativity in the Classroom* (pp. 24–72). Cambridge University Press.

Rimm, D. L. (2011). C-Path: A Watson-Like visit to the pathology lab. *Science Translational Medicine 3*(108), pp. 108–112. https://doi.org/10.1126/scitranslmed.3003252

Seligman, M. E. P. (1990). *Learned optimism: How to change your mind and your life.* Random House.

Singapore Ministry of Education. (2018). *Graduate Employment Survey—NTU, NUS, SIT, SMU, and SUTD.* https://data.gov.sg/dataset/graduate-employment-survey-ntunus- sit-smu-sutd

Sternberg, R. J. (1996). *Successful intelligence: How practice and creative intelligence determine success in life.* Simon & Schuster.

Sternberg, R. J. (2019). A theory of adaptive intelligence and its relation to general intelligence. *Journal of Intelligence, 7*(23). http://www.doi.org/10.3390/jintelligence7040023

Strawhacker, A., & Bers, M. U. (2019). What they learn when they learn coding: investigating cognitive domains and computer programming knowledge in young children. *Educational Technology Research and Development 67,* 541–575. https://doi.org/10.1007/s11423-018-9622-x

Zaber, M. A., Karoly, L. A., & Whipkey, K. (2019). *Reimagining the workforce development and employment system for the 21st century and beyond.* RAND Corporation. https://www.rand.org/pubs/research_reports/RR2768.html

About the Author

Joseph S. Renzulli is Director of UConn's National Research Center on the Gifted and Talented and Board of Trustees Distinguished Professor of Educational Psychology at the Neag School of Education. A leader and pioneer in Gifted Education, Dr. Joseph S. Renzulli was named among the 25 most influential psychologists in the world by the American Psychological Association. He received the Harold W. McGraw, Jr. Award for Innovation in Education, and was a consultant to the White House Task Force on Education of the Gifted and Talented. His work on the Enrichment Triad Model and curriculum compacting and differentiation were pioneering efforts in the 1970s, and he has contributed hundreds of books, book chapters, articles, and monographs to the professional literature. Dr. Renzulli established UConn's annual Confratute Program with fellow Educational Psychology Professor Sally Reis; the summer institute on enrichment-based differentiated teaching has served more than 25,000 teachers from around the world since 1978. He also established UConn Mentor Connection, a summer program that enables high-potential high school students to work side by side with leading scientists, historians, and artists, and is the co-founder of the Joseph S. Renzulli Gifted and Talented Academy in Hartford, which has become a model for local and national urban school reform.

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Appendix A
Practical Resources for Teaching Core Competencies

Thinking Skills

Francis, E. M. (2016). *Now that's a good question! How to promote cognitive rigor through classroom questioning.* Association for Supervision and Curriculum Development.
Seale, C. (2020). *Thinking like a lawyer: A framework for teaching critical thinking to all students.* Prufrock Press.
Stanley, T. (2020). *Promoting rigor through higher level questioning: Practical strategies for developing students' critical thinking.* Prufrock Press.
Wilberding, E. (2019). *Socratic methods in the classroom: Encouraging critical thinking and problem solving through dialogue.* Prufrock Press.

Creativity Skills

Eberle, B. (2008). *Scamper: Creative games and activities for imagination development* (Combined ed., Grades 2–8). Prufrock Press.
Kelly, L. (1996). *Challenging minds: Thinking skills and enrichment activities.* Prufrock Press.
Ketler, T., Lamb, K. N., & Mullet, D. R. (2018). *Developing creativity in the classroom: Learning and innovation for 21st-century skills.* Prufrock Press.
Renzulli, J. S. (2017). Developing creative activities across all areas of the curriculum. In R. A. Beghetto & J. C. Kaufman (Eds.). *Nurturing creativity in the classroom* (2nd ed., pp. 23–44). Cambridge University Press.
Resnick, M. (2017). *Lifelong kindergarten: Cultivating creativity though projects, passion, peers, and play.* The MIT Press.

Basic Investigative Research Skills

Bemiss, A. (2018). *Hands-on STEAM explorations for young learners: Problem-based investigations for preschool to second grade.* Prufrock Press.
Farland-Smith, D., & Thomas, J. (2017). *Eureka! Grade 3–5 science activities and stories.* NSTA Press.
Moorman, T. (2002). *How to make your science project scientific.* Jossey-Bass.
Renzulli, J. S., Heilbronner, N. N., & Siegle, D. (2010). *Think data: Getting kids involved in hands-on investigations with data-gathering instruments.* Prufrock Press.
Stanley, T. (2018). *Authentic learning: Real-world experiences that build 21st-century skills.* Prufrock Press.
Stanley, T. (2019). *Case studies and case-based learning: Inquiry and authentic learning that encourages 21st-century skills.* Prufrock Press.
Swan, K., & Lee, J. (Eds.). (2014). *Teaching the college, career, and civic life (C3) framework: Exploring inquiry-based instruction in social studies* (NCSS Bulletin 114). National Council for the Social Studies.

