University of Staffordshire

Research and Development of Resources to Promote Practical Learning Opportunities and Engineering Skills Related to CNC Machinery to University Students.

BEng in Mechanical Engineering

School of Digital, Technologies and Arts

Individual Engineering Project

ENGG61010

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Abstract

This report covers the issue of a practical skills gap in the newer graduating engineers. This issue and its consequences were discussed in detail, then as a solution, a curriculum support package was developed. This solution aimed to fill the skills gap of engineering graduates and provide technical machining experience with a CNC lathe so that they can confidently use machinery and are encouraged to use it in the future. This package covered the design, programming, and manufacturing of a spinning top, as well as two questionnaires to measure students' knowledge retention. A trial run of the curriculum support package was performed with two students. The results of this trial run were that the package is successful, and both students reported that they had learnt from the project and gained practical experience.

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Contents

List of Figures

List of Tables

List of Abbreviations

IET	The Institution of Engineering and Technology
CEng	Chartered Engineer
CNC	Computer Numerical Control
Design and Technology	D&T
Personal Protective Equipment	PPE
VARK	Visual Aural Read/Write Kinaesthetic
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacture
BTEC	Business and Technology Education Council
A-Level	Advanced Level
AHEP	Accreditation of Higher Education Programs
IPDS	Initial Product Design Specification
IMechE	Institution of Mechanical Engineers
G-code	Geometric Code

Chapter 1: Introduction

1.1 Project Rationale

In recent years, there has been a Noticeable skills shortage among newer and graduate engineers, as confirmed by Millar (2018), who wrote in an IET (the institution of engineering and technology) discussion about the necessity of practical skills for engineering: 'CEng now needs a master's degree, but master's students come out with no practical skills.' This means that new and graduate engineers do not have experience or the necessary knowledge in practical subjects that are required by employers. This skills gap leads to a large amount of wasted time by employers re-educating their engineers in practical subjects in which they should be experienced from their undergraduate or postgraduate degrees.

Practical Knowledge is necessary for all fields of engineering, including non-practical areas such as design. This is because without having practical experience and practical knowledge, the engineer will not be able to fully understand the limitations and real-world applications of materials, machinery and manufacturing processes. This project aims to address this issue by creating a teaching aid in the form of a curriculum support package that universities can use to provide learners with practical knowledge, experience, and skills. This report will cover the issue described in greater detail, research on topics such as learning theories, lesson plans to promote the best retention of knowledge, and the changes in how practical subjects are taught and implemented throughout school and university.

This report will also include a teaching aid in the form of a curriculum support package, which details a workshop that could be held by universities where the student would go through a process of designing, programming and machining a spinning top. This will include a description of how the project was managed, including project costs, how the curriculum support package was adapted and updated to be as efficient as possible, as well as a description of a trial run of the curriculum support package being used by a small group of students to find any overlooked areas or faults.

This curriculum support package could include lessons focusing on materials selection depending on the length of time available for the module and any previous modules covering materials selection or material properties. The materials selection would consist of informing the students of what materials the university or school has to offer, then each material's properties and price, through the process of elimination, the best material for the project could be chosen by the students individually or the class as a whole.

While this curriculum support package will only cover the design and creation of the spinning top itself, the module could lead to other areas of study such as physics behind spinning tops which itself could lead into the physics of gyroscopes and their uses in engineering along with other areas like material finishes and anodization, for example.

Defined aims and objectives can be found later in the document.

Chapter 2: Project Management

This project was managed using a Gantt chart to schedule tasks by assigning them deadlines and tracking their progression. This chart is attached in the appendix (see Appendix 8). The management of this project also required liaising with the technical skills specialist to arrange workshop sessions to experiment and create prototype spinning tops in the most efficient manner possible. This meant arranging workshops for times when the technical skills specialist was free without any interference from other modules or examinations, and having to reschedule workshops around sickness and other last-minute changes.

This project also required liaising with students to arrange a trial run of the curriculum support package. This required arranging meetings to run through different sections of the curriculum support package when both students were free.

2.1 Double Diamond Management Structure

A double diamond planning structure has been adapted to this project and is attached below to provide a framework for the design process. This project management tool

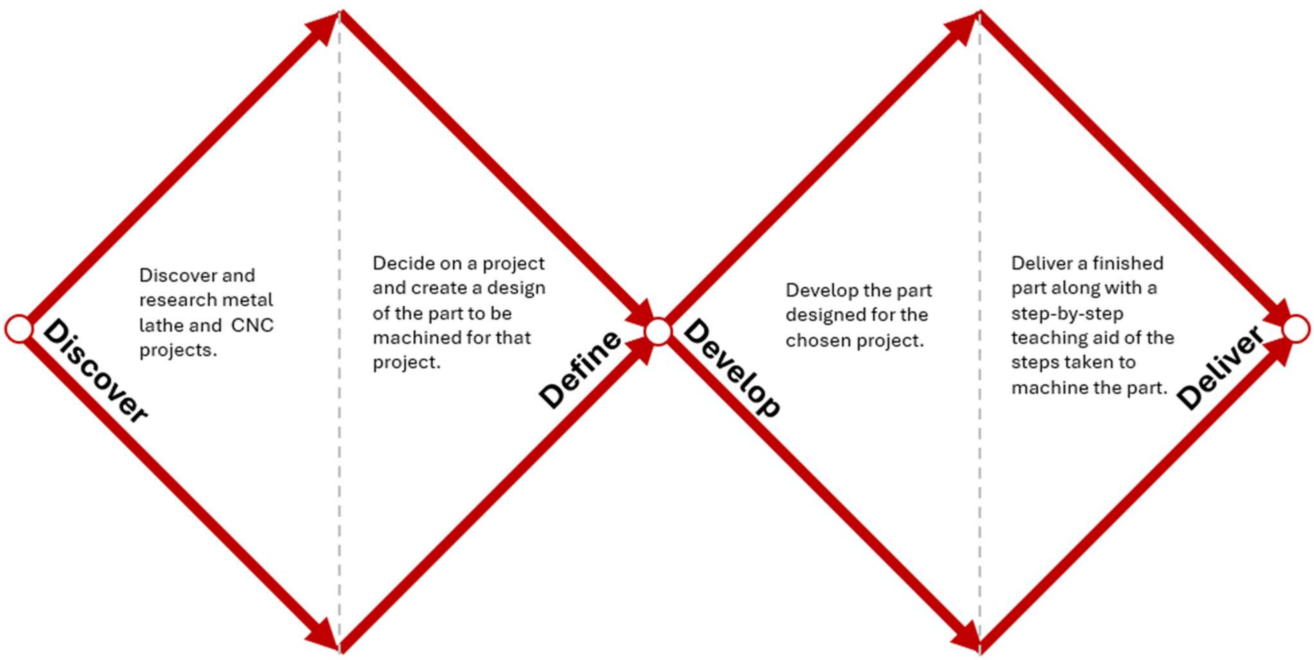

Figure 2-1 Double Diamond Management Structure.

was used along with the Gantt chart to create a clear, straightforward plan for undertaking this project.

2.2 Project Costs

The only costs of this project were material costs, which were covered by applying for financial support from the university. These costs amounted to £10 for the materials used for all the spinning top prototypes and the spinning tops manufactured by the students undertaking the trial run.

Chapter 3: Health and Safety

The health and safety issues and risks involved in this project were considered and assessed, and suitable solutions were then provided to ensure the safety of the author and any students undertaking the project suggested in the curriculum support package. These risks were assessed and neutralised by creating a risk assessment and reading any existing risk assessments for the workshop and any machines used, then following the safety protocols mentioned within those risk assessments. Risk assessments were made for the workshop containing the CNC (computer numerical control) lathe, the CNC lathe itself, and also for the CNC milling machine, which was not used but was considered to be used.

The safety protocols which were followed to ensure the safety of the students and the instructor were: to ware all the correct PPE (personal protective equipment) such as eye protection whenever using any of the machines, to ware overalls at all times when in the workshop, to ware steel toed shoes or steel toe protectors on top of regular shoes at all times in the workshop, to use barrier cream whenever using cutting fluid on the machine, to have long hair tied up at all times when using the machine.

Chapter 4: Ethical Considerations

Before beginning this project, the ethical impact and any ethical implications were given consideration. This was done using the code of conduct of the professional body chosen for this project, alongside filling out and submitting an ethical disclaimer form with the university, this form declared that no ethical issues had been found. The disclaimer form can be found in Appendix 1.

The IET's 'rules of conduct' were thoroughly inspected to identify any possible ethical implications not covered by the university's ethical disclaimer form. It was confirmed that this project poses no ethical risks to any persons or their information.

If any ethical risks or issues were to be found in the project, a research ethics application would have to be submitted to apply for ethical approval from the university before the beginning of the project.

Steps were taken to guarantee good ethical practice while working on this project, such as when working in the workshop, there is constant supervision by the technical skills specialist, so that the standards of good and safe use of the machine are maintained. Another step taken to remain ethical was to maximise the machining efficiency to minimise the power and material waste, which meant using parts from the scrap bin when possible and using stock that was as close to the desired diameter as possible, along with other methods.

Chapter 5: Research

For this project, many areas of teaching and learning needed to be researched to fill knowledge gaps and provide evidence and explanation for the problem that this project aims to challenge.

The practical project at university aims to reach the guidelines of the professional bodies, such as the Engineering Council. These guidelines, called AHEPs (Accreditation of Higher Education Programs), must be followed when marking and teaching the course to be accredited by the Engineering Council. The purpose of the project is to get the students using the tools and machines to manufacture an artefact.

A diverse group of students attend the university with many different learning preferences. To ensure that the curriculum support package best engages students, learning theories and lesson plans needed to be researched.

5.1 Learning Types

Research was conducted on different learning types and theories so that the teaching aid delivered in this project could, in the best and most efficient way, convey the teachings to all students from diverse backgrounds and prior education, and maximise knowledge and skill retention.

VARK is a model introduced by Neil Fleming back in 2006. It suggests that each person has a preference for how they best learn; these preferences are divided into four categories:

- V – Visual, these learners learn by watching videos and seeing images and graphics. Visual learners prefer to use flowcharts and graphs when learning.
- A – Aural, these learners prefer to listen to spoken words, such as a teacher speaking in a lecture; they learn best from listening to seminars, discussions or recorded lectures rather than anything written.
- R – Read/Write, these learners learn best from written words, whether that's writing notes or reading textbooks, handouts, and presentations.
- K – kinaesthetic, the final type of learner is one who learns by doing or interacting; they prefer a hands-on experience, which could be the use of models or props when teaching or just learning as they go. This type of learner, for obvious reasons, learns worst in a classroom or lecture setting.

These are the four categories of learners, however, the VARK model also describes how not everyone fits into just one category. This is because there are learners who are unimodal, meaning one mode of learning or multimodal which means that they learn best through two or even three modes of learning.

A study performed by Prithishkumar (2014) researched the distribution of different VARK modalities among 91 first-year undergraduate medical students. This study showed a result that the K modality is very common, being the most common preference for unimodal students, and when the students were multimodal (86.8%), the most common preferences were AK, AR, and VK. This study and ones like it are important to this project as it shows that many students are if not solely then partly kinaesthetic learners, this is important as most methods for teaching including practical subjects rely so heavily on lecture and classroom learning not at all adapting to kinaesthetic learners whereas the results of many studies suggest that adapting more kinaesthetic learning to classroom teaching could improve student's learning drastically.

Prithishkumar (2014) goes on to say, 'Awareness of these learning preferences amongst students necessitates a shift from the traditional large group teacher-centric lecture method to an interactive, small group student-centric approach incorporating various teaching learning strategies.' This is an excellent point and is exactly what this project aims to incorporate into the teaching aid so that learning and knowledge retention are maximised.

5.2 Lesson Plans

This curriculum support package encompasses all the necessary steps to manufacture a spinning top. To ensure that students do not feel overwhelmed with information, the lessons must be carefully planned according to a few established criteria. Research conducted on a book by Tobin (2012) focused on the best ways to retain information and learn from training programmes. Although the training programmes discussed were intended for jobs rather than schools, this curriculum support package aims to move away from typical classroom learning, so the methods proposed by the author should still be applicable. The techniques outlined by Tobin (2012) will aid in lesson planning, ensuring that all these methods are incorporated into the programme. Below are the techniques from Tobin (2012) that have been suitably adapted into the criteria that need to be addressed in the lesson plans.

- Before the teaching starts, have a discussion with the class about what is expected for them to learn from this program and how it can be used in future jobs and personal projects. Discuss the layout and plan for the program, outlining the key points that need to be learnt, those being the CAD (computer-aided design), the programming, the machine setup, and finally the CAM (computer-aided manufacture).
- Write down with the class the key objectives of this program and ask them what they want to learn from this program.
- Convey to the class that it is imperative that they feel free to ask questions as not only will it increase that person’s ability to learn but also the rest of the class. Optionally supply the students with an email or means of communication to answer any questions that may arise outside of the planned lesson time.
- At the end of the program, hold a final lesson consisting of a conclusion or a recap of the entire program and all the objectives. Detail what was done to reach each objective and give suggestions on what someone could do in their free time to cover any objectives they don’t feel they have fully achieved. Finish off by informing the class about resources or knowledgeable people they should seek out if they desire to continue beyond what was covered in the program.

These criteria are adapted from the methods used by Tobin (2012) to ensure learning are small, simple engagement-enhancing tools which aren’t too difficult to implement and are recommended to be added to the lesson planning when using the curriculum support package. However, other criteria should be considered, such as the learner's prior knowledge of CAD, CAM, and machining. For example, if students have already conducted a module covering in depth how to utilise CAD software, then that portion of the program does not need to be focused on.

5.3 National Curriculum

The national curriculum is a set of guidelines for what subjects must be taught and what must be taught within those subjects at different key stages. For this project, the national curriculum needed to be researched to understand what is currently taught in schools and how.

