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Cutting Edge Education: Exploring Continuous Improvement in CNC Training Across Academic Levels

Andrea Camacho-Betancourt, University of Florida
Dr. Katie Leanne Basinger, University of Florida

Lecturer and Undergraduate Program Coordinator at The University of Florida, in Industrial and Systems Engineering. My research is focused on practical applications of active and supplemental learning techniques for Generation Z students.

Iris V. Rivero, University of Florida

Dr. Iris V. Rivero is the Paul and Heidi Brown Preeminent Chair and Department Chair of Industrial and Systems Engineering at the University of Florida. She received her B.S., M.S., and Ph.D. in Industrial & Manufacturing Engineering from Penn State University. Prior to UF, she served as the Kate Gleason Professor and Department Head of Industrial and Systems Engineering at the Rochester Institute of Technology (RIT). In addition, she was a member of the faculty and Associate Chair in the Department of Industrial and Manufacturing Systems Engineering at Iowa State University. Her research group iMED (Interdisciplinary Manufacturing Engineering and Design) laboratory specializes in research to design scalable hybrid manufacturing techniques of a wide array of material systems ranging from biopolymers, metal alloys, and concrete. Her research expertise is in additive and hybrid manufacturing processes, and biomanufacturing. Applications of her research extend to applications ranging from in-situ nondestructive testing of manufacturing processes to design of Additive Manufacturing alloys for aerospace and biomaterials for tissue engineering. She was a fellow at NASAs Marshall Space Flight Center. She has over 100 peer-reviewed publications and over 100 invited talks and presentations. She is a fellow in the Institute of Industrial and Systems Engineers (IISE).

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Abstract

This research is evaluating the art of designing a course to allow students to explore their creativity while honing their technical design skills. This is done by analyzing and comparing the development and learning of two cohorts in a computer-numerical-control (CNC) manufacturing course. The cohorts analyzed in this work are: (1) bachelor's degree seeking students majoring in Mechanical and Aerospace Engineering or Industrial & Systems Engineering who complete the course over 6 weeks and (2) high school students who complete the course over 4 days. Alongside using qualitative based research methods, student perception of personal learning progression as well as the intuitiveness of creative problem-solving is analyzed. Results show that confidence level and knowledge after labs and lectures increase for both cohorts; however, underclassmen high schoolers have a slightly higher average for both. High schoolers also show a discrepancy in more knowledge gained with a slight drop in confidence after lab 2 when they are beginning to grasp more difficult concepts. This discrepancy indicates that high schoolers understand the knowledge leap taken from one lab to the next but are not confident in their abilities to put that knowledge into practice. Future work will collect data from more high school and college cohorts to support the trends observed and produce statistically significant findings. There will also be an analysis done comparing the perceived knowledge from on-line surveys to learning outcomes from technical quizzes delivered throughout the proposed course.

Introduction

This paper will discuss the progress of continuous improvement efforts made to an experiential learning computer-numerical-control (CNC) manufacturing course. The course is known as "bootcamps" due to the integration of an ACE bootcamp style teaching where all material is covered within a week. These bootcamps are created to equip students with transferable design skills through comprehensive theoretical understanding and practical application of CNC machining and computer aided manufacturing (CAM) technology. Students are expected to learn how to CAM on Fusion 360, resolve problems when applying the CAM to create parts on CNC machines, and The research revolving around this course aims to explore the differences in theoretical comprehension and practical application of CNC machining and CAM technology between college and high school cohorts.

This paper includes an analysis of one college and one high school cohort. The bootcamps include lectures, CAM assignments, and hands on work with CNC machines. A Qualtrics survey was administered to the students after each bootcamp session with questions regarding the student's perceived learning, confidence in being able to intuitively design components, the cohesiveness of the bootcamps and more. Our analysis of these bootcamps is an iterative process to increase the effectiveness of course delivery & student learning. This research intends to create a baseline for other experiential learning courses to best promote student learning outcomes.

Literature Review

Literature shows that there are plentiful ways for increasing the effectiveness of lectures. In a study done on college students, there's an emphasis on the need for prepping students with the proper knowledge needed to understand the concepts covered in lectures [4]. The same study also delves into the need for elaborating on and summarizing the topics covered in lectures from the students' perspective [4]. It is important to ensure students are processing concepts deeply so that they can understand the concepts when they see them applied in practice within programming or machining. With regards to high school students' retention from lectures, a study shows that increasing engagement in course delivery has positive outcomes on learning retention [5]. High school students are motivated to be more engaged in learning a subject when the academic challenge of the subject increases. The engagement of these students is further enhanced if there is a reward the students can work towards such as a high grade on an exam or a certificate as is the case in the ACE bootcamp [1]. Engagement is particularly important to look at because it is positively correlated with critical thinking and comprehension [2]. Engagement is also a good predictor of learning and academic achievement [2].

