Making and Doing Survival Skills for Non-traditional Technology Engineering and Design Teachers

Steven L. Miller, Ed.D.
Assistant Teaching Professor, Technology, Engineering, and Design Education
North Carolina State University, Raleigh, NC

Glenn R. Moore, III (Trey)
Technology, Engineering, and Design Teacher
New Hanover High School, Wilmington, NC

Author Note

Trey and I began this action research project as the result of our parallel journeys in teaching contemporary Technology, Engineering, and Design practices and principles in our respective classrooms. Our paths to practice began in the early 1990s. Steve was a traditionally prepared educator; Trey earned licensure through a Master's Degree in Technology Education. We are both long-standing makers and doers, but for various reasons, we've now come to a point in our careers, where we need to hone our high-tech skills in the "doing" of digital file preparation and 3D printing, as well as the "making" through CNC machining, and other materials processing technologies. The national crisis of teacher preparation has spurred us to look at our experiences and to seek effective ways to help other traditionally and non-traditionally prepared Technology, Engineering, and Design teachers. We are heavily invested in our Critical Action Research. There is both personal relevancy and an altruistic motivation to the work being presented.

For additional information regarding this conference proceeding, please contact either Steven Miller at 919.961.4608 or by email at slmille6@ncsu.edu. Glenn "Trey" Moore may be contacted at 910.619.7720 or by email at glenn.moore@nhcs.net.

Abstract

There has been a national teacher shortage crisis for many years (Devier, 2019) and the crisis has been exacerbated by the COVID-19 Pandemic. The Technology, Engineering, and

Design Education profession have not been spared from The Great Resignation (Thomas, L. 2022). Traditional Technology, Engineering, and Design Educator Preparation Programs (EPPs) fail to meet demand. Despite alternative paths to traditional Technology, Engineering, and Design Education licensure in North Carolina, there is a net shortage of teachers in Local Education Agencies (LEAs). When a teacher is hired, the cumulative effect of these deficits creates the likelihood of Technology, Engineering, and Design Programs being facilitated by an alternatively licensed, Beginning Teacher Candidate. In North Carolina, these candidates will enter under a Career Technical Education Restricted License or through a Residency Program (B. Curran, personal communication, August 15, 2022). A significant number of these teachers are not adequately prepared for the salient points of teaching Technology, Engineering, and Design Curricula - especially the cornerstone trademark of making and doing within the discipline (ITEEA, 2020, p.15). These teachers need survival skills to support making and doing as they gain general instructional skills. This Critical Action Research Project aims to develop effective instructional strategies to support these beginning teachers within the strand of high and low-tech making and doing in Technology, Engineering, and Design Education (Helgeson, 2010). Solutions from this project are intended to support teacher retention by providing Quick Start guides to ease the overwhelming burden many non-traditional teachers may experience upon entering the classroom.

Keywords: Technology Education, Technology Engineering, and Design Making and Doing, Lateral Entry Teacher, Beginning Teacher, Non-traditional Teacher, Critical Action Research

Introduction

Making and doing in the Technology, Engineering, and Design Education (TED) classroom is the "signature trademark of technology and engineering education, differentiating technology and engineering from other content areas" (ITEEA and CTETE, 2020, p.77). The instruction and rationale for these making and doing skills and practices are integral to traditional educator preparation programs (EPP). The decrease in the TED Education Preparation Programs and significant decreases in undergraduate and graduate TED teaching candidates elevates the demand to fill the middle school and high school TED programs with any candidate deemed initially qualified for licensure. Few, if any, of these candidates are traditionally prepared teachers. The dearth of traditionally prepared candidates forces many districts to fill needed positions with lateral entry, non-traditionally prepared teachers. In North Carolina, these new TED teachers are classified in one of two ways (Curran, 2022). A new teacher with a related degree, industry, or work experience is granted a provisional, restricted license. New teachers with a related undergraduate degree with no related work experience are entered into the North Carolina Residency Program. The intersection of teaching vacancies and new teachers with few or no foundational skills and dispositions of the TED discipline almost assuredly creates an additional crisis within the teaching profession. This absence of making and doing skills within our newest generation of teachers presents an opportunity for a critical action research project targeting the development of high-quality professional development activities to provide new teachers with the requisite making and doing dispositions and skills amid their other initial licensure activities.