Due to the university's diverse student body, some but not all students would have studied in England and Wales before university, meaning that they were taught using the national curriculum. This makes it important to know what is covered in the national curriculum and what experience and knowledge a large number of students would have received. The university does not require engineering students to obtain a BTEC (Business and Technology Education Council) or A-levels (advanced level) in engineering specifically, which means that a student who has done any other college course could attend the engineering university course. This is why it is important to look at earlier education under the national curriculum to have a proper baseline of the students' abilities before university.

The following analysis was performed on the current national curriculum for Design and Technology (D&T).

The description of design technology: 'Design and technology is an inspiring, rigorous and practical subject. Using creativity and imagination, pupils design and make products that solve real and relevant problems within a variety of contexts, considering their own and others' needs, wants and values. They acquire a broad range of subject knowledge and draw on disciplines such as mathematics, science, engineering, computing and art. Pupils learn how to take risks, becoming resourceful, innovative, enterprising and capable citizens. Through the evaluation of past and present design and technology, they develop a critical understanding of its impact on daily life and the wider world. High-quality design and technology education makes an essential contribution to the creativity, culture, wealth and well-being of the nation' (Department for Education, 2013)

This description makes it seem that this 'practical subject' will teach the students what they need to know about design and technology and then put that into practice 'make products that solve real and relevant problems' however upon further analysis of the requirements for the subject it became apparent that this description overemphasised the knowledge and experience the students would receive on the practical side.

The four subheadings detailing the required teaching areas for the current key stage 3 design and technology subject, Department for Education (2013):

- Design

    - This list details areas of design that need to be focused on, such as research, problem solving, creation of design specifications, generating creative ideas, avoiding stereotypical solutions, and developing detailed sketches and design plans.
- Make
    - Make details two areas that must be taught: tool selection and material selection.
    - In this ‘make’ section, however, it is important to highlight that there is **no mention** anywhere of practical skills, creation of any kind. All this ‘make’ section requires is that the student choose tools and materials. This means that the school that is running this subject could lead a very thorough workshop and have the students using many different kinds of tools, however this is not required and a school would also be allowed to completely move past this lesson, which means that the students would miss out on essential practical knowledge and experience if they choose to undertake a practical career like engineering. This is unfortunately a trend that often carries through higher education also, this author theorises that this lack of early education causes a difficulty in later life to learn the simpler beginner practical skills, which in turn leads to a practical skills shortage in newer engineers.
- Evaluate
    - This list of required areas includes analysis of others' past work, investigation of new technologies, evaluation and refining of students' “ideas” against a specification, and understanding of developments in D&T.
- Technical knowledge
    - This subheading requires students to understand and use material properties and structural elements to get functioning solutions, understand mechanical systems that produce changes in movement and force, understand advanced electrical systems, and apply computing to embed intelligence in products.
    - However, once again, there is no mention of using any of this knowledge other than ‘apply computing’, which is by many considered a base skill;

this means that the students learn about practical subjects and skills, but are not required to use, practice, or acquire any of them.

This analysis of the national curriculum shows that even if the student chooses D&T as an elective, they will not possess a lot, if any, practical skills, which means that a student selecting engineering at university without an engineering background would be subject to naiveté in many areas that those from an engineering background find fundamental such as simple measurements and tolerancing. This would result in the student having to focus on learning the basics of engineering while studying courses designed to elevate understanding of engineering principles to intermediate and advanced levels.

5.4 Project Product Selection

The last area to be researched, before the teaching aid and curriculum support package could be designed and created, is the product to be made in the project itself. The product selection is important because it is integral to the project as a whole, and if it is not engaging to the students, then the students will not be motivated and will not learn as well as they could. The criteria it needs to hit are shown in the decision matrix below. This project aims to allow students to use the CNC lathe and inspire its further use, so the part must be, at least partly, manufactured on the lathe, if not fully. Each of the following products used in the decision matrix was chosen with this specific requirement considered.

5.4.1 Possible Products

- Adjustable/Silent dog whistle, see Figures 5.8 and 5.7.
- Pen, see Figure 5.1.
- Engineer’s scriber, see Figure 5.2.
- Spinning top, see Figures 5.4 – 5.6.
- Cryptex, see Figure 5.13.
- Paper weight, see Figures 5.9, 5.10, and 5.14.
- Chess piece, see Figure 5.11.
- Ring, see Figure 5.12.

- Cylindrical whistle, see Figure 5.3.

Figure 5-2 Engineers Scriber.

Figure 5-1 Pen.

Figure 5-8 Dog Whistle.

Figure 5-7 Dog Whistle 2.

Figure 5-6 Spinning top.

Figure 5-5 Spinning Top 2.

Figure 5-4 Spinning Top 3.

Figure 5-3 Cylindrical Whistle.

Figure 5-12 Ring.

Figure 5-11 Chess Peice.

Figure 5-9 Paper Weight.

Figure 5-10 Paper Weight 2.

Figure 5-14 Paper Weight 3.

Figure 5-13 Cryptex.

Table 1 Project Product Decision Matrix.

Idea	Simplicity (4)	Machining time (5)	Is it Interesting? (2)	Is it Open to Creativity? (3)	Utility (1)	Machine ability (5)	Efficient use of material (3)	Total
Adjustable/Silent dog whistle	4	4	5	2	8	7	5	110
Pen	8	7	5	6	10	6	5	150
Engineer's scriber	10	9	3	6	8	9	7	183
Spinning top	10	9	7	7	2	9	6	185
Cryptex	1	1	10	6	6	2	4	75
Paperweight	4	8	6	10	7	10	6	173
Chess piece	9	9	4	6	2	8	6	167
Ring	9	9	5	8	3	10	5	183
cylindrical whistle	5	5	5	2	4	5	4	102

Table 2 Decision Matrix Key.

	Scoring criteria (10 – 1)	Weight, seen in brackets (5 – 1)
High	10	5
Low	1	1

The results of the decision matrix, seen in Table 1, are that the spinning top was the highest scoring idea, meaning that the spinning top is the product to be made for the project. The spinning top scored high in most categories, those being:

1. Simplicity: This is testing how simple the basic shape and components are.
2. Machining time, this is just scoring the product on how long it takes to machine. If it takes too long to manufacture, then it can't be used for the project, as there is a maximum time limit of 30 minutes for each student to use the machine.

3. Is it interesting? This category is scoring against how interested and engaged the students will be in making this part. If the students are uninterested and not engaged, they will not be motivated to learn.
4. Is it open to creativity? This category scores how much room there is in the part's design for the students to use creativity when creating a design. This is important to engage the students further and inspire them to innovate and think differently from their cohort.
5. Utility, how useful is the part? Why make a part that will not be used? Making the product useful or fun would also increase its sustainability, as there is less of a chance it will be discarded immediately.
6. Machineability, this category scores on how easily the part could be machined.
7. Efficient use of materials. This final category covers how efficiently the part could be machined, for example, a pen would score low because a lot of material is wasted from making it hollow, whereas a scriber would score high because it only removes the material from the tip.

Chapter 6: Aims

This project aims to fill the skills gap of engineering graduates and provide technical machining experience with a CNC lathe so that they can confidently use machinery and are encouraged to use it in the future.

Chapter 7: Objectives

The objectives for this project are:

- To develop a step-by-step teaching aid that caters to different VARK learning theories, allowing an inexperienced user to design a CAD model for the piece, to be accomplished by 01/04/2025
- To develop a step-by-step teaching aid that caters to different VARK learning theories and allows an inexperienced user to understand and program the tool pathing in the CNC software, to be accomplished by 01/04/2025
- To develop a step-by-step teaching aid that caters to different VARK learning theories that allows an inexperienced user to understand how to use the CNC lathe to machine a similar or the exact piece, to be accomplished by 01/04/2025
- To hold a trial run of the curriculum support package with students from the university as a proof of concept, to be accomplished by 13/04/2025

Chapter 8: Deliverables

The deliverables of this project will be:

- A physical product produced by the CNC lathe project.
- A step-by-step teaching aid on how to design, program, and machine the said product.
- An in-depth report on the current engineering technical skills gap and the importance of technical hands-on skills in the engineering career path.

Chapter 9: IPDS (Initial Product Design Specification)

9.1 IPDS for the Curriculum Support Package.

Performance

This curriculum support package will be designed to supplement a module for university and higher education to educate students on the practical aspects of engineering and give them practical experience. It will do this by supplying the student with a project to machine a spinning top and provide all the instructions on all the parts of the process from start to finish.

Economy

This curriculum support package will provide advice and examples on how to design the part to be an efficient process meaning that it is as cost effective as possible by limiting the machining time and power usage while also at the same time reducing material waste.

Quantity and Manufacturing Facilities

This curriculum support package should be available digitally and instantly to any customer; however, the customer will require the appropriate facilities, equipment and software. That being: a CNC lathe or other machine to adapt the curriculum support package to, appropriate facilities to house that machine, a suite of computers with CAD software so that the students can design their part.

Customers

Customers for this product would be universities and other higher education institutions teaching engineering, looking to properly equip their students with practical knowledge for their future careers.

Competition

The competition for this product would be other curriculum and module support packages offered by institutions such as IMechE (Institution of Mechanical Engineers) and the Design and Technology Association.

Environment

The curriculum support package requires CNC machinery, a safe workshop, a suite of computers capable of using CAD software, and optionally a classroom where to teach the theory; however, this may be done in the computer suite.

Maintenance

This product will have to be maintained by the user in the sense that they would have to adapt the program to their specific time, equipment, and knowledge constraints. For example, the user would have to adapt the program to suit their students' timetables, and the technical specifics of the machine would have to be adjusted if a different CNC lathe is used. Prior knowledge, meaning that if the students are already very familiar with CAD, then that portion of the program may be drastically shortened.

Materials

The user will have to provide the materials used during the project; however, the program will suggest appropriate materials.

Ergonomics

The product is designed to adapt to all learning styles of students and even includes a questionnaire so that the teaching plan can vary according to the student's current knowledge and experience.

Packing & Shipping

The product would be packaged digitally and would be available instantly.

Safety

The curriculum support package contains advice and instructions so that the project is carried out as safely as possible; however, physical safety measures and protocols should also be taken into consideration, such as constant supervision by the technical skills specialist when using the machine and proper use of personal protective equipment (PPE).

Shelf life/storage life

This product should last and remain relevant until new technology is introduced, making all the techniques used in this program redundant or obsolete.

Personnel

This curriculum support package requires students that are willing to learn and use the machinery, teaching staff that is either already knowledgeable on the software and machinery or teaching staff that can learn these lessons before teaching, and lastly this program requires a technical skills specialist that is knowledgeable and experienced in using the machinery in a correct and safe manner.

9.2 IPDS for the spinning top.

Performance

The performance of the spinning top would be as a fidget toy that would spin for around a minute.

Economy

This product will be made cost-effectively by reducing waste material and designing for efficient manufacturing, reducing power and time usage.

Quantity and Manufacturing Facilities

This product should be a made-to-order individual item, as the students will be manufacturing it for themselves.

All the parts of the product can be made in-house and at the same time, on the same machine.

Customers

The customer of this product would be the student who has designed, modelled, programmed, and machined this product.

Competition

This product would have to compete with many brands, including Foreverspin, Vorso Spin, and any other spinning top company.

Environment

This product would most likely be subjected to lots of varied environments, as it could be carried in the user's pocket and used anywhere. It would obtain wear on the tip from spinning and friction, and on the "handle" part due to handling.

Size

This product should be no larger than 50mm in height to reduce material costs and no more than 35mm in diameter due to the size of the stock material.

Weight

This product should not be heavy. Due to the material and size of the billet used the result should not be more than 100g.

Maintenance

This product should not require maintenance.

Materials

The materials used for this product would be a free-machining aluminium alloy 2011 T3. This material was chosen because aluminium is a soft, lightweight metal, and this alloy contains small amounts of copper and lead to improve machining properties.

Ergonomics

This product should be straightforward, easy to use and comfortable to handle.

Appearance

This product is very customisable at the design stage and due to the user designing and machining the final product, it will always be attractive to the user.

Finish

The finish on this product could be burnished metal straight off the lathe or polished, this depends on the user, other finishes could also be applied for example anodising and knurling on the handle.

Packing & Shipping

This product will not be sold, so it will require no packaging or shipping.

Safety

When machining the part, all safety procedures of the workshop will be followed, and all students will wear appropriate PPE

Shelf life/storage life

This product will have a lifetime guarantee as it will be made of a resilient material and will not be put under enough stress or use to ever fail in its lifetime.

Personnel

The student will have to be trained on the CNC lathe before machining the product, the technical skills specialist will also need to be present to supervise

Chapter 10: Curriculum Support Package Development

There is a problem that newer graduate engineers do not possess the necessary technical or practical knowledge or experience. This means that these engineering companies need to spend more money to teach their employees something which they should already know. Even if a job does not contain a physical or practical aspect, it may require knowledge that is not obtained by reading a book or studying but by understanding through practical experience.

This skills gap may have been caused by universities and lower education no longer requiring any practical experience or knowledge to gain a degree in engineering, which is arguably a practical subject. If an engineer is one who solves real-world problems using maths and science, why would an understanding of maths and science be needed but not an understanding of the real world? However, relaxing the requirements to gain a degree in engineering is not the only cause for this skills gap issue; another culprit is the advances in technology. Similar to how past crafts and skills have died out due to technology making them redundant or inefficient, an engineer with practical skills is needed less and less often due to emerging technology and machinery, which is either more convenient, faster, more efficient, or more precise. However, although these practical jobs are becoming less common, there are still many which are integral to society, yet learning institutions are starting to decrease or even dispose of the need to gain this practical experience. Practical knowledge and experience are also essential to all aspects of engineering, not only physical or hands-on disciplines. Having practical knowledge and experience supplies an engineer with essential common sense, from knowing the physical limitations of materials to knowing when a design would be impossible to manufacture.