One study found key differences in the learning styles of college and high school students [6]. High school students are found to be more interested in self-test learning because they learn to master a specific subject and tackle problems in the manner of which they were taught [6]. High school students are motivated to learn to earn a good letter grade relating to the subject matter. College students on the other hand are more interested in vocational oriented learning, meaning they seek to apply problem-solving skills related to the concepts learned to their future careers. College students learn to gain a deeper level of understanding than the surface level understanding high school students aim for [6]. In the same study, the study assessed the cognitive processing strategies of both groups. College students were found to use significantly more critical processing and analyzing strategies than high school students [6]. There is a lack in further research with a comparative analysis of the learning styles of college and high school students.

One way to analyze the perceived learning of students is by considering the Dunning-Kruger Effect. The Dunning-Kruger Effect shows that those with a low grasp on a topic such as novices, tend to be overly confident in their skills because they don't recognize the gaps in their knowledge. Those with a higher competency level tend to undervalue their abilities and have much lower confidence levels regarding the topic because they acknowledge how much of the topic is still unknown to them [3].

Methods

Course interventions

Lectures

One-hour lectures are held to best prepare students for the experiential learning aspect of the course. Lecture topics are: Intro to Machining, G-code Basics, Tools, Toolholding, Workholding, Additive Manufacturing, Tolerances, Dynamics, Cost, CAM+, and Speeds & Feeds. For the college cohort, the lectures are held at the beginning of the week before any labs. For the high school cohort, the lectures are held on the same day as their bootcamp.

CAM assignments

Students program the toolpaths that will be used to create their parts via a process called CAM in Fusion 360. Students create the toolpaths (CAM) the same part that they are machining in lab that week/day. For the college cohort, the CAM assignments are made available to them after lectures, and they are welcome to complete it as a homework assignment before or after their lab section with a deadline of the end of the week. For high school students, the CAM assignments are completed during the day of their bootcamp. High school students are allowed to work on it interchangeably with time on the CNC machines. That is to say that high school students may start off their day either on the CAM assignments and be pulled away to enter lab due to machine availability or they may start their day on the CNC equipment. To clarify, the college cohort completes CAM assignments on their own time, outside of lectures and labs, whereas the high school cohort completes the CAM assignments throughout the day of the bootcamp. Students are provided with a CAD file as well as a pdf with an explanation of how to get started with each CAM assignment. For the first assignments, the pdf thoroughly explains stock setup, work coordinate systems, and creating toolpaths. The later assignments are less detailed, enabling the students to put more thought into their work.

Lab

All labs use G-code that has been provided by the instructor and is known to be error-proof; however, the students must do safety checks each time a tool is switched during the program to ensure the CNC machine is correctly displaying where the tool should be at that point in time. This involves stopping the tool approximately 3 inches above the part and measuring the distance between the bottom height of the tool and where the Z height was probed to on the stock. If the measured height is equivalent to the distance displayed on the CNC machine, then they are okay to continue with the process. Otherwise, students must stop to find the error. This safety check must be done for every tool of every program that runs throughout the bootcamps. Each lab introduces a new topic to the students. The first lab is the students' introduction to the machine and has a built-in probing cycle. Here students are simply familiarizing themselves with the machine interface and safety requirements. Lab 2 is where students learn how to probe their own stock. The quality checks for this lab are especially important because this is the first time students could run into an error. In lab 3, students probe both their stock and each tool involved in their program. In lab 4, instructors are expected to be entirely hands-off; students are no longer receiving direct guidance or suggestions from an instructor but are instead expected to remember how to interact with the machine. Each lab leads to the completion of a different part of an air engine such that students complete the ACE bootcamp with a fully functioning air engine as pictured in Figure 1 with the deconstructed air engine in Figure 2. Lab breakdown and corresponding lecture for each cohort is shown in Table 1. Note that Lab 5 is not completed by the high school cohort due to time constraints.

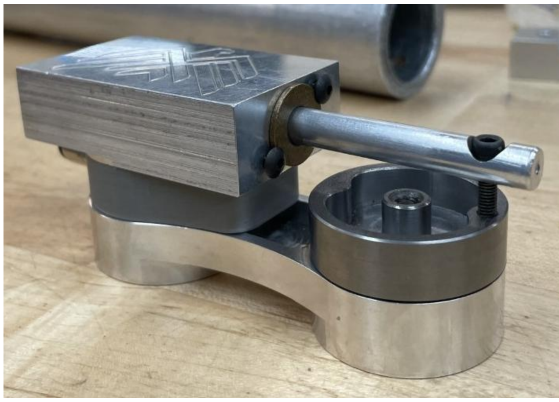

Figure 1. Completed Air Engine **Figure 2. Deconstructed Air Engine**

Lab Number	Part Machined	Lecture Topics (HS)	Lecture Topics (College)
1	Base	Intro to Machining & G-code Basics	Intro to Machining
2	Piston Block	Tools, Toolholding, & Workholding	G-code Basics
3	Valve Block & Piston	Additive Manufacturing & Tolerances	Tools & Toolholding
4	Wheel	Dynamics, Cost, and CAM+	Workholding & Work Coordinate Systems
5	Engraving		Speeds and Feeds

Table 1. Breakdown of each cohorts' labs, machined part, and corresponding lectures.