Executive Function Skills

Bean, S. M. (2010). *Developing leadership potential in gifted students.* Prufrock Press.
Delisle, D. S., & Delisle, J. R. (2020). *Creating kind and compassionate kids: Classroom activities to enhance self-awareness, empathy, and personal growth in grades 3–6.* Prufrock Press.
Mofield, E., & Peters, M. P. (2018). *Teaching tenacity, resilience, and a drive for excellence: Lessons for social-emotional learning for grades 4–8.* Prufrock Press.
Mussey, S. (2019). *Mindfulness in the classroom: Mindful principles for social and emotional learning.* Prufrock Press.
VanTassel-Baska, J., & Avery, L. D. (2013) *Changing tomorrow: Leadership curriculum for high-ability students* (series). Prufrock Press.
White, D. A. (2001). *Philosophy for kids: 40 fun questions that help you wonder about everything!* Prufrock Press.

Learning-How-To-Learn Skills in Technology
Housand, A. M., Housand, B. C., & Renzulli, J. S. (2017). *Using The Schoolwide Enrichment Model with technology*. Prufrock Press.
Housand, B. C. (2018). *Fighting fake news! Teaching critical thinking and media literacy in a digital age (Grades 4–6).* Prufrock Press.
LaGarde, J., & Hudson, D. (2018). *Fact vs fiction: Teaching critical thinking skills in the age of fake news.* International Society for Technology in Education.
Williams, J. (2019). *Teach boldly: Using edtech for social good.* International Society for Technology in Education.

Appendix B
Free or Inexpensive Web Sites for Teaching Coding

Many websites and apps are available to introduce the principles of coding to children, often by having fun solving puzzles. The following lists includes several of the most popular sites.

Free Sites

Block-based Coding

1. SCRATCH (https://scratch.mit.edu) – Kids use blocks of code, some of which are editable, to create programs. Multiple programs can run simultaneously or in sequence to create animations or interactive games. Premade graphics are available, and artistically-inclined kids can also design their own or edit the premade graphics in a pixel-art editor.
2. BotLogic.us (https://botlogic.us/) – Players use block-based directional codes to direct a robot in this puzzle game.

Multiple Coding Styles

1. Code.org (https://code.org) – This organization promotes computer science education at all levels and in all formats, including coding. They curate and create content to introduce coding skills and to get kids excited about computer science. Their content is organized by grade level and includes information about careers in computer science. They also offer professional development for educators who seek to learn more about computer science and teaching coding, and advocacy resources to help educators and families bring the importance of computer science to the attention of school boards and legislators.
2. Blocky (https://developers.google.com/blockly) – Blockly is a block "translation" tool developed by Google. It could be used to help students transition from a tool like Scratch to a real programming language, because the user creates codes with blocks and Blockly translates the code into the selected code language.

Language-based Coding

1. Khan Academy (https://www.khanacademy.org) – This site teaches introductory courses in several popular coding languages. They also have an introduction to digital animation and storytelling offered in partnership with Pixar.
2. CodinGame (https://www.codingame.com/start) – This site for advanced coders enables coders to play turn-based games to improve their skills and to compete with other players. It is also a recruitment site for employment. Much like recruiting varsity football players to the NFL, recruiters contact the best performers in the arena to offer them a job in software development.

Paid Sites

Block-based Coding

1. Mblock & Sons (https://www.mblock.com) – This website builds on the https://scratch.mit.edu platform; expanded functions include compatibility with MakeBlock robots, Arduino, Internet of Things devices, and an artificial intelligence engine. The parent company MakeBlock is also the host of a robotics competition called MakeX, which has four levels of entry for students from kindergarten through college.
2. Kodable (https://www.kodable.com) – This game is both web-based and available in a tablet app. It is a block-based curriculum designed for K–5 students to learn the very basics of computational thinking and coding.

Language-Based Coding

1. CodeMonkey Studios (https://www.codemonkey.com) – This subscription-based site is designed for teachers to use with entire classes of students. Each student works at their own pace to solve

coding challenges to help the monkey get a banana. The teacher interface enables progress monitoring.

2. CodeCombat (https://codecombat.com) – This site includes two games, Code Combat and Ozaria. Code Combat is more game-like, while Ozaria is designed as a course. Both programs adapt automatically to the player to keep the puzzles challenging but achievable. The class platform includes assessment tools, premade project-based learning experiences, and progress monitoring functions.

Multiple Coding Styles

1. Tynker (https://www.tynker.com) – This website offers three levels of coding courses that are designed for children and teenagers. The youngest coders use directional buttons to solve puzzles, the middle group uses a block-based coding tool similar to https://scratch.mit.edu, and the most advanced use real coding languages. The teacher interface includes progress monitoring and assessment tools, and also offers premade project-based learning modules.
2. Codemoji (https://codemoji.com) – This site uses “emojis” to create lines of code in the format of code languages. The use of emojis speeds up the process of creating code for students who are not proficient at typing, and also eliminates the potential for typos to interfere with success.