To combat this issue, a small, minimum 5-day project, which could be used to supplement a module or university course, was created. This curriculum support package would offer a product, on which the project is based, as well as three step-by-step, detailed teaching aids that instruct students on how to design, program, and machine this product on an XYZ Proturn RLX 355, shown in Figure 10.1. The package also includes recommendations and prototype lesson plans to create a lesson plan that caters to all learning preferences and ensures student engagement and knowledge retention.

This curriculum support package will supply the students with the practical and hands-on experience and knowledge to allow them to develop and expand on their own in the future.

Figure 10-1 XYZ Proturn RLX 355 CNC Lathe.

10.1 Lesson Planning

Using the lessons from learnt from Tobin (2012) in the research chapter, the following prototype lesson plan and recommendations have been provided.

When creating a lesson plan for this program, the sessions must not exceed two consecutive hours, as any longer session may lead to boredom and loss of the student's attention.

This curriculum support package could be enacted as a weeklong workshop, meaning five days. This could consist of two hours of theoretical lessons in the morning, then after a 30-minute break, three hours of practical lessons with a five-minute break after the first two hours.

These days could be split in different ways, such as theory in the morning and practice in the afternoon or select specific theoretical or practical objectives to cover on each day, such as the prototype plan below.

- Day 1: Have the students complete the questionnaire to provide a baseline for teachers so that the lessons and focus on different subjects can be adjusted for the class's prior knowledge and experience. Introduction to the workshop, theory about the machine, and theory about the CNC software.

- Day 2: Induction on the machine, allow the students to use the machine to make a trial piece, and start and finish the initial design phase.
- Day 3: Start and finish the CAD.
- Day 4: Start and finish programming, start sending students to the lathe to start machining
- Day 5: Complete the machining and have the students complete the questionnaire to show learning and growth by comparing the answers from the questionnaire from day 1.

The above lesson plan is a prototype that could be built upon, this means that the topics covered on each day may have to be altered or moved around to allow enough time for each task and the user of the curriculum support package would have to take facilities, time, and personnel into consideration when writing an official lesson plan.

This means that instead of a five-day workshop, it could be changed to a ten-day workshop to allow more time for each task to be taught in more depth. This would all depend on the number of students and the instructor planning the lessons. The instructor may also need to either take a short course or go through the program themselves first to familiarise themselves with it, this is so that they can answer any questions that may arise and be able to supervise and correct mistakes with the CNC programming section.

10.2 First Prototype Spinning Top

Below is a detailed account of the process of developing and machining the first prototype spinning top. This was then followed by another prototype, which used a different design. Both reports were used to create the teaching aids. The teaching aids not only used the steps followed in these prototyping sessions but also the lessons and corrections discovered through mistakes during these sessions.

10.2.1 Report

The stock bar used for this prototype was made of free-machining aluminium alloy 2011 T3 and was 38.5mm in diameter. The dimensions of the spinning top are seen

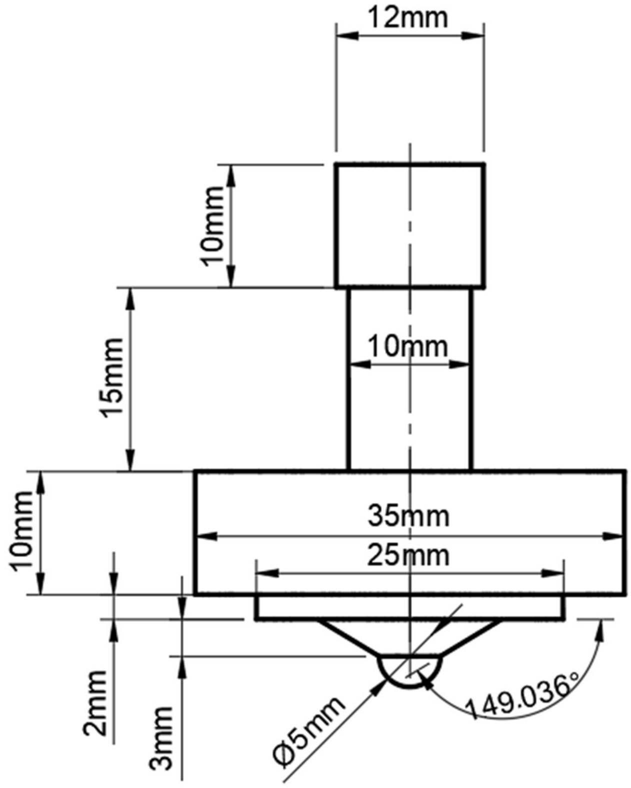

Figure 10-2 Spinning Top Prototype Dimensions.

below in Figure 10.2.

These dimensions were chosen specifically so that the top could be machined all in one go without removing the piece from the chuck. This meant the 'handle' and grip could not be too thin to prevent the spinning top from breaking off during manufacturing. This was a possibility because the faces would be cut using a groove, rather than turning down, which exerts more force onto the piece at the thinnest point. These dimensions were chosen on the day as an experiment testing whether this diameter is sufficiently thick as not to critically fail. The amount of stock sticking out from the chuck was 60mm. This is because the spinning top is 42.5mm long, rounded up to 45mm and an additional 3mm, which is the thickness of the parting off tool. This is so that it can part off without cutting off the top of the grip by 3mm, but also so that it doesn't have to unnecessarily part off the whole diameter of the stock. This also allows for a chamfer to be made on the grip's edge. This leaves 48mm, which was rounded up to 50 for simplicity and an additional 10mm for safety coming out of the chuck. This is why 60mm is the length of the stock sticking out of the chuck.

The way the spinning top was manufactured was to start with the point and turn down the steps and ballpoint, then turn down the length of the bar to 35mm from 38.5 so that the surface is all even. After that, using the grooving tool, wide grooves were cut forming the handle and grip, the parting-off tool was then used to part off the finished spinning top.

10.2.2 Pros

The pros of this first attempt were that the thickness of the handle and grip were well estimated and easily handled the force of making the grooves while still spinning nicely. The ballpoint and steps were correctly designed, programmed and cut.

10.2.3 Cons

The cons of this first attempt were that the grooving tool left a disk in between the two grooves, the handle and the grip, see Figure 10.3. This was due to a miscalculation and wrong input to the program. In the next attempt, the program was altered so that the mistake was corrected, to ensure a disk did not form again, an overlap was made between the two grooves; however, this again caused a disk. During the overlap of the grooves the disk was still produced due to how the grooving tool works, by cutting from the middle outwards, when it came to the overlap the disk was so thin it bent out of the way, this meant that despite it later getting cut off and separated it was still created during the manufacturing process meaning the program could be further improved. Unfortunately, there was another mistake found in version 2, which was that the parting-off tool came in at too harsh an angle so that it collided with the widest part of the spinning top; this was a catastrophic failure. This mistake was fixed partway through the program by adding a tool position command before starting parting off.

Figure 10-3 First Failed Prototype Spinning Top.

For the third and final attempt of the first design the grooving was approached differently, instead of two grooves right beside each other it was treated as a long groove with another deeper groove within it. This meant that no disk was made as the material for the disk was already removed before the second groove was cut. The parting-off issue was also solved using the same fix as before, by adding a position command before the parting-off. By this third attempt, a successful and most efficiently machined spinning top was produced.

Despite having found the spinning top's most efficient and correct method of manufacture, each one of the tops still contained the same flaw, they were left with small 'nibs' from the parting off where the material got too thin and broke off before it was fully cut away, see Figure 10.4. To solve this problem, each top would have to be either finished by hand, see Figures 10.5 and 10.6, or put back into the chuck backwards and quickly faced off. This could be an issue as it took approximately 30 minutes to write the program, check it, and then machine the part. This time did not include cleaning time. This means there would be no time to remove this 'nib'; however, if the program was written and checked at an earlier time before the machining time slot on the lathe, then the time would be drastically shortened, and there would be plenty of time to finish off the spinning top.

Figure 10-4 Spinning Top Displaying 'Nib'.

Figure 10-5 Finished Spinning Top Prototype.

Figure 10-6 Finished Spinning Top Prototype Displaying Removed 'Nib'.

10.2.4 Design for manufacture and limits of the design.

This design had to be made with manufacturing in mind for several reasons.

1. The stock bar had a certain diameter; this meant that the widest part of the top must be smaller or the same diameter as the stock, ideally, it would be at least 1mm smaller to make the surface even and remove any marks on the stock.
2. The thickness of the thinnest parts of the handle and grip must be thick enough so that it does not break off under the forces of the grooving tool and the high speeds of the lathe.
3. Any curves on the spinning top must be fixed radius arcs, not splines, as they cannot be programmed in the software.
4. The design cannot have material that needs to be removed in places that cannot be reached by the lathe without special tools. Ideally, the tool changes should be as few as possible, 2-3 maximum.
5. There must be no grooves that are deeper than the grooving tool can go, and similarly for the parting off tool
6. There must be no grooves thinner than 3mm, as this is the width of the tool.

If these conditions are met when designing, the spinning top's profile is completely up to the designer's creativity and imagination.

10.3 Second Prototype Spinning Top

10.3.1 Report

For the second prototype spinning top, a curved design was made as seen in Figure 10.7. This second design had a thinner weighted segment at the bottom, a radial curve at the point, and a radial curve on the handle. This meant that it had to be manufactured differently from the first prototype. Because the second design had a curve on the handle as well as on the point, this meant that the handle would have to

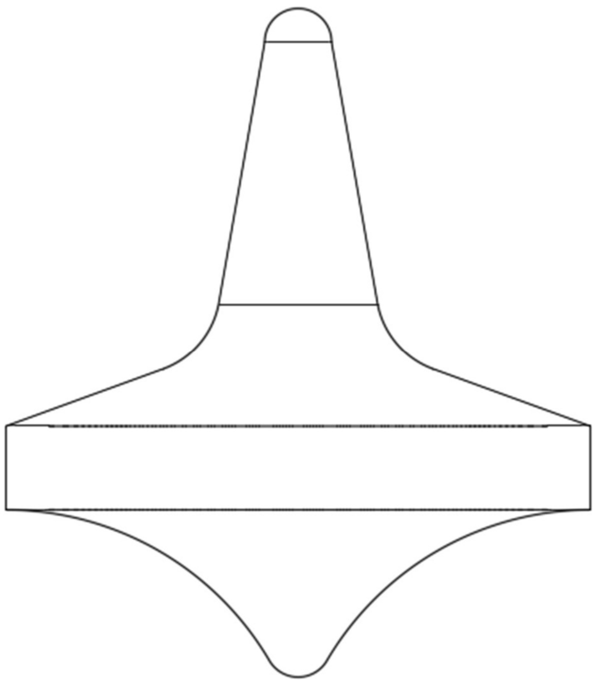

Figure 10-7 Design for the Curved Spinning Top Variation.

be turned first, then parted off, turned around in the chuck, and finally somehow re-mounted so that the point could be turned. This was a problem because there was not enough area on the spinning top to be safely held in the chuck without the tool hitting the chuck during the operation.

To manufacture the spinning top in this way, a method of holding or stabilising the handle in the chuck would need to be made. However, after discussing and deliberating over many different ideas with the technical skills specialist, it was decided that a collet of some sort would have to be manufactured to hold the handle in the chuck. This would, however, take far too long and be too expensive for a single spinning top. Due to this conclusion, the spinning top's design was changed so that, much like the first prototype, it could be manufactured all at once, with the final operation being parting off. This meant that the grooving tool would have to create the arc on the handle, which it could not do due to the size of the arc. This meant the design was changed from an arc to a slope with a slight arc in the corner where the slope met the handle, as seen in Figure 10.8.

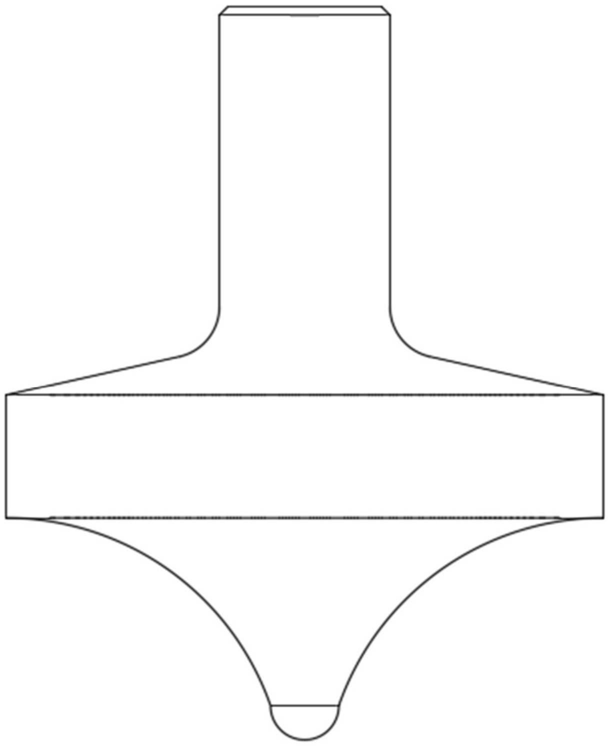

Figure 10-8 The Design Used for the Second Prototype.

Following the manufacture of this spinning top, another method of manufacture was devised so that the handle could be profiled to match the point. This method entailed turning the handle so that the weight, or the widest part, of the spinning top and the base of the handle met at a 90° angle, as seen in prototype one, allowing the end of the handle to be given a curved edge or even a ball point. This would then be parted off and put back into the chuck held onto by the handle so that the point could be turned. This is different from the first design because the weighted part of the spinning top met the handle at a 90° angle instead of an arc or a slope, which meant that the handle could be securely fitted into the chuck while allowing enough space to safely turn the point without contacting the chuck. Unfortunately, this method could not be attempted in the same session due to the software glitching. By the time these software glitches were fixed, there was not enough time left in the session to attempt this manufacturing method.

10.3.2 Pros

The pros of this second prototyping session were that the spinning top was made correctly without any mistakes on the first attempt, which meant that there was no wasted material on failed spinning tops, as there was in the first prototyping session (see Figure 10.9).