Data collection

Qualtrics surveys are used to collect data from ACE participants. That data is then converted to qualitative data to allow for the analysis of differences in student perception of learning progression and intuitiveness of creative problem-solving. The surveys were developed using a Likert Scale model, meaning each question offers 5 different responses, ensuring the scale is non-biased to a particular response. Each option was linked to a value between 1 and 5 to allow for statistical analysis. Using the Likert scale presents participants with a balanced viewpoint as they can consider the varying degrees of opinion rather than a binary or neutral response. Before performing any in-depth analysis an anonymized excel sheet was created to store the results of each survey. Each student had the option to opt in or out of the data collection process at the beginning of each survey and only responses from those who opted in are included in this paper. Differences between the surveys for each cohort were primarily to accommodate for differences in the speed of which the topics were covered. High school students answered questions about various labs within one survey whereas college students had a survey correlating with each lab.

Cohorts

The first cohort was in Fall 2021 where college students learned first on a desktop five-axis PocketNC, then transitioned to a three-axis HAAS VF3. This first cohort did not finish all the assignments planned for the semester due to underestimating the time needed to learn skills for CNC. The second college cohort in Spring 2022, there was more of an emphasis placed on learning using the VF3. The third college cohort in Spring 2023 experienced the implementation of the ACE CNC Machining Training Program [1] incorporated into the first 6 weeks of the course while learning solely on the VF3. The ACE curriculum will be referred to as the ACE bootcamp for the remainder of this paper. The fourth college cohort in Spring 2024 continued to use the ACE bootcamp for the first 6 weeks of the course and used two HAAS MiniMill2s as their primary CNC equipment for learning. The first high school cohort for the ACE bootcamp was taught over the course of four days during Spring Break 2024. This paper will focus on the fourth college and first high school cohorts and beyond.

The college cohort submitted two surveys, after labs 3 and 5, receiving 22 and 21 responses respectively. Since only two surveys were released, all data analysis for this cohort is completed using T-tests. The first survey consisted of 14 questions, where the first three questions were rating the knowledge gained from each lab. The second survey consisted of 13 questions where the first 2 were rating the knowledge gained from each lab.

For the high school cohorts, surveys were released after each lab, receiving 11, 13, 8, and 7 responses respectively. Since 4 different datasets needed to be analyzed in comparison to each other, ANOVA tests were used. Each survey consisted of 10 questions. Questions regarding lab 5 were omitted, as well as a question regarding whether the students know what is expected of them before arriving the day of lab (this was deemed irrelevant because lectures, CAM assignments, and labs all occur on the same day). A breakdown of how many students opted into each surveys sorted by cohort is provided in Table 2.

	College Cohort		High School Cohort			
Survey #	Survey 1	Survey 2	Survey 1	Survey 2	Survey 3	Survey 4
Labs covered	1, 2, & 3	4 & 5	1	2	3	4
# Questions	14	13	10	10	10	10
# Responses	22	21	11	13	8	7

Table 2. Overview of surveys given to college and high school cohorts

Results

Analysis was done for each cohort individually followed by evaluating similarities and differences between cohorts. All questions in each survey were analyzed, though this paper highlights the questions with important impact on the learning, comprehension, and confidence of students learning in an experiential lab course. Using the anonymized excel sheet with all student answers, the mean and mode were calculated for each question of each survey and generalizations were made regarding the data to identify which questions to perform further statistical analysis on in the form to T-test or ANOVA depending on the cohort.

In Question 6 (Figure 3), the college cohort were asked about their confidence in intuition of their design capabilities. A two-sample T-test with a 95% confidence interval resulted in a p-value of $0.062 > 0.05$ which means the results are not significant. However, the value is relatively close to 0.05 (if the $p\text{-value} < 0.05$, then it would have been significant) meaning that the results are approaching significance, which could be due to the small sample size of this work at this time. Regardless of its insignificance, it is important to note the progression of learning as the mean confidence level rose from 3.6 on survey 1 to 4 on survey 2 on a range of 1 (not confident at all) to 5 (very confident), the distribution of results is shown in Figure 4. This shows the progression of learning as students feel more confident in the intuitiveness of their design capabilities after lab 5.