Teacher Shortage

The intersection of high and low-tech making and doing skills is crucial to delivering high-quality technology education. The data provided in the prior section regarding the shortage of teachers in TED is mirrored in every educational discipline. The shortage is beyond acute, and it is at a critical mass. To compound the shortage's urgency, it is common for new teachers to exit the profession after only a few years of teaching. According to the National Association of Secondary School Principals, "In the United States, 8 percent of teachers leave the profession annually, and more than 50 percent quit teaching before reaching retirement." Additionally, the turnover rate is frequently higher in high-poverty schools (*Making teachers stick: January 2020*). Data collection specifically related to Technology, Engineering, and Design Education as well as Trade and Industrial Education is being collected as of the presentation of this conference paper.

Even though a non-traditional teacher candidate likely has a hook that has brought them into a TED position, they very likely do not have all the fundamental dispositions of a traditionally trained TED teacher. Teachers who have a related degree but do not have work experience are enrolled in the NC Teaching Residency Program. They lack the TED skills and dispositions of the discipline due to a lack of work experience, and they are also without pedagogical skills. As they enter teaching, they will be required to complete a variety of requirements within three years to clear their initial provisional license and then receive their first five-year license. The requirements in their Beginning Teacher Program (BT I - III) work to ensure the teachers complete an induction program to support them emotionally and educationally as well as with initial practical teaching skills.

New Teacher Recruitment, Preparation, and Induction.

So much of this research project hinges on the preparation, and induction of these new teachers, no matter their path to teaching. It is important to include global information pertaining to the necessary conditions to bring candidates' from pre-service to in-service in North Carolina and nationally with the intent that enough professionals - especially policymakers and influencers will implement a plan to turn the tide of the teacher shortage in all areas of teaching. According to a statement released by all of the major teaching professional organizations, the shortage may be resolved by effectively implementing the following commitments. “We must create a sustainable system that prepares, retains, and supports teachers through accessible, high-quality teacher preparation, competitive compensation, ample resources, and ongoing professional learning and mentoring opportunities” (Business Wire, 2022).

Also in a recent call-to-action opinion piece, Dean Paola Sztajn, of the NC State University College of Education (2022), reiterates many of the same imperatives. She provides us with five imperatives beyond fair compensation. We must support high-quality teacher preparation programs - including hybrid, fully online, and alternative paths to licensure. We must remove financial barriers to teaching. Teachers must graduate debt-free or have a clear debt-forgiveness pathway. We must build strong professional teams to promote student success with teams of principals, counselors, and other para-professionals. It is important to note that work within the NC State University College of Education is supportive of faculty who provide service or extension services to schools and teachers. If viable, this research endeavor may be considered a part of this professional team approach. We must treat teachers as professionals. Teachers have professional knowledge that goes beyond what is required and their voices should be amplified. Her last recommendation is to share the rewards that this profession offers. Teaching is powerful; teaching is transformational. Find joy in the moments of student success (Sztjan, August 2022).

These recommendations and many similar strategies are necessary steps in recruiting all types of pre-service teaching candidates. They are all-encompassing and include the non-traditional as well as our traditional teaching candidates. Multiple paths to in-service teaching are most definitely required because the number of traditionally motivated and prepared are so scarce. Even the relatively limited number of traditionally prepared, pre-service candidates may benefit from this proposed mechanism of high-quality in-service professional development survivals for new and non-traditionally prepared teachers.

New Technology, Engineering, and Design Teacher's Paths to Licensure.

In addition to the BT I-III program, TED teachers must complete a series of New Teacher Induction Modules which are also designed to provide the new TED with discipline-specific content beyond what other academic teachers are required to complete. The rationale for the additional requirements is based on the very specialized content of TED and Trade and Industrial Education. The specialization relates to safety, federal regulations, and the incorporation of Career and Technical Student Organizations (CTSOs). Each of these requirements extends beyond daily lesson planning and classroom teaching. These requirements can be extremely difficult to navigate and some turnover results. Teachers who complete the BT I-III Program are granted their first five-year license. This license is renewed each five-year

cycle by completing eight renewal continuing education units (CEU). The eight CEUs consist of general educational content, subject area content, and digital learning content (NCDPI, 2022).