Figure 10-9 Finished Spinning Top Prototype 2.

Another pro was that a different type of spinning top was successfully made that was aesthetically quite different from the first design. This shows that the spinning top project is open to the designer's creativity, and many different designs can be made.

This session also allowed for the discovery of more limitations of the machine. This is advantageous because the new limitations can be documented in the curriculum support packet, which will reduce the time spent problem-solving during the teaching of the project.

10.3.3 Cons

The cons of this session were that a lot of time was wasted debating different ideas for how to manufacture the curved profiles of the 1st version of the curved spinning top design.

Another con of this session was that the method of manufacture that was introduced at the end of the session could not be attempted due to software glitches and time constraints.

10.4 Teaching Aid for Designing the Spinning Top

To instruct the students on how to create their design for the spinning top and how to create a guide to help in later steps from this design, a step-by-step, detailed teaching aid was written. This teaching aid includes a design specification at the beginning, this is so that the students are informed of the design limitations of the spinning top, due to the machining method. Having this design specification means that the students can design the spinning tops with their own unique profile and look while keeping within the limitations of the lathe.

The teaching aid is comprised of detailed step-by-step instructions supported by screenshots of the design and drawing process of a sample design for demonstration. This teaching aid can be found attached in the appendix, Appendix 3.

10.5 Tool Pathing Simulation

To simulate the tool pathing that the CNC lathe would use to manufacture the spinning top before the programming stage, Fusion 360’s manufacturing area was used. This can be useful for ensuring no critical failures are performed, however this was not included in the teaching aids as it is only an additional step that is not necessary, this means that it could be performed by the students during the project if there is enough time scheduled however it is not essential as the CNC software for the lathe shows a simulation of the profile and paths during programming.

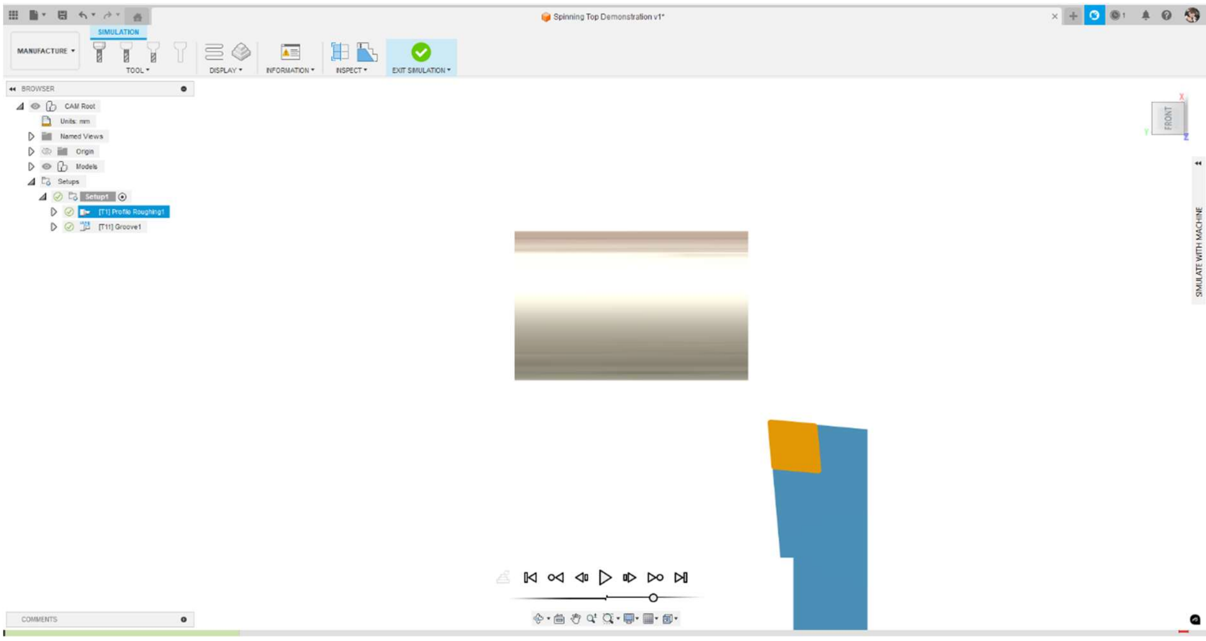

Figure 10-10 Tool Pathing Simulation Step 1.

Figure 10.10 shows the Fusion 360 tool pathing simulation at the beginning of machining; it shows the amount of stock available beyond the chuck and the tool. If the tool pathing moves beyond the left end of the stock, that is a critical failure, as this would result in a collision between the tool and the chuck.

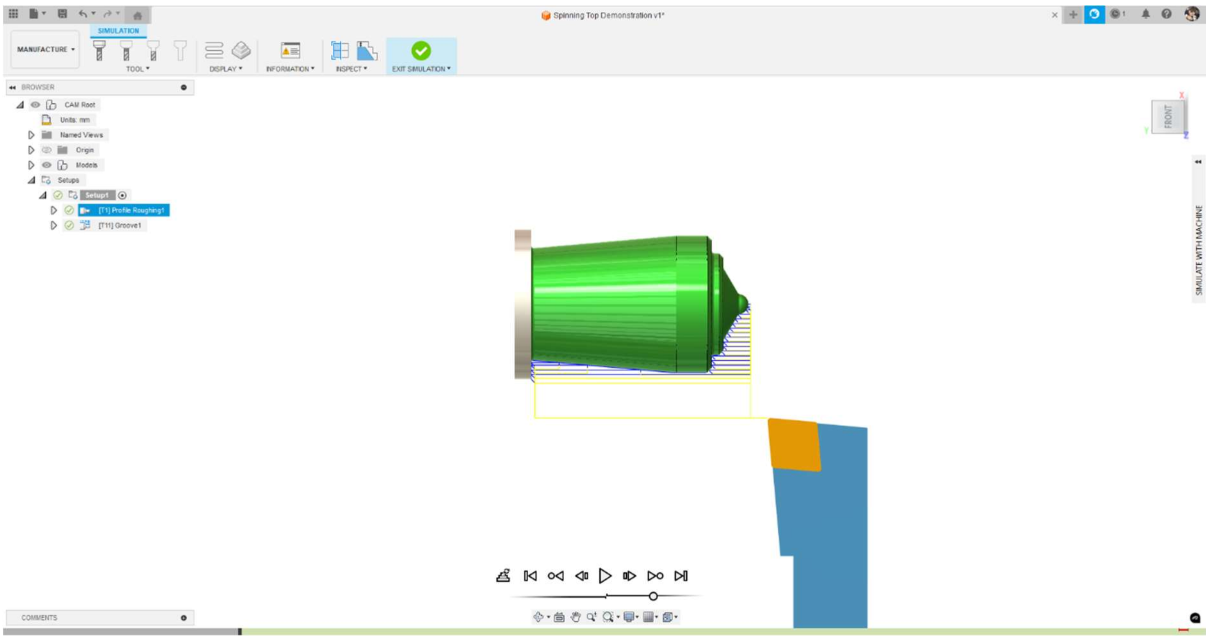

Figure 10-11 Tool Pathing Simulation Step 2.

Figure 10.11 shows the end of the tool pathing for the first tool; the blue lines represent cuts, and the yellow lines represent position moves. At this time, the point of the spinning top has been shaped, and the roughing for the rest of the spinning has been completed; the turning tool now needs to be changed to a grooving tool to complete the spinning top. This method differs slightly from the method used in reality, as this roughing pass also tapered the left side past the ‘weight’ of the spinning top, whereas in actuality, this was just a straight turn down; this could be a method of reducing machining time. Another difference in the simulation is that the first tool is used only for a roughing pass; in reality it is also used for a finishing pass on the tip and the ‘weight’, this is because the simulation will later do a finishing pass with the grooving tool, this could be another time saving method, however, the grooving tool would create a lower quality finish on the final pass compared to the turning tool.

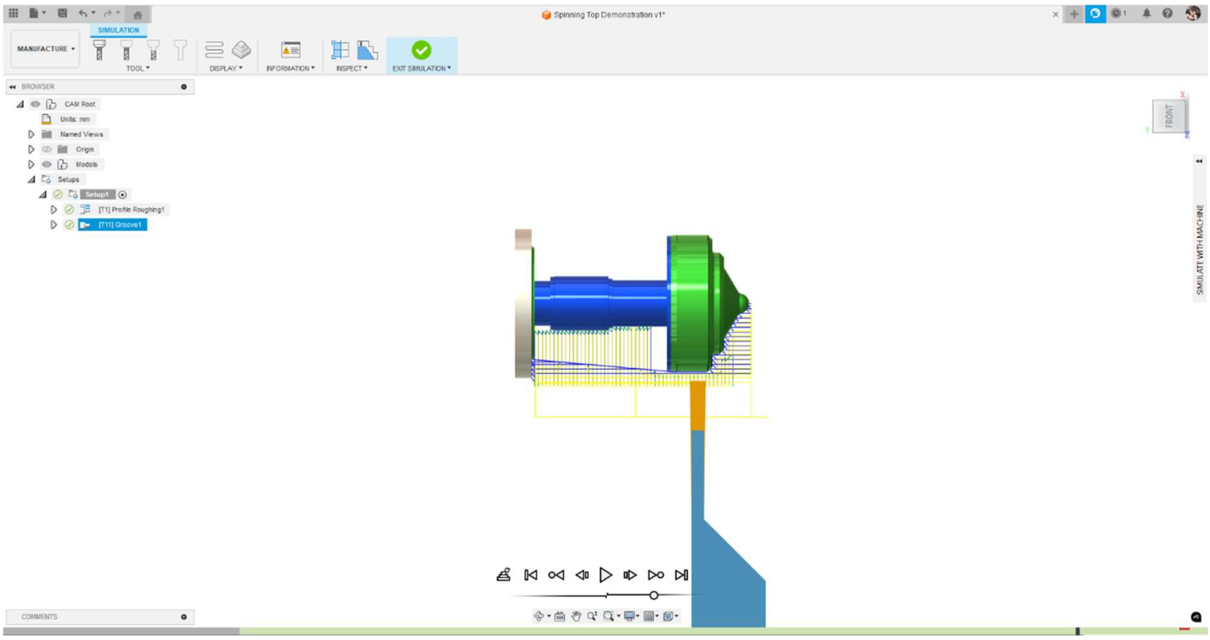

Figure 10-12 Tool Pathing Simulation Step 3.

Figure 10.12 shows the grooving tool having completed the grooving operations. The simulation is now ready for the final finishing pass.

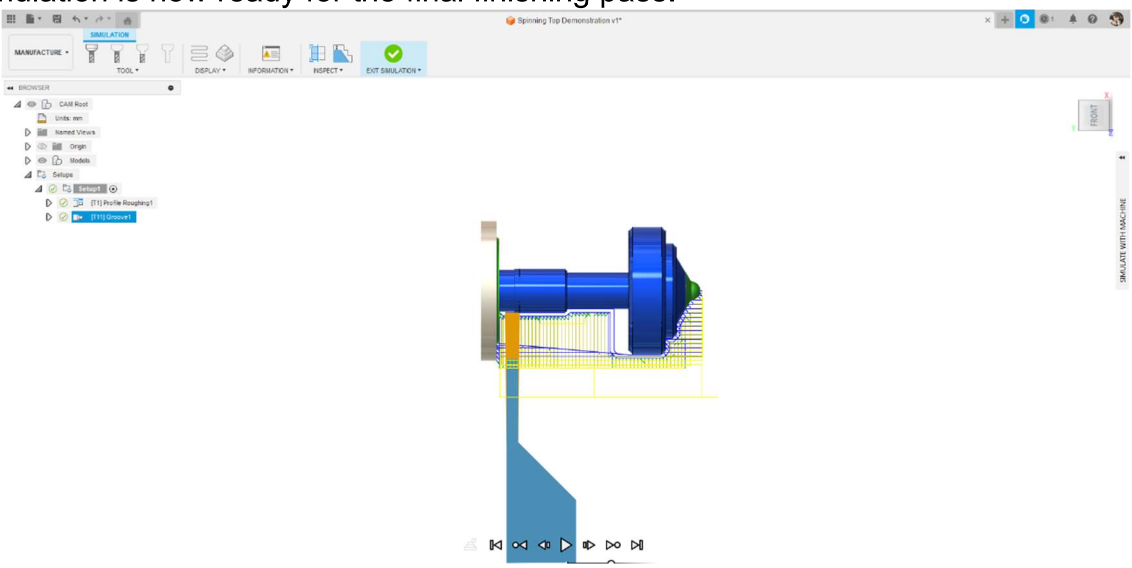

Figure 10-13 Tool Pathing Simulation Step 4.

Figure 10.13 shows the grooving tool having completed the finishing pass and is now ready to part off. This again shows differences from how it was machined in reality, as the simulation cuts the final diameter of the thinnest part of the handle and the chamfers on the finishing pass where in reality those were cut during the grooving event, and the finishing pass only removed a very small layer of material to give it a more polished finish.