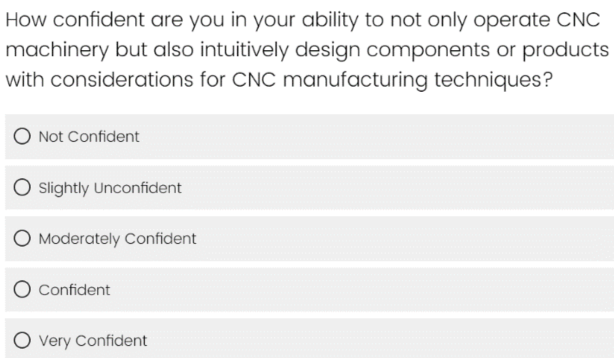

Figure 3. Question 6 from survey

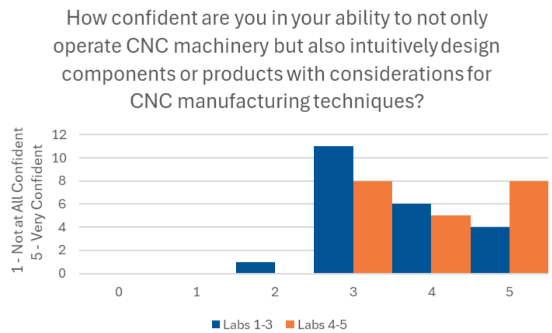

Figure 4. College cohort results from question 6

In Question 8 (Figure 5), the college cohort were asked whether they prefer for their instructor to ask them questions or be provided solutions during labs. A two-sample T-test with a 95% confidence interval resulted in a p-value of 0.083 > 0.05, which means the results are not significant. While not significant, it is important to note the rise in mean from 1.9 in survey 1 to 2.3 in survey 2 on a scale of 1 (prefer question) to 5 (prefer solutions), the distribution is shown in Figure 6. Students preferred their instructor asking them questions during the first three labs but then shifted to a more neutral stance with a slight preference of instructors providing them with explanations during the last two labs.

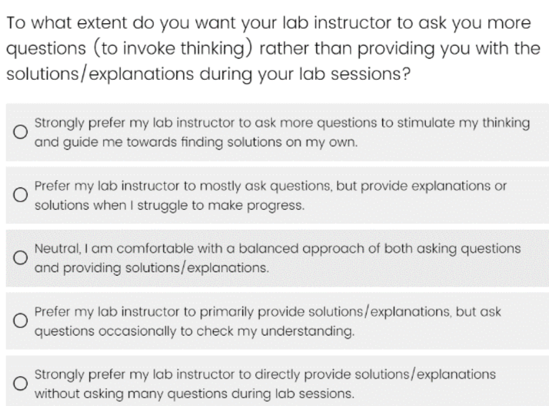

Figure 5. Question 8 from survey

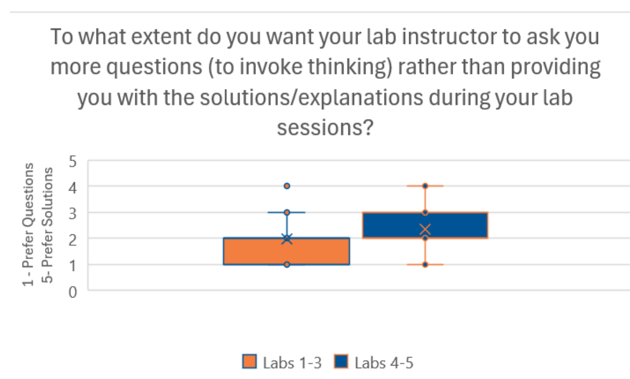

Figure 6. College cohort results from question 8

Trends observed in high school students' confidence to intuition of design capabilities are shown in Figure 7. Note the drop in confidence level after lab 2 that then increases after labs 3 and 4. An ANOVA test was used to see if this drop was statistically significant. The ANOVA test produced an F-value of 0.634 < F-critical 2.874; since the F-value is less than F-critical, the results are not significant meaning hence the different labs did not have significantly different impacts on students' confidence levels in operating the CNC machines. This suggests that the labs are equally effective in augmenting students' confidence levels. While not significant, there is a shift in the mean confidence level from 4 to 3.62 to 4.13 to 4.57 after each survey on a range of 1 (not at all confident) to 5 (very confident), with lab 2 being the lowest before it begins to rise. The lack of statistical significance shows that confidence levels remain roughly consistent. Another observation in the results is that the variances within the responses of each lab converge after labs 2, 3, and 4 (Figure 7) showing a more collective increase in knowledge after each lab.