Teacher Retention

Teacher turnover and retention have been a concern for many years and have reached an all-time crisis. Many factors influence a teacher's decision to leave the classroom such as pay, demands on time, school climate, administrative support (or lack of it), student behavior, and even as Coats stated, being a "singleton, or the only TEE teacher in a school." (Coats p.153) In the discussion of her findings, Coats observed that participants in her study "heavily [relied] on other colleagues either within their schools or within professional organizations during their first years to develop course content and [navigate] their school environments." (Coats p.159) Her participants spoke of how these relationships impacted their comfort level and development in the classroom. We believe that what we are promoting in our research has the potential to be a very powerful tool in retaining teachers new to TED in the way it can offer practical and interpersonal support; mirroring the findings of Coats' dissertation. According to Darling-Hammond et al. (2019), teachers self-report within the NC Teacher Working Conditions Survey that retention is increased when teachers have individualized decision-making, collaboration, and administrative support. Shortages would also be helped by lower cost of entry, teaching supports, including coaching and mentoring, as well as the availability of necessary materials and supplies (Darling-Hammond p. 4). Success with a research project proposed in this conference paper amplifies the need for retention and recruitment because teachers within this discipline arguably require additional support, resources, and classroom autonomy beyond the norm.

Importance of Making and Doing

If one simply walks into a Technology Education classroom or flips through a publication on Technology Education making and doing is central to nearly all you find. Making and doing is what frequently separates TED from other related disciplines. According to Daiber and LaClair (1986), Industrial Arts always involved hands-on and minds-on learning and, as such, must continue as a foundational principle of Technology Education. In the article "International Perspectives of Technology and Engineering Education," one of the key findings in their analysis of lesson plans from teachers across the world was that "all lessons included some aspect of 'making.'" (Bartholomew et al., 2022). Furthermore, Niiranen states that "Commonly, technology education, engineering design or design and technology education emphasize learning by doing…" (Niiranen p. 84) Undoubtedly making and doing is a central activity in Technology Education and the need to offer support to teachers in these dispositions, in particular, non-traditionally trained teachers, is imperative.

Hypothesis, Aims, and Objectives

The critical need to reinforce the foundational making and doing components of the TED profession cannot be emphasized enough. A key assumption we are making is that by providing

instructional materials that support making and doing, non-traditional teachers may be more likely to stay in the classroom and stay past a commonly observed five-year benchmark in which many teachers leave the profession.

Methodology

Action Research is the methodology for this qualitative applied research project. According to Donato et al. (2003), there are four major steps for action research; (1) developing a plan for improvement, (2) implementing the plan, (3) observing and documenting the effects of the plan, and (4) reflecting on the effects of the plan for further planning and informed action. Action research is touted as a practitioner's research methodology because it focuses on school and system improvement from the ground up. Teachers and other practitioners identify an opportunity for improvement, develop the plan, implement, observe and document it, and then reflect upon its success or opportunities for refinement. Altricher, et. al (2002) published The Concept of Action Research *in Learning Organization* as an early formalized introduction to a school and organizational improvement methodology. Building from the work of Kemmis and McTaggart (1996) the methodology was adopted by Fullan (2002) and others who believed that systemic organizational change must be engaged ground-up as well as top-down. This methodology advocated for teachers and front-line personnel to engage in Action Research and provided guiding principles and processes. One of Helgeson's first recommendations in his chapter on Instructional Strategies in the CTETE Yearbook Research in Technology Education (2010) is a call for teacher educators to mentor teachers in the conduct of action research (Helgeson p.88). In addition to serving peer classroom professionals as mentors, this Critical Action Research will follow the four prescribed steps.