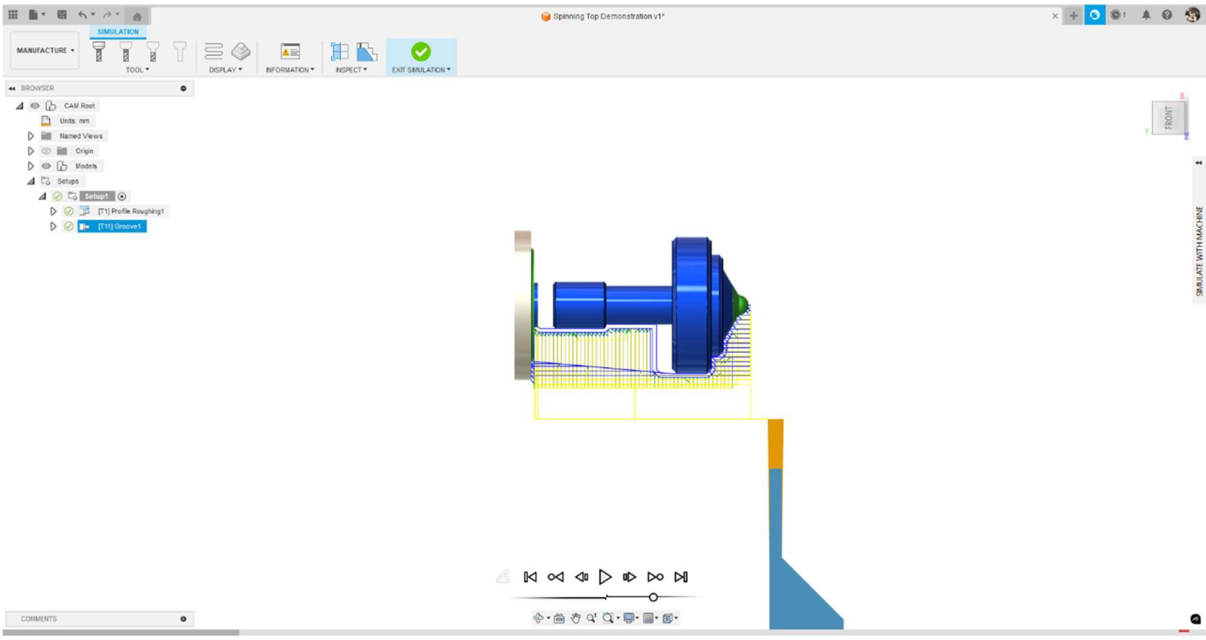

Figure 10-14 Tool Pathing Simulation Final Step.

Finally, Figure 10.14 shows the finished process with the part being parted off and the tool positioned back at the start.

Simulating the tool pathing using Fusion 360's manufacture space, before the programming stage could be added into the lesson plan as it is a perfect opportunity to teach the student how to use this tool and may even boost student engagement, however, as the Fusion machine library does not contain the XYZ Proturn RLX 355, and for that reason creates a different tool path to the one used by the CNC lathe, it is not essential to the completion of this project.

10.6 Teaching Aid for Programming the Tool Pathing

To instruct the student on how to use their guides from the design step to program the tool pathing using the CNC software, a step-by-step teaching aid was written. The teaching aid included a description of the CNC software, along with detailed steps and instructions on how to program the tool pathing for the design used in the design teaching aid. These instructions are demonstrated using screenshots of the piece being programmed. The teaching aid also included tips on how to change aspects to fit different profiles, and also when to put in a position move before a cut and why. The programming teaching aid can be found attached in the appendix, Appendix 4.

10.7 Teaching Aid for Machining the Spinning Top

A teaching aid for the workshop session was also written; however, unlike the previous two aids, this one did not aim to provide step-by-step instructions accompanied by pictures, but rather an overview of the workshop session so that the student may know what they need to bring or prepare and what they should expect to do. This is because the workshop session would be run by the technical skills specialist. The students can be prepared for the session and know what to expect; however, for safety reasons, the students should follow the technical skills specialist's lead and instructions only.

This teaching aid includes a list of PPE the students should bring to the workshop session and what measures will be put into place in case the student does not own that PPE, along with a list of safety procedures that should be taken into account prior to the session this being, for example, to tie up long hair or not wear anything that droops or dangles. This teaching aid can be found attached in the Appendix, Appendix 5

10.8 Pre-Project and Post-Project Questionnaire

To properly teach the students, undertaking the spinning top project, a baseline of the students' knowledge and experience had to be created. The baseline was needed so that the lesson planning and teaching could be modified and focused on the students' needs, for example, if the students had already taken a module about CAD, the basics of CAD do not need to be covered in detail, meaning that more time can be spent on less familiar subjects. This baseline was made using a questionnaire which asks students about their knowledge, experience, and confidence in subjects such as design to specification, CAD, CAM, and machining. This pre-project questionnaire can be found attached in the Appendix, Appendix 6.

After the project had been completed, a way to determine whether the students had learnt from the experience was needed. This was done by questionnaire again. The questions were the same as in the pre-project questionnaire; however, at the end, it contained two additional questions which asked if the student thought they had learnt something, and to provide an example of something they had learnt if they could. This meant that not only could the answers to the earlier questions be compared to check for improvement in knowledge, confidence, or experience, but also the student would confirm whether they think they had learnt or not, which is essential to show the project achieving its goal. This post-project questionnaire can be found attached in the Appendix, Appendix 7.

10.9 Small Student Trial Run

To ensure that the curriculum support package performed as it was designed and instilled the correct knowledge in students a small trial run with two students using the teaching aids was undertaken. This trial run was conducted as a class undertaking the project, the author played the part of the instructor, and the technical skills specialist supervised where needed.

This trial run consisted of four parts, two of which were practical sessions:

1. Part 1 consisted of the two participants completing a short knowledge questionnaire, which is attached in the appendix (see Appendix 6). This questionnaire contained 14 simple questions designed to test the participant's knowledge and create a baseline for the teacher to adapt to the needs of the students. The responses to this questionnaire showed that both students, while 'somewhat' confident with CAD, were not confident with using CNC machinery or programming CNC machinery; however, both students admitted to feeling confident undertaking the project as long as there is someone to help and supervise.
2. Part 2 consisted of the first practical session; this was creating a program using the ProtoTRAK software installed on a computer, following the steps described in the programming teaching aid attached in the appendix (see Appendix 4). The first student was led through the programming process with heavy supervision, the first student was effectively used as a demonstration of the programming process. The second student then followed, needing very little supervision. This showed that leading a student through programming their design could be a good way of teaching and demonstrating to the students, allowing them to ask questions while doing the demonstration, which also helped the second student avoid mistakes and errors. The programs were made using technical drawings as guidelines, these drawings were made by

the students for their own design in their free time using the help of the CAD teaching aid, which is attached in the appendix (see Appendix 3).

3. Part 3 consisted of the second practical session; this was the workshop session where the students used the machine to create their spinning tops. Unfortunately, one of the students was unable to attend this workshop, and due to the technical skills specialist's availability, this could not be rescheduled. The student undertaking the workshop was led through the step-by-step process of using the machine to create their part, with heavy supervision from the technical skills specialist. During the machining, there was an unforeseen collision. The grooving tool collided with the part while backing out, snapping the part and resulting in a critical failure. A picture of this failed part may be seen in Figures 10.15, 10.16, and 10.17. The student was then led through the necessary steps of correcting the program, clearing the stock and starting over. The second attempt was completed successfully without any further complications, see Figure 10.18. The steps followed by the student are the same as the ones described in the workshop teaching aid attached in the appendix (see Appendix 5).

Figure 10-15 Failed Student Trial Run Piece.

Figure 10-16 Failed Student Trial Run Piece Showing Top.

Figure 10-17 Failed Student Trial Run Piece Showing Bottom.

Figure 10-18 Finished Student Trial Run Spinning Top.

4. Part 4, the final part of this project, consisted of the participants taking the post-project questionnaire. This questionnaire is fundamentally identical to the pre-project questionnaire, however, with 2 additional questions allowing students to mention something they learnt. This second questionnaire was taken to test whether the students have developed and learned, and what they have learned. The post-project questionnaire is attached in the appendix (see Appendix 7). The results of the questionnaire were very positive, and any points at which one or the other students were lacking knowledge or experience, such as no knowledge of centre lathes, were now improved.

The results of the questionnaire showed that both students gained knowledge and experience. This fact, along with both participants admitting that they learnt from this project, shows that this curriculum support package achieves its intended goal of decreasing the practical skills knowledge gap in newer engineers.

10.10 Possible Areas of Study Post-Project

After the students have completed the spinning top project the spinning tops could be used to lead into other areas of study. These new areas could be finishing or post processing of part, this could be taught by having the students experiment using different finishes and processes on their spinning tops. For example the students could give their spinning top a polished finish or even look into anodising the aluminium into a different colour.

Another area could be material studies, research and learn about different materials and possibly manufacture more spinning tops from different metals such as steel and brass, then note the differences and finally decide upon the best material.

The new areas of study do not have to be only practical; however, this project could also lead to a design module, where, for example, the students could be presented with a competition to take what they have learnt and, through product development, create another spinning top designed to spin longer. The longest-lasting spinning top would then win this competition.

Another more theoretical subject this project could lead to is the science behind the spinning top and the study of gyroscopes and their uses in engineering. The spinning tops the students made in the project could be studied and used as a tool to engage students when teaching about gyroscopes.

Chapter 11: Resources

The main resources for this project were the University of Staffordshire for providing use of the facilities and covering the cost of materials and production, and the XYZ Proturn RLX 365 CNC lathe.

This project also heavily relied on the resources provided by the IMechE and IET websites, these resources were used for researching the issue of a skills gap and solutions such as learning support packages which they provide. Other resources used for this project are other websites detailing packages to support practical learning, such as the Design and Technology Association.

The supervisor for this project, Chris Wayman, was used as a resource for learning and classroom information due to his experience in the area. The technical skills specialist, Niall Sloane, was used as a resource for technical knowledge in the workshop when manufacturing prototypes and deciding on the best and most efficient methods of manufacture.

The library was also a useful resource used to research the skills gap, national curriculum, learning types and needs, and about learning support packages.

Chapter 12: Evaluation

This project covered the research of tools and needs of students when learning and the areas which require development, such as practical engineering skills and experience. The development of a curriculum support package was also covered in detail, from the creation of a project that allows students the opportunity to gain practical knowledge and experience, to the development of different teaching aids to support the curriculum support package. Theoretically, the research provided in this project, along with the curriculum support package once implemented, should work towards the aim of this project, which is to decrease the practical skills gap in new-age engineers.

However, if nothing is changed in higher education and practical skills, knowledge, or experience continues not to be required to achieve a degree, then the skills gap in the new age of engineering may continue to increase to a point where engineering companies are no longer able to provide the necessary practical education to emerging engineers. This could cause a severe decrease in the quality of products and engineering services, and decrease the stability of the economy due to having to rely on other countries.

12.1 National curriculum

The national curriculum for D&T, while briefly mentioning ‘making products’, does not in actuality require any school teaching design and technology to provide the students with experience of practical and hands-on skills. This, combined with an engineering background not being needed to attend the engineering course at university, results in engineering students studying a bachelor's or combined master’s degree in engineering without the necessary basic knowledge that is assumed to be understood, meaning that students are forced to either spend more time focusing on teaching themselves the basics of engineering while studying intermediate and advanced engineering principles, or ignore the basics and spend more time memorising to be able to pass a test or assignment rather than learning and putting that knowledge into practice.

To improve this, the curriculum would need to require any school that teaches D&T to provide their students with time using hand tools and information about them, something that would allow them to, in future, create something by hand if they had a want or need to do so. This would supply them with knowledge and experience that would not only greatly reduce the naivety in some students studying engineering in higher education, but also possibly influence or inspire more students to become engineers.

12.2 Curriculum Support Package Trial Run

A trial run of the project was also performed and documented to provide insight into the curriculum support package and to test its efficacy.

The students undertaking this trial run were first required to answer a questionnaire about their previous experience and knowledge. This revealed that the students possessed a fundamental understanding of CAD and were reasonably confident using it; however, they were severely lacking in any knowledge or experience of or using lathes and CNC machinery. Both students were very willing and motivated to undertake this project; however, they admitted to only being comfortable if given constant supervision.

After the project and machining were complete, the students were once again asked to complete the questionnaire, this time with an additional two questions asking whether the student felt as though they had learnt and to write down one thing they had learnt. The post project questionnaire revealed that the curriculum support package seemed to have worked as, despite one student being unable to attend the machining workshop, both students said they felt as though they had learnt from the project and their practical knowledge, and for one of them, their experience had improved from the beginning of the project.

The trial run took 3 sessions to complete, the longest of which lasted 2 hours. This, however, would be a different amount of time necessary as the class size was two students, and the time needed would certainly increase with a larger class size. Despite this trial run not being 100% conclusive, due to the small sample size, it still works as a proof of concept that, with motivated and engaged students, the curriculum support package does lead to greater knowledge, experience, and understanding of CNC machinery and other practical skills.

12.3 Project improvements

Despite the project being successful at teaching the students practical skills and supplying them with practical experience, this project could still be improved in many ways.

For example, one improvement could be making the part more cost-effective by reducing the cost of running the machine by improving the efficiency of the machining process.

Another integral improvement to this project would be to develop either a new product or an addition to the spinning top that uses additional processes or machines, such as the laser cutter, milling machine, or 3D printer. This would be an important improvement because it would allow the students to gain experience and knowledge in various processes, rather than solely the CNC lathe.

The material cost could also be lowered by selecting a less expensive material option, however, this cheaper material could come with downsides and drawbacks, such as lower product quality or durability. Another improvement could be reducing the machining time by having all the parts be identical, however, this would take away the creative aspect of the project and decrease student engagement.

These are general suggested improvements; however, the project could also be improved more specifically to suit the class undertaking it. This could be done by modifying the lesson plans to focus more on certain aspects of the process, or even extending the machining time per person, allowing for more complex and difficult-to-machine spinning top designs to be made.

Chapter 13: Conclusion

In conclusion, there is a large practical skills gap found in newer engineering graduates. This report discusses what that means for the future of the industry and why it is important to fix this issue. The report provided a possible small-scale solution to this issue by developing a curriculum support package.

This package contains insight into learning preferences, lesson planning techniques to maximise student engagement, and a project to create a spinning top. This project is essential to remedying the issue of the practical skills gap by providing the students with practical knowledge and hands-on experience using a CNC lathe.