In Question 9 (Figure 8), students were asked about the perception of their knowledge gained after each lab. An ANOVA test was done to evaluate whether any fluctuations in knowledge level was statistically significant. The ANOVA test produced an F-value of 0.767 < F-critical 2.874; since the F-value is less than F-critical, the results are not significant meaning the different labs did not have significantly different impacts on students' perceived knowledge gained. While not significant, the data shows a shift in mean perceived knowledge level of 3.91 to 4.31 to 4.25 to 4.57 as the labs progressed from a scale of 1 (struggle to grasp concepts) to 5 (have a deep understanding of concepts). There was a slightly greater increase in perceived knowledge after lab 2. This data also shows a convergence in variance as the labs progress.

Perceived knowledge level and confidence level are graphed in the same chart on Figure 7 to show the opposite correlation after lab 2 where perceived knowledge level increases and confidence level decreases.

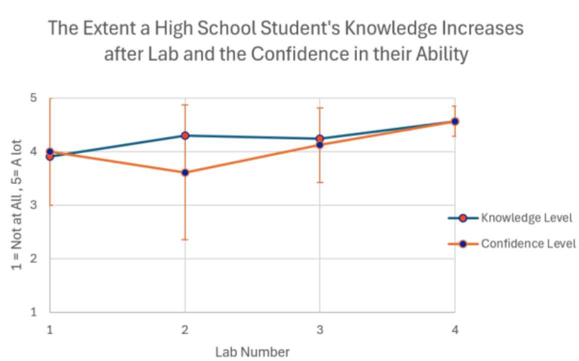

Figure 7. Results from Questions 6 and 9

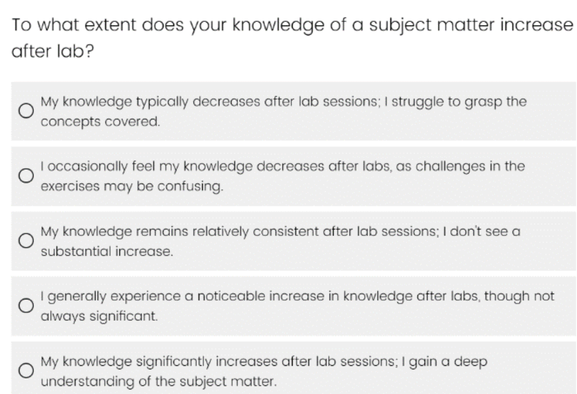

Figure 8. Question 9 from survey

At the beginning of each survey, students were asked to score the impact of each lab to their knowledge of design for CNC. While lecture topics varied slightly between the cohorts, the lab sections consisting of CAM and machining parts remained the same for both cohorts. The results from both the college and high school cohorts are shown below in Figure 9. There is a slight overall downwards trend for the college cohort and a slight overall upward trend for the high school cohort.

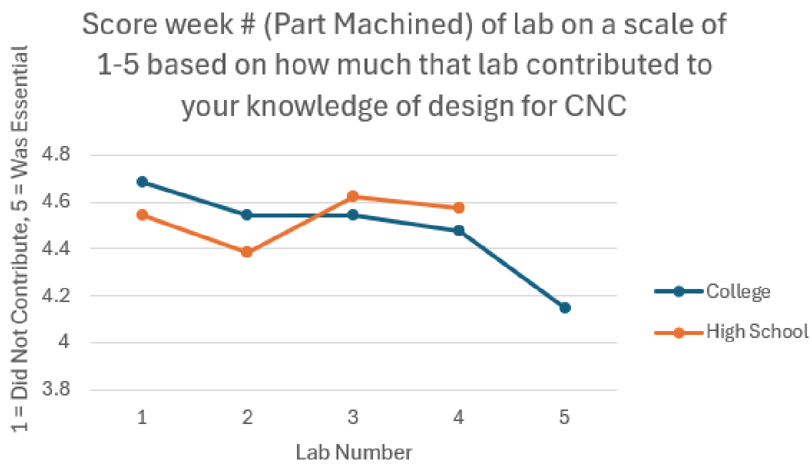

Figure 9. Comparison of results college and high school cohorts regarding knowledge gained after each lab

Figure 10 shows other key findings when comparing the college and high school cohorts at the completion of the ACE bootcamp. High school students consistently rate higher than college students on confidence level, knowledge after lectures, and circling back to lectures.

High school students also lean more towards their instructor asking them more questions because they want to solidify the knowledge gained. These students prefer questions that lead them to the next step in the machining sequence. High school students also rate slightly higher in their perception of how well lectures, CAM assignments, and labs complement each other.