Research Procedures

First, we have identified a school classroom-level problem needing a solution. Because each of us has experienced a professional need to build our repertoire of high-tech skills, we've chosen this theme as our Step 1. Delving more deeply into this topic, it became clear that the problem is multi-tiered. Tier One is developing and creating easily accessible professional development modules designed to create high-tech skills for our new teachers. In addition to developing high-tech skills, we recognized that many teachers are in environments devoid of traditional TED Fabrication Space tools, machines, and equipment. They will have to build from the ground up using low-tech, high-impact, design, and problem-solving techniques. This research project will elaborate on these skills later. We hypothesize that these accessible professional development survival skills may work toward the second tier of the stated educational crisis of a lack of teachers and the departure of a significant number of teachers who made an attempt to become a teacher and, entered either the Restricted Licensure Beginning Teaching Induction Program or the NC New Teacher Residency Program and found for one reason or another they choose not to remain in the classroom beyond the five-year mark. Tier Two of the research is retaining those new teachers long-term if they are effective. The rationale behind the importance of problem identification for Tier Two is that solving the problem is literally a force multiplier. If these professional development and support survival skills are

highly effective, the user will thrive in the classroom and remain in the classroom for a career. Currently, there is a likelihood of their departure within several years.

Critical Action Research Questions

This Critical (participatory) Acton Research methodology will follow the aforementioned steps. In the midst of developing the plan and supporting materials, the researchers also drafted and submitted an NC State University IRB (#25428) request. The request is being edited and is under review. After approval, the researchers will collaborate with local education agencies (LEA) representatives and the NC Department of Public Instruction to locate potential study participants. After locating and connecting with five to ten teachers who are in their first or second year in the classroom, the researchers will provide them with the developed resources, instruction with the resources, and collaboration/mentoring. After a suitable amount of time to ascertain the environmental and experiential baseline of the participant, their classroom, and/or fabrication space/shop space, the researcher will follow with a semi-structured, open-ended interview. The interviews will be video recorded and will be analyzed for themes related to their new teaching experience(s), the effectiveness of the materials, collaboration/mentoring, and other resources or lack thereof. The standard research questions being incorporated into the semi-structured interview are listed below.

RQ 1 - What is necessary for you to implement low-tech making and doing?

RQ 2 - What is necessary for you to implement high-tech making and doing?

RQ 3 - What will increase your comfort level for making and doing?

RQ 4 - Will instructional support materials (quick start guides) assist the implementation of making and doing?

RQ 5 - What additional needs for content in instructional support materials (beyond quick start guides)?

RQ 6 - How likely will these resources help with your adherence to the STELS?

RQ 7 - Describe your perspective on these activities and interactions serving as mentoring.

After the interview and transcription, they will be analyzed for trends. Barring a finding from the participant indicative of them expressing no benefit or no further interest, the researcher will continue the collaborative/mentoring relationship with the teacher. Multiple data points indicate the importance of the teacher having a professional network and mentorship. It is not unusual for such mentor-mentee relationships to grow into peer relationships. During the ongoing contact, the researcher will provide advice and encouragement regarding involvement in professional associations, Career-Technical Student Organizations (CTSO), and STELs. This Critical (participatory) Action Research Project has the potential to contribute to the induction of new TED teachers - even if it is just a small step toward ensuring one more teacher remains in the classroom long term and becomes a highly capable TED teacher.

Instructional Support Materials

This research endeavor intends to provide supportive and impactful, domain-specific, professional development activities and human capital support for new, restricted license, and residency teachers through action research and Quick Start Guides pertaining to fundamental Technology, Engineering, and Design Education skills and dispositions. Skills and dispositions may or may not be shared directly with them in any other format. These skills and dispositions fall into a region of teacher induction not covered in new teacher professional development. On the one hand, the new teacher hasn't had the opportunity to participate in an EPP which teaches the skills, and on the other hand, these skills are too granular to be taught in a brief and intensive new teacher induction program. Helgeson notes that "many teachers lack support to plan and deliver high-quality instruction" and that "in addition to teacher preparation, we have the continuing challenge of professional development … [that] … update[s] the knowledge, skills, and strategies that teachers bring into the classroom. No professional is equipped to practice without ever receiving additional training." (Helgeson pp. 83-85) While this is certainly true of every teacher, it is especially true of teachers new to the profession and the discipline for whom, as already stated, lack the fundamental dispositions of the traditionally trained TED teacher. The need for instructional support materials extends internationally as well. In a recent survey of international teachers conducted by ITEEA's Committee for Technology and Engineering Teacher Education, one key finding was that participants identified among the resources they would like to have been online resources, printed resources, and network platforms (Bartholomew et al., 2022). Training teachers, especially new, non-traditionally trained teachers, to be as confident in their understanding and delivery of TED content as they are in behavioral management is critical. After all, the two go hand in hand.