This project contains three main sections, each accompanied by a teaching aid. The design part has the students create a design to a specification and then, through the use of CAD, develop a model and technical drawing to use as a guideline for the next section. This section could also include lessons on the topic of material properties and selection. The next section is programming, where the students use their technical drawing to program a tool pathing using the ProtoTRAK RLX CNC software. This section could also, depending on the prior knowledge of the class, include a lesson on CNC, lathes, and G-code (geometric code). Finally, the workshop section covers the machining of the actual part and hands-on use of the machine, this section could include a lesson on finishes and post processes, anodising, for example. The package also includes two questionnaires, the first to create a baseline of student knowledge and experience, and the second to check if the students have learnt anything by asking them similar questions about their knowledge and experience and comparing the answers.

The report also contained a detailed account of a trial run of the project using two students, which was used as a proof-of-concept for the curriculum support package. The trial run was successful, and the students reported that they had received practical skills, knowledge and experience from the project.

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Appendix

13.1 Appendix 1: Ethical Disclaimer Form.

Research Ethics

Disclaimer Form

The following declaration should be made in cases where the researcher and the supervisor (where applicable) conclude that it is not necessary to apply for ethical approval for a specific research project.

PART A: TO BE COMPLETED BY RESEARCHER

Name of Researcher:	Jakub Wroblewski
School	University of Staffordshire

<table>
<tr><td colspan="4">Student/Course Details (If Applicable)</td></tr>
<tr><td colspan="2">Student ID Number:</td><td colspan="2">22010764</td></tr>
<tr><td colspan="2">Name of Supervisor(s)/Module Tutor:</td><td colspan="2">Chris Wayman</td></tr>
<tr><td colspan="2">PhD/MPhil project: ☐</td><td colspan="2"></td></tr>
<tr><td>Taught Postgraduate Project/Assignment:</td><td>☐</td><td>Award Title:</td><td>BEng (Hons) Mechanical Engineering</td></tr>
<tr><td>Undergraduate Project/Assignment:</td><td>☒</td><td>Module Title:</td><td>Individual Engineering Project</td></tr>
</table>

Project Title:	Research and development of resources to promote practical learning opportunities and engineering skills related to CNC machinery to University students		
Project Outline:	Learning about and developing teaching aids around the new CNC lathe by practicing on it and experimenting with different techniques. Then researching and potentially developing a project for level 4 undergraduates that takes utilises available time/resources to manufacture and promotes the use of CNC processes that mainly focus on the lathe.		
Give a brief description of research procedure (methods, tests etc.)	Design and manufacture small projects using CNC machines.		
Expected Start Date:	22/11/2024	Expected End Date:	12/05/2025

Declaration

I/We confirm that the University's Ethical Review Policy has been consulted and that all ethical issues and implications in relation to the above project have been considered. I/We confirm that ethical approval need not be sought. I/We confirm that:

The research does not involve human or animal participants	☒
The research does not present an indirect risk to non-participants (human or animal).	☒
The research does not raise ethical issues due to the potential social or environmental implications of the study.	☒
The research does not re-use previously collected personal data which is sensitive in nature, or enables the identification of individuals.	☒

Has a risk assessment been completed for this project?	☒ Yes ☐ N/A

Signature of Researcher:	JakubW	Date:	05/11/2024
Signature(s) of Project Supervisor(s) (If student) OR Signature of Head of Department/ Senior researcher (if staff)	Chris Wayman	Date:	06/11/2024

NB: If the research departs from the protocol which provides the basis for this disclaimer then ethical review may be required and the applicant and supervisor (where applicable) should consider whether or not the disclaimer declaration remains appropriate. If it is no longer appropriate an application for ethical review **MUST** be submitted.

13.2 Appendix 2: Risk Assessment.

Risk Assessment

Below is a signed risk assessment regarding the use of computer-related equipment when writing the final-year report.

The purpose of this is to highlight risks and suggest mitigations.

More will be developed according to practical tasks yet to be decided.

Below that are risk assessments written by the technician Niall Sloane which will be followed when in the workshop.

Three Risk assessments:

- In the workshop
- Using the XYZ CNC lathe
- Using the Axminster CNC milling machine

GENERAL RISK ASSESSMENT FORM			Severity multiplied by Likelihood equals Risk Rate. NB: Calculated after taking in to account existing precautions				
School/Service School of Digital, Technologies and Arts		Severity Likelihood	Insignificant (1)	Minor (2)	Moderate (3)	Serious (4)	Fatal/Critical (5)
Task/Activity/Area: Writing FYP report		Almost Certain (5)	5	10	15	20	25
		Likely (4)	4	8	12	16	20
Assessed By: Jakub Wroblewski	Signature: JakubW	Possible (3)	3	6	9	12	15
Dept Manager: Chris Wayman	Signature: C Wayman 13/11/24	Unlikely (2)	2	4	6	8	10
Date of Assessment: 06/11/2024	Review date: 06/11/2025	Rare (1)	1	2	3	4	5

	Activity/Process/Machines	Hazard	Persons in Danger	Severity 1-5	Likelihood 1-5	Risk Rate	Measures/Comments	Result
1	Using a Computer Display	Eye Strain	Student	2	3	6	Use an Anti-Glare Display. As per HSE website: https://www.hse.gov.uk/msd/dse/ Use the 20-20-20 rule (every 20 minutes look at something 20 feet away for 20 seconds). As per medical news today website: https://www.medicalnewstoday.com/articles/321536 Use Text Size that is Easy to Read.	3
2	Sitting at the Desk	Bad Posture Leading to Back Issues	Student	2	4	8	Use an Adequate office chair with properly adjusted lumbar support. https://www.hse.gov.uk/msd/dse/	4

3	Using a Mouse	Wrist Strain	Student	2	3	6	Prevent Arm Overreaching. Don’t leave your hand on the device when not in use. Ensure a relaxed and straight wrist. https://www.hse.gov.uk/msd/dse/	3

University of Staffordshire

School/Service: Technical Services – Smart Technology			
Task/Activity/Area: K038 Engineering Workshop – General workshop activities			
Assessed By: (Print Name):	N Sloane	Signature:	Niall Sloane
Approved by: (Print Name):		Signature:	
Date of Assessment:	08/07/2024	Review Date:	08/07/2025

Severity multiplied by Likelihood equals Risk Rate And calculated after taking in to account existing controls					
Severity / Likelihood	Insignificant (1)	Minor (2)	Moderate (3)	Serious (4)	Fatal/ Critical (5)
Almost Certain	5	10	15	20	25
Likely (4)	4	8	12	16	20
Possible (3)	3	6	9	12	15
Unlikely (2)	2	4	6	8	10
Rare (1)	1	2	3	4	5

***Key to result:** **T** = Trivial Risk, **A** = Adequately Controlled, **N** = Not Adequately Controlled, **U** = Unable to decide, (further information required).

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
1	Trailing cables, obstructions, spillages	Slips/Trips and Falls	Staff, Students, Visitors & Contractors	1. Working area to be kept clean & tidy at all times. 2. Trailing cables should not be used where practicable. 3. Work systems organised to minimize the likelihood of oil and fluids spilling on	3	1	3	T

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
				to floor. 4. All spillages of fluids to be removed using spill-kit equipment or Absorbent Granules. 5. Appropriate PPE (Apron/Coveralls, appropriate footwear etc) to be worn at all times when working in lab area.				
2	Noise, dust, sparks, flying objects - During angle grinding	Inhalation of particulates, eye irritation and/or injury, damage to hearing	Staff, Students, Visitors & Contractors	1. PPE (Safety glasses/visor, Ear Defenders) to be used at all times by operator and bystanders when using the angle grinders 2. Local Exhaust Ventilation hood to be positioned over grinding area to remove fine dust generated. **LEV not currently operational so processes requiring LEV not to be**	3	4	12	N

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
				used until repaired 3. Work to be positioned carefully and planned to avoid causing sparks to trail over walkways, flammable substances, or in the vicinity of others. 4. Cutting/grinding discs to be inspected before use and training followed to work in a safe manner to reduce risk of breakage and potential flying objects/debris. 5. All work to be clamped securely before grinding. 6. Training and supervision to ensure correct operation.				
3	Moving & rotating parts - during use of	Entanglement, crushing & trapping	Staff, Students, Visitors & Contractors	1. Long hair to be secured. 2. Loose clothing should be secured, and suitable protective clothing should be worn.	3	1	3	T

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
	power tools & machine tools			3. Dangling jewellery should be removed, rings should be taped or removed.				
4	Oils/Fluids/ Cleaning Fluids/ Anti-Freeze/ Hydraulic Fluids - contact with fluids	Skin irritation or allergic reaction, dermatitis	Staff, Students, Visitors & Contractors	1. Barrier Cream to be used at the start of work. 2. Disposable latex/vinyl gloves to be worn when practicable. 3. PPE (Rubber Apron/Gauntlets) to be used at all times when using cleaning fluids.	2	2	4	T
5	Electrocution - use of electrical equipment; pull down sockets	Electrical burns, electrocution, loss of life	Staff, Students, Visitors & Contractors	1. Visual check of machines and cables before use 2. Machinery subject to annual maintenance inspection & PAT as applicable. 3. Additional emergency stop/electrical isolation buttons located within lab.	4	1	4	T

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
	and/or lighting			4. Water/fluids to be kept away from electrical systems				
6	Pneumatic Air - Using Air power tools and associated compressed air equipment	Impact injury from whipping air line, blood clots from compressed air, projectile impact	Staff, Students, Visitors & Contractors	1. All workers trained in safe working procedures and dangers of horseplay. 2. Airline has dead man's handle. 3. System inspected and serviced annually under contract. 4. Anti-whip hose to be used with vibrating air tools to minimise risk of quick-release connector detaching and causing impact injury	3	1	3	T
7	Oils/Fluids/ Cleaning Fluids/ /Hydraulic Fluids – handling,	Skin irritation, dermatitis, eye irritation	Staff, Students, Visitors & Contractors	1. Barrier Cream to be used at the start of work. 2. Disposable latex/vinyl gloves to be worn when practicable. 3. PPE (Rubber Apron/Gauntlets) to be used at all times when working with oils &	1	2	2	T

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
	draining, filling of oils during maintenance			hydraulic fluids. 4. Oil pan/collection container to be adjusted to beneath drain area. 5. Contents should be monitored closely to avoid overfilling collection drum. 6. All waste oils and cutting fluids to be disposed of in designated area. 7. During transportation of drum/container care should be taken to avoid spillage. 8. Manual handling techniques should be adopted when attempting to lift drum, assistance should be sought where applicable. 9. Wet vac used to empty sumps 10. Technical Instruction on safe working in workshop environment.				

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
8	Inhalation of fumes and particles; coolant mist	Irritation to lungs from particulates, fume, oil mist and/or bacteria	Staff, Students, Visitors & Contractors	1. Use supplied Local Exhaust Ventilation (LEV) system to remove fumes/mist whilst using metalworking coolants or any dust-producing cutting/grinding processes or fume-producing activities such as hot work. 2. Ensure the intake of the LEV is placed close to the workpiece and is drawing the fumes away effectively 3. Any health problems arising from the activity should be brought to the attention of the technician immediately 4, When cleaning filters wear an FFP3 Dust mask, and carefully remove dust so as not to make it airborne. If using a vacuum cleaner, ensure it is fitted with a HEPA filter. **- NOTE: Any processes requiring use**	2	1	2	T

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
9				**of the room LEV system must not be used until general room LEV system is repaired/replaced. Laser cutter has its own extractor system.**				
9	Fire – caused by e.g. electrical fault or hot work	Burns, loss of life & property	Staff, Students, Visitors, Contractors	1.Keep area clean 2. If any cabling is showing signs of damage stop using the equipment and report the damage to a technician	3	1	3	T
10	Sharp tools; injury from wood/metal swarf	Cut injuries to hands/fingers, eyes, body	Staff, Students, Visitors, Contractors	1. Induction to area, where carried out, includes requesting that users of the area register verbally with the supervisory staff first for greater awareness, highlights the possibility of such potential injuries, reinforces safe working practices, and	2	3	6	A

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
				recommends the wearing of suitable P.P.E. as appropriate 2. Supervision is present across the area during booked hours. 3. First aid kits available				

School/Service: Technical Services – Smart Technology			
Task/Activity/Area: K038 Engineering Workshop – XYZ CNC lathe			
Assessed By: (Print Name):	N Sloane	Signature:	Niall Sloane
Approved by: (Print Name):		Signature:	
Date of Assessment:	09/07/2024	Review Date:	09/07/2025

Severity multiplied by Likelihood equals Risk Rate
And calculated after taking in to account existing controls

Severity / Likelihood	Insignificant (1)	Minor (2)	Moderate (3)	Serious (4)	Fatal/ Critical (5)
Almost Certain	5	10	15	20	25
Likely (4)	4	8	12	16	20
Possible (3)	3	6	9	12	15
Unlikely (2)	2	4	6	8	10
Rare (1)	1	2	3	4	5

***Key to result:** **T** = Trivial Risk, **A** = Adequately Controlled, **N** = Not Adequately Controlled, **U** = Unable to decide, (further information required).