Findings based on COMPLETION of ACE Training

■ High School ■ College

4.57 vs **4** confidence level
2.71 vs **2.33** more questions
4.43 vs **3.9** knowledge after lectures
3.14 vs **2.76** circling back after lectures
4.57 vs **4.19** lectures, CAM, labs being complementary

Figure 10. Comparison of findings between cohorts after completion of ACE bootcamp

Discussion and conclusion

The shift in college cohort from wanting more questions asked to them (to invoke thinking) to wanting more explanations is likely due to a shift from wanting to know how versus wanting to know why. During the first few labs students are learning the very basics of operating CNC machines so they are more concerned with ensuring that they press the right buttons in the right sequence. Hence, they are more comfortable with their instructor probing them with questions to lead them to the right sequence. During the last two labs, the students feel more comfortable in their ability to operate the CNC machines; hence, they are inclined to ask their instructors for suggestions on how to apply what they have learned. College students are seeking explanations due to a more thorough level of problem solving.

Results show that students' confidence in intuition of design capabilities and perceived knowledge increase after each survey. While neither statistical analysis test showed significant results, future cohorts should be observed to see if the trends observed uphold with larger data sets. The lack of statistical difference means that amount learned after each lab stayed relatively the same. This means no lab is more helpful than another, hence the order of the labs is likely correct. The convergence in variance in perceived knowledge of the high school cohort after each lab indicates a collective increase in knowledge as the course progresses. The same trend is evident in confidence in intuition of design capabilities where the variance converges.

The high school cohort shows an opposite correlation after lab 2 where perceived knowledge level increases and confidence level decreases. This opposite correlation is likely due to lab 2 being the first lab that is not foolproof. In lab 1, G-code is provided and all probing is done for the student. In lab 2, students must probe the stock themselves, meaning there is variability in error. It is likely that knowledge level increases because students are learning a probing cycle that has a direct influence in how the lab section is going to go. Their confidence level decreases because they are unsure of how well they can apply the knowledge gained.

Rating each lab's contribution to the students' CNC knowledge shows trends that correlate with the Dunning-Kruger Effect. High school students are more readily available to say that they experienced large increases in knowledge both because they learn to regurgitate information exactly as they received it without learning to apply it critically and because they are at the peak of enthusiasm in the Dunning Kruger Effect. They simply do not know how much knowledge they lack. College students on the other hand do not perceive themselves to gain as much knowledge as high school students do because they are aware of how much they do not know. They enter the labs with the mindset of applying concepts critically and can see where they wish for their knowledge to grow. Future work considering technical tests before the bootcamp and after each lab will be used to determine whether actual learning follows the same trends as students' perceived learning.

College students are likely climbing their way out of the valley of despair towards the slope of enlightenment on the Dunning-Kruger Effect. Having already had a few semesters in college, these students have come to terms with the fact that there are a lot of concepts that they do not understand and the more they learn, the more they discover how much they do not know. High school students on the other hand learn with the objective of mastering skills in the exact way that it was given to them. They are more focused on regurgitating or repeating the information than being able to apply knowledge gained to problem solving. This could also be because they complete all their learning outcomes in one day, enabling regurgitation of information rather than problem solving. High school students also do not have as much experience with problem solving, hence they are not aware of how much they do not know. They would be at the peak of enthusiasm on the Dunning-Kruger Effect. High schoolers rate their knowledge level purely on how well they can duplicate their learnings rather than being able to apply it in different scenarios. This can again be attributed to where each cohort sits on the Dunning-Kruger Effect.

High school students consistently rate higher than college students on confidence level, knowledge after lectures, and circling back to lectures. This trend could be due to high schoolers completing all three in the same day hence feeling more confident in completing all tasks since the knowledge from lectures is fresh on their minds whereas college students have a full week to get through the three learning outcomes, they are more inclined to ponder and think past surface level knowledge. The trend could also be because of their learning orientation: college students are vocational-oriented, seeking to apply the problem-solving skills learned versus high school students are self-test learners seeking to master a subject as it was taught. High school students don't delve as deeply into the material so they may be more inclined to passively say that the different assignments are complementary.

The lab structure is likely in the right order as learning increases in a steady manner as the bootcamp progresses. Following trends in literature, this study shows that college students are more vocational learners and high school students are more self-tested learners. Future studies should aim to continue to show this trend. Identifying the differences in learning styles for both cohorts will allow instructors to vary their teaching style to best teach each student transferable design skills. Lectures, CAM assignments, and labs can be altered to enable students gaining a comprehensive theoretical understanding and practical application of CNC machining and CAM technology.

Future work

This work will continue to evaluate future college and high school cohorts to increase sample sizes. Larger datasets are expected to give more accurate statistical analysis and confirm trends seen in this work. Moving forward, Qualtrics surveys should be released after each lab for the college cohort to allow for clearer visualization of how each lab/week has impacted student learning. Survey completion should be incentivized by incorporating completion as a small percentage of student grade. Since the grade would be based on completion, students would still be allowed to opt out without any consequences, their data would just not be used in the analysis. Comparison across cohorts will be increased by adding the data of the 2 Summer 2024 high school bootcamp cohorts. The college and high school cohorts can also be compared with a general population cohort to explore the differences in confidence, learning preferences, and perception of progression of CNC knowledge across 3 different populations. Additionally, future work should include a comparison of perceived CNC knowledge from Qualtrics surveys to actual outcomes from technical quizzes. These quizzes could have technical questions pertaining to topics covered in each of the 5 labs. The surveys should be released once before the bootcamp starts, then after each lab section to evaluate actual progression of knowledge. Results will allow us to have a better understanding of the Dunning-Kruger Effect. In implementing all this future work, with additional data collection from more cohorts and technical quizzes, there is hope to be able to prove the trends explained in this essay in a statistically significant manner.