Making and Doing Professional Development and Induction

Teachers first need to become familiar with the engineering design process in preparation for making and doing. The use of the engineering design process is foundational and sets the stage for making and doing activities from the low-tech to the high-tech. Once the problem has been defined and research conducted, ideating and modeling, the making and doing, quickly follow. Visualization is integral to ideating and can be done simply by putting pen to paper to communicate ideas to oneself or others. Creating models of solutions is the heart of it all; it's making and doing at its finest. Modeling can be done with a wide range of tools, materials, and processes varying from low-tech to high-tech. Two of the key objectives of learning by doing that Niiranen notes of the National Core Curriculum for Basic Education in Finland are "Guiding pupils in choosing between different techniques, tools, machines and equipment and in using them in their work" and "Selecting and using tools and equipment that are suitable for the work." (Niiranen p.88)

The Classroom/Fabrication Space and Shop Environment

Upon entering the classroom, the teacher will need to assess their classroom, fabrication space, and/or shop environment in order to determine where they fall on the low-tech to high-

tech spectrum. This can be a daunting and, at times, depressing task. Regardless of what is available to the teacher, making and doing can and must still be central to class instruction.

The physical space found in a Technology Education program covers a wide range of circumstances. Some teachers will find themselves in a classroom that could house any teacher for any content area; others may be in a more traditional shop, a modular lab, a Fab Lab, STEM Lab, a Makerspace, or a computer lab. The configuration of each of these spaces, labs, or classrooms has specific characteristics (Roy & Love, 2017). The environment could be heavy on traditional shop tools or computers. Students may be seated at desks, tables, work benches, or a combination of these. The type and amount of tools and materials the teacher will find in their classroom can vary widely from a well-stocked program to a program with few-to-no tools. A helpful resource to assess the facility and then evolve the space for local optimization may be found in *Safer Makerspaces, Fab Labs, and STEM Labs: A Collaborative Guide* (2017). Ken Roy and Tyler Love have created their comprehensive guide to TED and STEM facilities. It is well worth having as a reference in any TED or STEM space.

If the teacher finds the program heavy on the low-tech end of the spectrum, look for ways to use tools closer to the high-tech end as resources allow. Even in locales with extremely limited funding, there are many external funders through grants or business and industry partnerships. If heavy on high-tech, then implement low-tech instruction as well. Within high-quality Technology, Engineering, and Design Programs, it's not low-tech over high-tech or vice versa; they are both effective methods that dovetail well for student learning. Instruction in making and doing that moves back and forth along a low-tech to high-tech spectrum can be very powerful.

Quick Start Guides

Guidance for low-tech making and doing may be as simple as pointing out that common classroom supplies can be used for making and doing. Making and doing is not totally dependent upon access to a computer lab. In the event that the teacher is forced to work in an environment or facility without daily access to high-tech tools, high-quality TED is still achievable. On the high-tech end of the spectrum, the fundamentals of digital file prep can be easy enough: save as a specific file type, prepare and convert, and then save as a file type readable by the machine. However, when one is face-to-face with the machine, it becomes intimidating. The proposed quick start guides are intended to help ease some of the bewilderment by providing a generic, platform-agnostic, self-help guide meant to provide simple, direct, and accessible support documentation. We envision open-source, wiki-style Quick Start Guides. Once the initial product is implemented, it can be expanded by a community of teachers. We hope that the Quick Start Guides will show teachers how they can find ways to work with students across the low-tech/high-tech spectrum no matter their classroom environment.

High-tech Visualization, Solid-Modeling, and Digital File Preparation

In the realm of solid modeling and high-tech visualization, a wide range of software and applications (apps) are available for solid modeling and digital file preparation. These apps

bridge the spectrum from low-cost or free solid modeling and visualization to expensive, industry-leading, modeling, visualization, and model analysis packages. Depending on your budget, environment, and hardware, you may start from the low end of high-tech apps and build upon the rudimentary foundation. Starting simple is a recommendation if possible. The high-tech industry-leading software packages are frequently so complex that even the most simple modeling and digital file preparation is overwhelming.