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
1	Entanglement/ Trapping - During	Crushing injuries	Staff, Students, Visitors &	1. CNC machine to be operated by authorised persons only, or student under close supervision.	3	1	3	T

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
	machine operation and from moving machine parts under power feed		Trespassers	2. Loose clothing, long hair to be secured/tied back. 3. Dangling jewellery to be removed when operating. 4. Mushroom-headed emergency stop button fitted. 5. All guards to be in place during CNC operation. 6. The machine should be electrically isolated, or the computer programme should be stopped, before making any adjustments.				
2	Tripping/Slipping on obstructions, spills or swarf - During	Slips trips & falls	Staff, Students, Visitors & Trespassers	1. Sufficient space around the machine is to be maintained to avoid the operator being accidentally pushed by passers-by. 2. Manual Handling techniques to be adopted when moving accessories & material in and around machine.	2	1	2	T

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
	machine operation			3. Area around machine to be kept clear of waste. 4. The floor surface should not be slippery and be kept free of loose items of swarf.				
3	Sharp edges on tools, workpieces, swarf - During machine operation	Cutting or Severing injuries	Staff, Students, Visitors & Trespassers	1. Swarf is not to be removed during machine operation. 2. Waste material/swarf to be removed with suitable implement and not by hand. 3. Training and supervision to reduce risk of cuts from handling sharp tooling and/or workpieces/swarf	3	1	3	T
4	Contact with or inhalation of Metalwork coolant fluid / mist - During	Eye irritation, skin irritation, dermatitis,	Staff, Students, Visitors & Trespassers	1. Coolant/Lubrication to be used as and when required with machine door closed (fully enclosed). Wait for any coolant mist to settle for 30 sec before opening door. LEV hood can be used during extended operation to	2	4	8	A

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
	machine operation	lung irritation		extract any mist that escapes the enclosure. **LEV not currently operational so not to be used for continuous/frequent operation until repaired** 2. Only properly marked CoSHH container to be used for coolant/lubrication 3. Cutting fluid in use (DPI SMF 02 BM) is fully synthetic and contains no oil, so is low hazard for misting and biological growth. Manufacturer's instructions to be followed to maintain correct concentration with regular checks. 4. Safety glasses must be worn during operation, especially with door open.				
5	Electrocution - During machine use	Electrocution, electrical burns	Staff, Students, Visitors &	1. Visual check of machines & cables before use	4	1	4	T

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
			Trespassers	2. Machinery subject to annual maintenance inspection. 3. Additional emergency stop/electrical isolation buttons located within lab.				
6	Flying Debris/Objects - During machine operation	Impact injuries, cuts, eye injuries	Staff, Students, Visitors & Trespassers	1. Care should be taken to ensure the work mounted to a faceplate, a chuck or between centres is properly secured and balanced to prevent excessive vibration. 2. The rotational clearance should be checked by hand before starting the machine. 3. The cutting tool should also be carefully checked for security before starting the machine. 4. Safety glasses must be worn during operation, especially with door open. 5. Chuck guards (interlocked) must be used.	2	2	4	T

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
				Correct chuck guard for chuck in use (3 or 4 jaw) must be fitted prior to use.				
7	Incorrect handling or setting of Tooling and fixturing	Cutting injuries, severing, impact injuries	Staff, Students, Visitors & Trespassers	1. Only specific tooling shall be used with the machine 2. Cutting tools must be located in a specific tooling cabinet marked for the purpose 3. Machine must be isolated before changing tools 4. Specified spanners/wrenches/sprung chuck key must be used to perform tooling changes or load stock - all spanners/wrenches/chuck keys must be removed from machining areas and chuck prior to restarting machining. 5. Only specific chucks, face plate and steadies may be used to hold work - no modified clamping may be used.	3	3	9	A

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
				6. Training & supervision to reduce risk of incorrect fitting				
8	Automated operation without correct simulation – programming or setting errors	Impact injuries, machine damage, projectile injuries	Staff, Students, Visitors & Trespassers	1. All workpieces must fit within the machine's envelope 2. Students must present a Shop Documentation sheet (usually generated from CAM software) detailing operation, tooling, stage machining images along with a GCODE file postprocessed only via specific postprocessors. 4. GCODE data files must be simulated via https://nraynaud.github.io/webgcode/ in addition to CAM simulations - GCODE or any manually-set programs must then be "simulated" on controller software prior to machining 5. Metal cutting programs must be stepped through using 'traking' prior to running in full	3	3	9	A

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
				auto mode 6. Tool-setting must be verified by an authorised person prior to running in AUTO/CNC mode				
9	Manual handling - Changing chucks or workpieces, risk of heavy falling objects	Impact injuries, crushing	Staff, Students, Visitors & Trespassers	1. Only authorised person e.g. technician to change chucks or workholding devices. 2. Use board to protect bed when changing chucks etc 3. Safety boots or toe caps to be worn when using the lathe - when changing chucks, workpieces, changing tools etc there is a risk of heavy falling objects causing injuries to the foot.	2	3	6	A

School/Service: Technical Services – Smart Technology
Task/Activity/Area: K038 Engineering Workshop – Axminster CNC milling machine

Severity multiplied by Likelihood equals Risk Rate And calculated after taking in to account existing controls					
Severity / Likelihood	Insignificant (1)	Minor (2)	Moderate (3)	Serious (4)	Fatal / Critical (5)
Almost Certain (5)	5	10	15	20	25
Likely (4)	4	8	12	16	20
Possible (3)	3	6	9	12	15
Unlikely (2)	2	4	6	8	10
Rare (1)	1	2	3	4	5

Assessed By: (Print Name):	N Sloane	Signature:	Niall Sloane
Approved by: (Print Name):		Signature:	
Date of Assessment:	08/07/2024	Review Date:	08/07/2025

***Key to result:** **T** = Trivial Risk, **A** = Adequately Controlled, **N** = Not Adequately Controlled, **U** = Unable to decide, (further information required).

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
1	Entanglement/ Trapping - During machine operation and from moving machine parts under power feed	Crushing injuries	Staff, Students, Visitors & Trespassers	1. CNC machine to be operated by authorised persons only, or student under close supervision. 2. Loose clothing, long hair to be secured/tied back. 3. Dangling jewellery to be removed when operating. 4. Mushroom-headed emergency stop button fitted.	3	1	3	T

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
				5. All guards to be in place during CNC operation. 6. The machine should be electrically isolated or the computer programme should be stopped beforemaking any adjustments.				
2	Tripping/Slipping on obstructions, spills or swarf - During machine operation	Slips trips & falls	Staff, Students, Visitors & Trespassers	1. Sufficient space around the machine is to be maintained to avoid the operator being accidentally pushed by passers-by. 2. Manual Handling techniques to be adopted when moving machine accessories and material in and around machine. 3. Area around machine to be kept clear of waste at all times. 4. The floor surface should not be	2	1	2	T

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
				slippery and be kept free of loose items of swarf.				
3	Sharp edges on tools, workpieces, swarf - During machine operation	Cutting or Severing injuries	Staff, Students, Visitors & Trespassers	1. Swarf is not to be removed during machine operation. 2. Waste material/swarf to be removed with suitable implement and not by hand. 3. Training and supervision to reduce risk of cuts from handling sharp tooling and/or workpieces/swarf	3	1	3	T
4	Contact with or inhalation of Metalwork coolant fluid / mist - During machine operation	Eye irritation, skin irritation, dermatitis, lung irritation	Staff, Students, Visitors & Trespassers	1. Coolant/Lubrication to be used as and when required with machine door closed (fully enclosed). Wait for any coolant mist to settle for 30 sec before opening door. LEV hood can be used during extended operation to extract any mist that escapes the enclosure.	2	4	8	A

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
				LEV not currently operational so not to be used for continuous/frequent operation until repaired 2. Only properly marked CoSHH container to be used for coolant/lubrication 3. Cutting fluid in use (DPI SMF 02 BM) is fully synthetic and contains no oil, so is low hazard for misting and biological growth. Manufacturer's instructions to be followed to maintain correct concentration with regular checks. 4. Safety glasses must be worn during operation, especially with door open.				
5	Electrocution - During machine use	Electrocution, electrical burns	Staff, Students,	1. Visual check of machines & cables before use	4	1	4	T

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
			Visitors & Trespassers	2. Machinery subject to annual maintenance inspection. 3. Additional emergency stop/electrical isolation buttons located within lab.				
6	Flying Debris/Objects - During machine operation	Impact injuries, cuts, eye injuries	Staff, Students, Visitors & Trespassers	1. Care should be taken to ensure the work mounted to machine bed, vice, chuck or fixture is properly secured, and balanced to prevent excessive vibration. 2. Clearance should be checked manually before starting the machine. 3. The cutting tool should also be carefully checked for security before starting the machine.	2	1	2	T

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
7	Dust - During milling of foam material	Irritation of lungs, irritation of eyes	Staff, Students, Visitors & Trespassers	1. During work with foam material Local Exhaust Ventilation (LEV) is to be used at all times unless machine is fully enclosed. 2. LEV equipment subject to annual inspection & testing protocols.	2	1	2	T
8	Incorrect handling or setting of Tooling and fixturing	Cutting injuries, severing, impact injuries	Staff, Students, Visitors & Trespassers	1. Only specific chucks/collets shall be used with the machine 2. Cutting tool arbors and collets must be located in a specific tooling cabinet marked for the purpose 3. Note maximum tooling capacity - End Milling Capacity 25 mm Face Milling Capacity 80 mm 4. Machine must be isolated before performing tool changes 5. Bespoke / specified spanners and	3	3	9	A

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
				wrenches must be used to perform tooling changes - all spanners must be removed from machining areas and spindle prior to restarting machining. 6. Only M12 Tee-nut fastening shall be used to secure items to the machine table - no special modified clamping may be used 7. Only the bespoke Vices and other workholding clamps may be used with any machine setup. 8. All workholding equipment must be stored in a specific, labelled and secure location 9. When handling sharp cutting tools extra care must be taken to protect the bed and operators. NEVER support tools in the hand, always leave the				

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
				draw bar screwed in a few turns prior to breaking tapers				
9	Automated operation without correct simulation	Impact injuries, machine damage, projectile injuries	Staff, Students, Visitors & Trespassers	1. All workpieces must fit within the envelope of the machine (mm) - X-295, Y- 150, Z- 275 2. Additional care must be applied when using 4th Axis dividing head and special fixturing - NOTE use of this attachment will reduce machine capacity 3. Students must present a Shop Documentation sheet (usually generated from CAM software) detailing operation, tooling, stage machining images along with a GCODE file postprocessed only via specific postprocessors.	3	3	9	A

#	Hazard	Harm/Injury	Persons at Risk	Controls	Severity 1-5	Likelihood 1-5	Risk Rate	Result*
				4. GCODE data files must be simulated via https://nraynaud.github.io/webgcode/ in addition to CAM simulations - GCODE must then be "simulated" via SEIG software prior to machining 5. Metal cutting programs must be proven using foam or other soft materials prior to finishing parts 6. Tool-setting must be verified by an authorised person prior to running in AUTO mode				

13.3 Appendix 3: Design Teaching Aid.

Design Brief

This design was made in Fusion 360 however, other CAD programs can be used.

The design brief for this project is to create a spinning top using a CNC lathe. This spinning top would be no more than 50mm long and 35mm in diameter due to the size of the stock material.

The spinning top should be designed to be turned down without repositioning in the chuck. This means that the profile will be turned in one go, with the final operation being parting off. **Sketching**

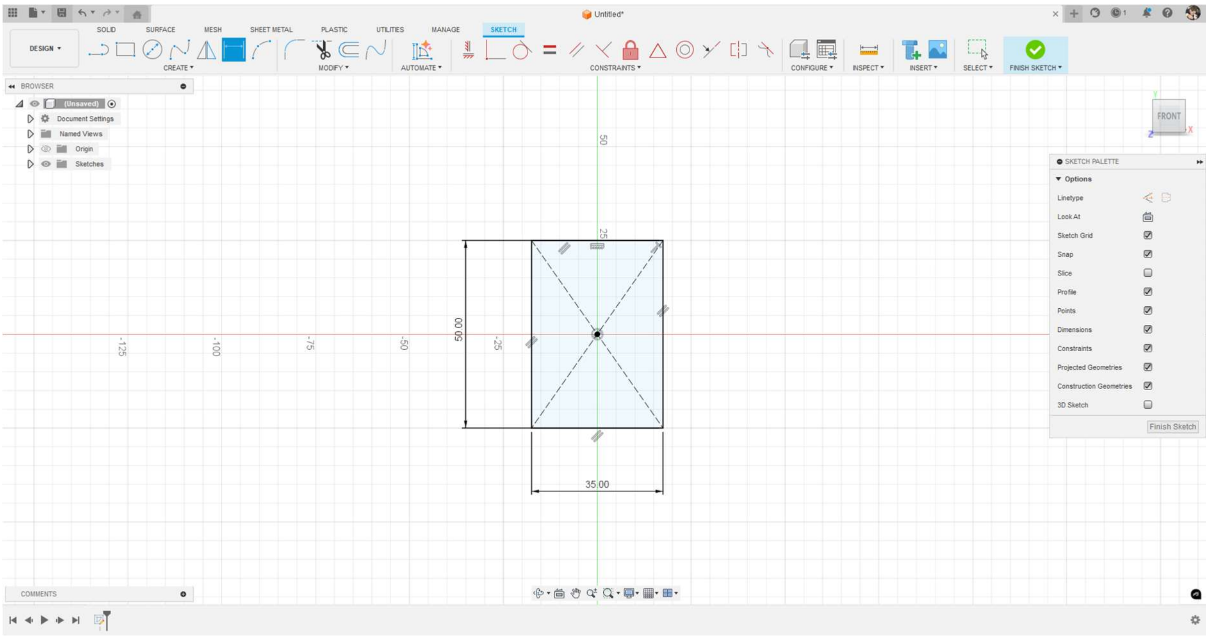


Figure 0-1 Sketch boundary.

The first step, as shown in figure 1, is to create a sketch outlining the boundary of the piece, 35mm by 50mm. This can be done by drawing a centre rectangle which is 35mm by 50mm; this will be the maximum size of the spinning top. The dimensions can also be changed by using the dimension tool and selecting the edges.