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Appendix

All questions from high school surveys:
Questions 1-4 were only included in the survey corresponding the lab of the part that students just completed (ex: Base, Piston Block, Piston and Valve Block, Wheel).

1) Score day one (Base) of lab on a scale of 1-5 based on how much that lab contributed to your knowledge of design for CNC?
    a. 1 - did not contribute to my learning
    b. 2
    c. 3 - partially contributed to my learning
    d. 4
    e. 5 - was essential to my learning
2) Score day two (Piston Block) of lab on a scale of 1-5 based on how much that lab contributed to your knowledge of design for CNC?
    a. 1 - did not contribute to my learning
    b. 2
    c. 3 - partially contributed to my learning
    d. 4
    e. 5 - was essential to my learning
3) Score day three (Piston and Valve Block) of lab on a scale of 1-5 based on how much that lab contributed to your knowledge of design for CNC?
    a. 1 - did not contribute to my learning
    b. 2
    c. 3 - partially contributed to my learning
    d. 4
    e. 5 - was essential to my learning
4) Score day four (Wheel) of lab on a scale of 1-5 based on how much that lab contributed to your knowledge of design for CNC?
    a. 1 - did not contribute to my learning
    b. 2
    c. 3 - partially contributed to my learning
    d. 4
    e. 5 - was essential to my learning

All other questions (6-15) were included in every survey

6) How confident are you in your ability to not only operate CNC machinery but also intuitively design components or products with considerations for CNC manufacturing techniques?
    a. Not confident
    b. Slightly unconfident
    c. Moderately confident
    d. Confident
    e. Very confident
7) Are the directions from the lab instructors clear?
    a. Not clear
    b. Slightly unclear

c. Moderately clear
d. Clear
e. Very clear

8) To what extent do you want your lab instructor to ask you more questions (to invoke thinking) rather than providing you with the solutions/explanations during your lab sessions?
   a. Strongly prefer my lab instructor to ask more questions to stimulate my thinking and guide me towards finding solutions on my own.
   b. Prefer my lab instructor to mostly ask questions, but provide explanations or solutions when I struggle to make progress.
   c. Neutral, I am comfortable with a balanced approach of both asking questions and providing solutions/explanations.
   d. Prefer my lab instructor to primarily provide solutions/explanations, but ask questions occasionally to check my understanding.
   e. Strongly prefer my lab instructor to directly provide solutions/explanations without asking many questions during lab sessions.
9) To what extent does your knowledge of a subject matter increase after lab?
   a. My knowledge typically decreases after lab sessions; I struggle to grasp the concepts covered.
   b. I occasionally feel my knowledge decreases after labs, as challenges in the exercises may be confusing.
   c. My knowledge remains relatively consistent after lab sessions; I don't see a substantial increase.
   d. I generally experience a noticeable increase in knowledge after labs, though not always significant.
   e. My knowledge significantly increases after lab sessions; I gain a deep understanding of the subject matter.
10) Please explain why it was easy or hard to receive help while in the lab.
   a. This was a short answer question.
11) To what extent does your knowledge of a subject matter increase after lectures?
   a. Not at all, I still feel lost
   b. Somewhat, I understood about 50% of the content
   c. Moderately, I understand some but have some questions
   d. Mostly, I have one or two questions
   e. Significantly, I understood the entire lecture and have no questions
12) I believe that what I have learned in this course is important for my future.
   a. Strongly disagree
   b. Somewhat disagree
   c. Neither agree nor disagree
   d. Somewhat agree
   e. Strongly agree
13) Do you find yourself having to circle back to lecture material often?
   a. No, I seldom or never need to circle back to lecture material; I grasp the concepts well during the initial learning phase.
   b. Rarely, I can usually grasp the concepts without needing to go back to the lecture material.
   c. Neutral, I revisit lecture material as needed, but it's not a frequent occurrence.

d. Occasionally, I find it helpful to review lecture material for clarification.
e. Yes, I frequently need to revisit lecture material to reinforce my understanding.