For easy implementation of high-tech visualization, we have a preference for web-based drafting applications because of their ease of access to a variety of classroom settings and they can be found to suit a range of skill levels. However, even the high-tech low-cost modeling apps can still be extremely daunting for the novice, teacher, or student.

Digital File Preparation Applications

Within the context of this research project, digital file preparation refers to the creation of various, ubiquitous, file-types which form the basis from which all manner of high-tech materials and processes are derived. Some examples of ubiquitous digital files include: .STL, .DXF, .NC, .gcode, and, .svg. for use with 3D printers, laser cutters, vinyl cutters, and CNC machines. Each of these machines is dependent upon preferred file characteristics, but those files were built upon the vectors such as drawing exchange format (.dxf) and scalable vector graphics (.svg). can be dependent on a specific model or machine. Some basic procedures and file types are still common across platforms.

Rube Goldberg and Automata Mechanical Toys and Beyond

Our initial research conversations began with a focus on automata mechanical toy projects, but we now find ourselves in a place where making and doing across a low to high-tech spectrum can occur with almost any project-based activity. Starting low-tech is cost-effective and great for early-stage TED students with little experience. Begin to introduce high-tech in new iterations of prototypes developed by low-tech means. The Rube Goldberg Machine is an example of one project that can easily be implemented across a range of low-tech to high-tech making and doing. Beginning with low-tech tools and a combination of recycled and off-the-shelf materials. The Rube Goldberg problem-solving activities easily transition from low-tech to high-tech. Working with advanced students on an automata mechanical toy project can follow the same trajectory. Combine low and high-tech methods as appropriate to budget, time, and needs/demands of the solution. It’s about what suits instructional needs and what’s available.

Implications

The results from this critical action research may provide a critical lifeline to our next generation of TED Teachers. We cannot overstate the importance of the lifeline. Each of us has recently experienced the challenges of learning the requisite skills and components of high-tech making and doing. We are long-time veteran teachers with many years of experience with all of the general teaching skills and dispositions that function hand and glove in education but are not directly included within the discipline. Despite our teaching experience, the learning curve of mastering high-tech, solid modeling, digital file preparation, and CNC skills has been daunting.

We hope that the insights provided by this research study will ally the challenges and fears that making and doing is accessible and increase the comfort level of incorporating making and doing activities by having readily available support resources through Quick Start Guides. The Quick Start Guides are seen as a "living document" that encourages collaboration and helps build relationships vital to teacher retention.

Providing instructional materials that demonstrate how teachers can move across the low-tech to high-tech spectrum will strengthen their understanding and instruction of the STELS. We have stated throughout how "Making is an inherent part of technology and engineering education" (ITEEA. 2020). Through the Quick Start Guides, teachers will hopefully begin to extensively incorporate making and doing activities with readily available support. Repeated throughout Standards 1, 2, 7, and 8 of the Standards for Technology and Engineering Literacy is using a range of tools, materials, and skills to develop products and systems. The engineering design process is also reinforced as students move through various iterations of their work across low-tech and high-tech means - starting with low-tech to initiate making and doing and moving along a path to high-tech as budget, experience, and comfort allow.

Conclusions

Action is needed to support new and non-traditionally prepared in-service TED teachers through their teacher induction process and alleviate the growing shortage of teachers, particularly the number of teachers who quickly leave the profession. Research routinely points out that teachers feel they lack the support and resources needed to deliver instruction. This isolation and lack of support are often stated as one of the reasons for their departure within the first five years of teaching. TED is no exception considering that many new teachers frequently lack the experience and skills needed to teach making and doing, a central activity of TED.

A ground-up, top-down initiative is needed. This critical action research endeavor is needed to find practical, real-time means for supporting teachers. To improve the system from a holistic perspective, we support the work of Fullan, who defines educational sustainability as "the capacity of a system to engage in the complexities of continuous improvement consistent with deep values of human purpose" (2005; p. 10). Without the classroom level of solving large-scale challenges, the sustainability of the TED discipline is in question. These low-tech, high-tech making and doing skills are not always natural or known to new teachers. Since making and doing is the cornerstone of our discipline, the instructional support materials we are proposing are vital to continuing the inherent practice of making and doing.

References

Altrichter, H., Kemmis, S., McTaggart, R., & Zuber-Skerritt, O. (2002).