14) To what extent does your knowledge of design for CNC manufacturing increase after completing the CAM assignments?
    a. My knowledge typically decreases after CAM assignments; I struggle to grasp the concepts covered.
    b. I occasionally feel my knowledge decreases after CAM assignments, as challenges in the exercises may be confusing.
    c. My knowledge remains relatively consistent after CAM assignments; I don't see a substantial increase.
    d. I generally experience a noticeable increase in knowledge after CAM assignments, though not always significant.
    e. My knowledge significantly increases after completing the weekly CAM assignments; I gain a deep understanding of the subject matter.
15) To what extent do the lectures, labs, and daily CAM assignments complemented each other?
    a. The lectures, labs, and CAM assignments appeared to be entirely independent, lacking integration and making it difficult to grasp a holistic understanding of the material.
    b. The lectures, labs, and CAM assignments seemed somewhat disconnected, making it challenging to see how they complemented each other.
    c. The lectures, labs, and CAM assignments had some connections, but they often felt like separate components rather than a cohesive learning experience.
    d. While there was some alignment between lectures, labs, and CAM assignments, there were occasional gaps or inconsistencies.
    e. The lectures provided a solid theoretical foundation, the labs offered practical application, and CAM assignments reinforced both aspects seamlessly.

All questions from college surveys

Questions 1-5 were only included in the survey corresponding the lab of the part that students just completed (ex: Base, Piston Block, Valve Block and Piston, Wheel, Engraving).

1) Score week one (machine base) of lab on a scale of 1-5 based on how much that lab contributed to your knowledge of design for CNC?
    a. 1 - did not contribute to my learning
    b. 2
    c. 3 - partially contributed to my learning
    d. 4
    e. 5 - was essential to my learning
2) Score week two (machine piston block) of lab on a scale of 1-5 based on how much that lab contributed to your knowledge of design for CNC?
    a. 1 - did not contribute to my learning
    b. 2
    c. 3 - partially contributed to my learning
    d. 4
    e. 5 - was essential to my learning

3) Score week three (machine valve block and piston) of lab on a scale of 1-5 based on how much that lab contributed to your knowledge of design for CNC?
    a. 1 - did not contribute to my learning
    b. 2
    c. 3 - partially contributed to my learning
    d. 4
    e. 5 - was essential to my learning
4) Score week three (fly wheel) of lab on a scale of 1-5 based on how much that lab contributed to your knowledge of design for CNC?
    a. 1 - did not contribute to my learning
    b. 2
    c. 3 - partially contributed to my learning
    d. 4
    e. 5 - was essential to my learning
5) Score week three (engraving) of lab on a scale of 1-5 based on how much that lab contributed to your knowledge of design for CNC?
    a. 1 - did not contribute to my learning
    b. 2
    c. 3 - partially contributed to my learning
    d. 4
    e. 5 - was essential to my learning

All other questions (5-15) were included in every survey

5) Each week, I know what is fully expected of me in this class?
    f. Strongly disagree
    g. Disagree
    h. Neutral
    i. Agree
    j. Strongly agree
6) How confident are you in your ability to not only operate CNC machinery but also intuitively design components or products with considerations for CNC manufacturing techniques?
    a. Not confident
    b. Slightly unconfident
    c. Moderately confident
    d. Confident
    e. Very confident
7) Are the directions from the lab instructors clear?
    a. Not clear
    b. Slightly unclear
    c. Moderately clear
    d. Clear
    e. Very clear
8) To what extent do you want your lab instructor to ask you more questions (to invoke thinking) rather than providing you with the solutions/explanations during your lab sessions?

a. Strongly prefer my lab instructor to ask more questions to stimulate my thinking and guide me towards finding solutions on my own.
b. Prefer my lab instructor to mostly ask questions, but provide explanations or solutions when I struggle to make progress.
c. Neutral, I am comfortable with a balanced approach of both asking questions and providing solutions/explanations.
d. Prefer my lab instructor to primarily provide solutions/explanations, but ask questions occasionally to check my understanding.
e. Strongly prefer my lab instructor to directly provide solutions/explanations without asking many questions during lab sessions.

9) To what extent does your knowledge of a subject matter increase after lectures?
   a. My knowledge significantly increases after lab sessions; I gain a deep understanding of the subject matter.
   b. I generally experience a noticeable increase in knowledge after labs, though not always significant.
   c. My knowledge remains relatively consistent after lab sessions; I don't see a substantial increase.
   d. I occasionally feel my knowledge decreases after labs, as challenges in the exercises may be confusing.
   e. My knowledge typically decreases after lab sessions; I struggle to grasp the concepts covered.
10) Please explain why it was easy or hard to receive help while in the lab.
   a. This was a short answer question
11) To what extent does your knowledge of a subject matter increase after lectures?
   a. Not at all, I still feel lost
   b. Somewhat, I understood about 50% of the content
   c. Moderately, I understand some but have some questions
   d. Mostly, I have one or two questions
   e. Significantly, I understood the entire lecture and have no questions
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   a. Strongly disagree
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