The concept of action research. *The Learning Organization*, *9*(3), 125–131. https://doi.org/10.1108/09696470210428840

Bartholomew, S.R., Mahoney, M.P., Papadopoulos, J., Oliver, S.D., Sung, E., Lecorchick, D., Wright, G., Kelley, T.R., (2022): International perspectives of technology and engineering education. *Technology and Engineering Teacher*, *82*(1), 8–17.

Business Wire. (September 2022). *Joint statement on sustainable systems for quality teaching.* Business Wire - A Berkshire Hathaway Company. Retrieved October 20, 2022, from https://www.businesswire.com/news/home/20220921005102/en/Joint-Statement-on-
Sustainable-Systems-for-Quality-Teaching.

Coats, T. (2021). *Should "I" stay, or should "I" go? An exploration of and examination of technology and engineering education teacher identity and retention* [Unpublished doctoral dissertation]. North Carolina State University.

Curran, B. (2022): Personal communication, August 15, 2022.

Darling-Hammond, L., Bastian, K., Berry, B., Carver-Thomas, D., Kini, T., Levin, S., & McDiarmid, W. (2019). Educator Supply, Demand, and Quality in North Carolina: Current Status and Recommendations. Palo Alto, CA: Learning Policy Institute.

Devier, B. (2019): Teacher shortage and alternative licensure solutions for technical educators. *Journal of Technology Studies*

Donato, R. (2003, December). *Digest Edo-FL-03-08 • December 2003 action research - edfutures*. Ed Futures. Retrieved August 10, 2022, from https://edfutures.net/images/7/7a/Action_Research-RICHARD-DONATO.pdf

Fullan, M. (2005). *Leadership and sustainability: System thinkers in action.* Thousand Oaks, CA: Corwin Press.

Helgeson, K. (2010): Instructional strategies. *Research in Technology Education* Eds. Philip Reed, James LaPorte. Council on Technology Teacher Education, 59th Yearbook.

International Technology and Engineering Educators Association. (2020). *Standards for technological and engineering literacy: The role of technology and engineering in STEM education.* https://www.iteea.org/STEL.aspx

Jones, R. E., Wright, J. R., Daiber, R. A., & LaClair, T. D. (1986). Chapter 4 High School Technology Education. In *Implementing Technology Education* (35th ed., Ser. American Council on Industrial Arts Education, pp. 95–137). essay, Glenco Pub. Co.

National Association of Secondary School Principals. (2020, January 1). *Making teachers stick: January 2020*. NASSP. Retrieved November 11, 2022, from https://www.nassp.org/publication/principal-leadership/volume-20/principal-leadership-january-2020/making-teachers-stick-january-2020/

North Carolina Department of Public Instruction. (2022). *Renewal and reinstatement requirements*. NCDPI. Retrieved November 10, 2022, from https://www.dpi.nc.gov/educators/educators-licensure/renew-or-update-your-professional-educators-license

Niiranen, S. (2019). Supporting the development of students' technological understanding in craft and technology education via the learning-by-doing approach. *International Journal of Technology and Design Education*, *31*(1), 81–93. https://doi.org/10.1007/s10798-019-09546-0

Reed, P. A., & LaPorte, J. (2010). *Research in technology education*. Council on Technology Teacher Education.

Roy, K. R., & Love, T. S. (2017). *Safer makerspaces, Fab Labs, and Stem Labs: A collaborative guide!*

Sztjan, P. (2022, August 15). *If NC wants to attract more teachers, it must do the following things.* The News & Observer. https://www.newsobserver.com/opinion/article264422201.html.

Thomas, L. (2022): The great teacher resignation. *Chief Learning Officer*. https://www.chieflearningofficer.com/2022/05/01/the-great-teacher-resignation/. Retrieved August 20, 2022.

APPENDIX A

Quick Reference for Related Technology, Engineering, Education Teaching Resources

Problem-Solving

Three Tools for Teaching Design in Your ClassroomTechnology Engineering Ideation and Problem-solving skills, September 2022 (TET, Isabell, T., Mentzer, N. et. al.)

Graphic Organizers

Technical Sketching

Design Sketching, October 2022, (TET)

Simple Mechanisms

Constructopedia, Tufts University