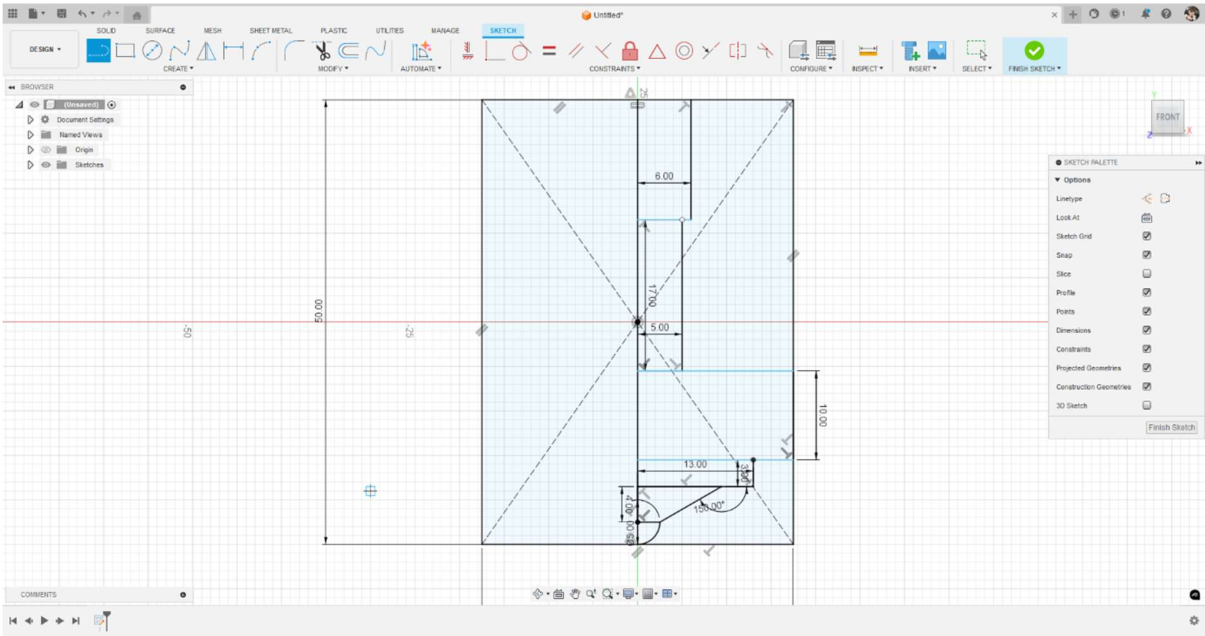


Figure 0-2 Sketch of the spinning top profile.

The next step, as shown in Figure 2, is to create a sketch of the spinning top profile. This profile only needs to be defined across one half of the boundary, as it will be revolved and, therefore, symmetrical. The profile should be drawn with a centre line so that it remains symmetrical; this centre line will act as the axis for the revolve operation. This profile is entirely up to creativity. The profile shown in Figure 2 is just an example and may be changed completely.

Because of the manufacturing method, there is a requirement for the handle thickness to prevent it from detaching when subjected to the forces of turning. The handle thickness must be a minimum of 10mm diameter at the thinnest point.

Any curves used in the design must be radial arcs, not splines; this is because splines cannot be programmed into the CNC software.

Any grooves in the design cannot be thinner than 3mm because that is the thickness of the grooving tool. The grooving tool also has a limited depth due to its being 25mm long. This is another reason that the thinnest point in any part of the handle must be no less than 10mm in diameter.

Tip: For the top to spin well, the top should have a wide segment towards the bottom on the spinning top, which acts as a weight.

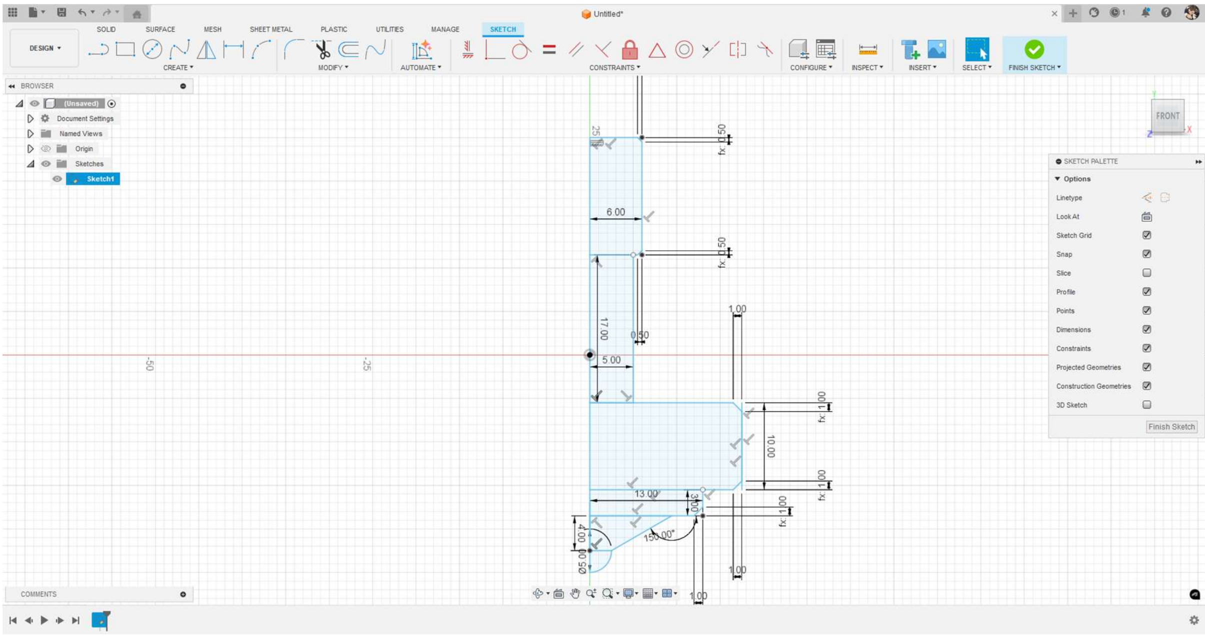


Figure 0-3 Sketch of the spinning top profile.

Modelling

Figure 3 shows an optional step, which is to add chamfers or fillets to the edges for aesthetics. the chamfers must be equal distance chamfers and must stay at a 45-degree angle, the fillets must also be equal distance fillets. These modifications can be made using the Chamfer and Fillet tools located in the Modify section of the sketch workspace.

Another optional step is to trim the boundary to make it quicker when selecting the profiles for the revolve. This can be done using the Trim tool located in the Modify section of the sketch workspace.

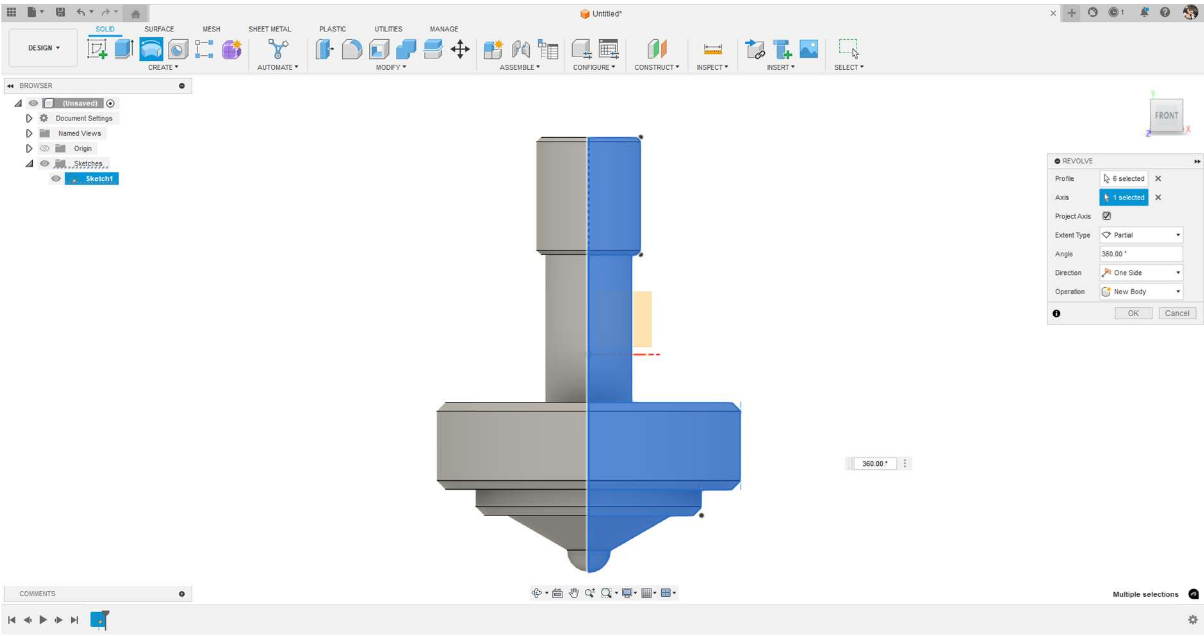


Figure 0-4 The revolve operation is being performed on the spinning top sketch.

Figure 4 shows the spinning top profile being revolved about its centre axis. This is done using the Revolve tool in the Create section of the design workspace.

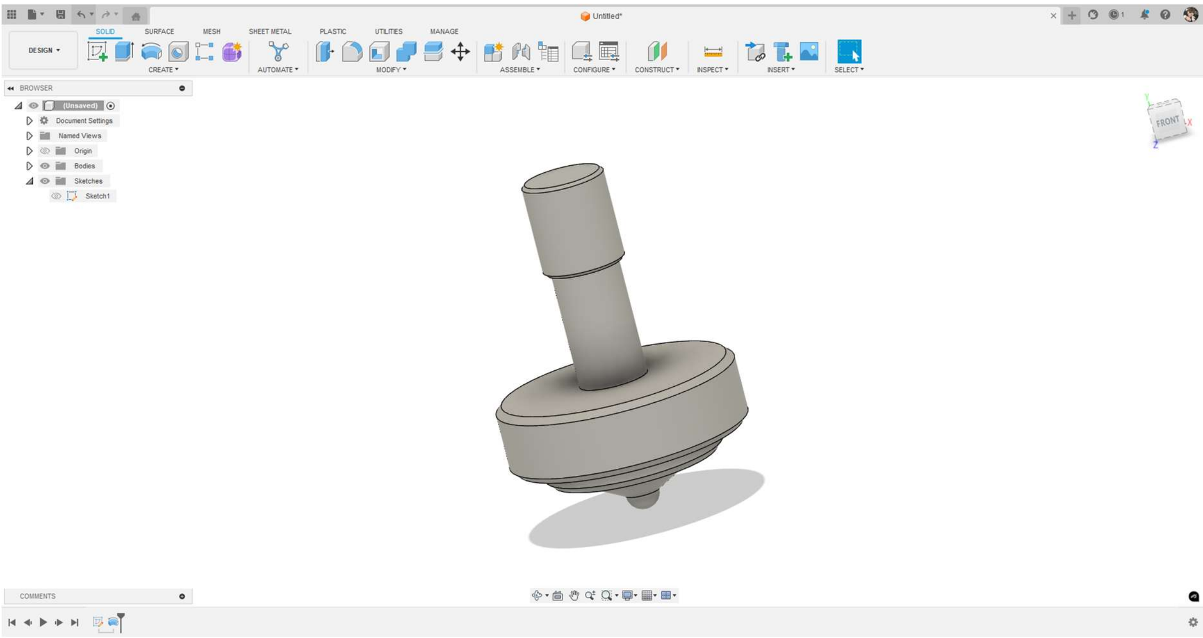


Figure 0-5 Finished spinning top.

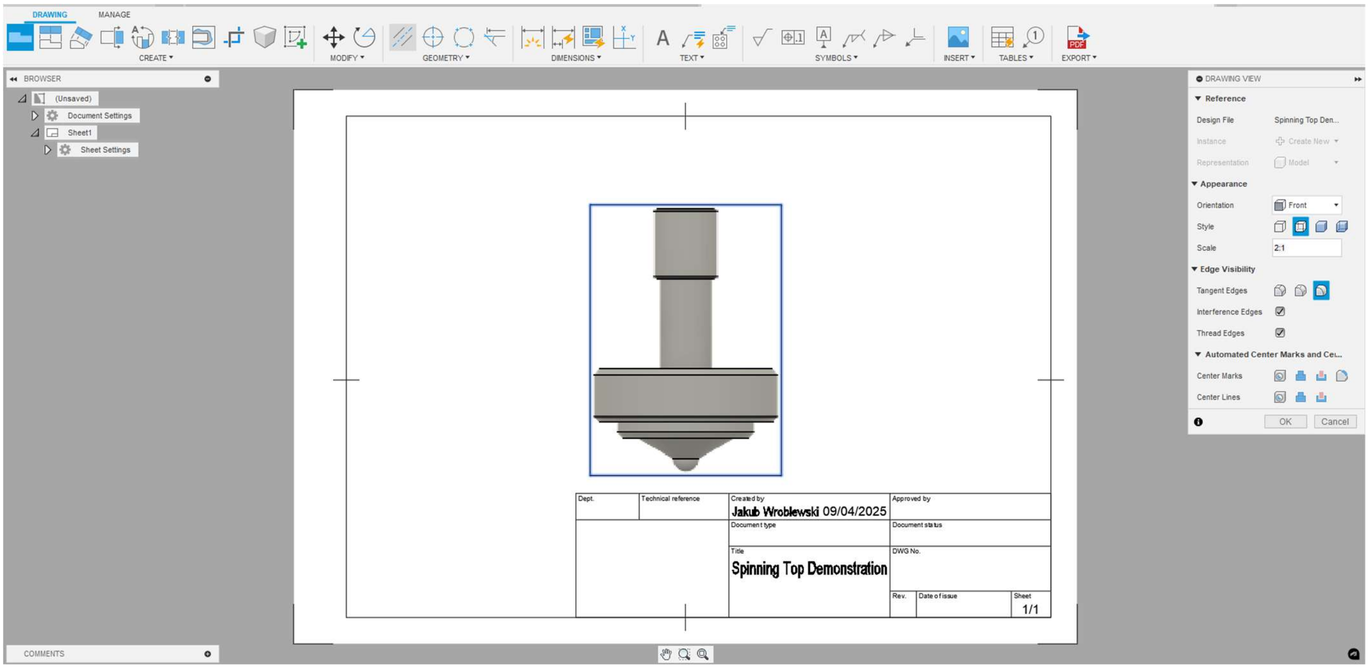


Figure 0-6 The Drawing workspace.

Drawing

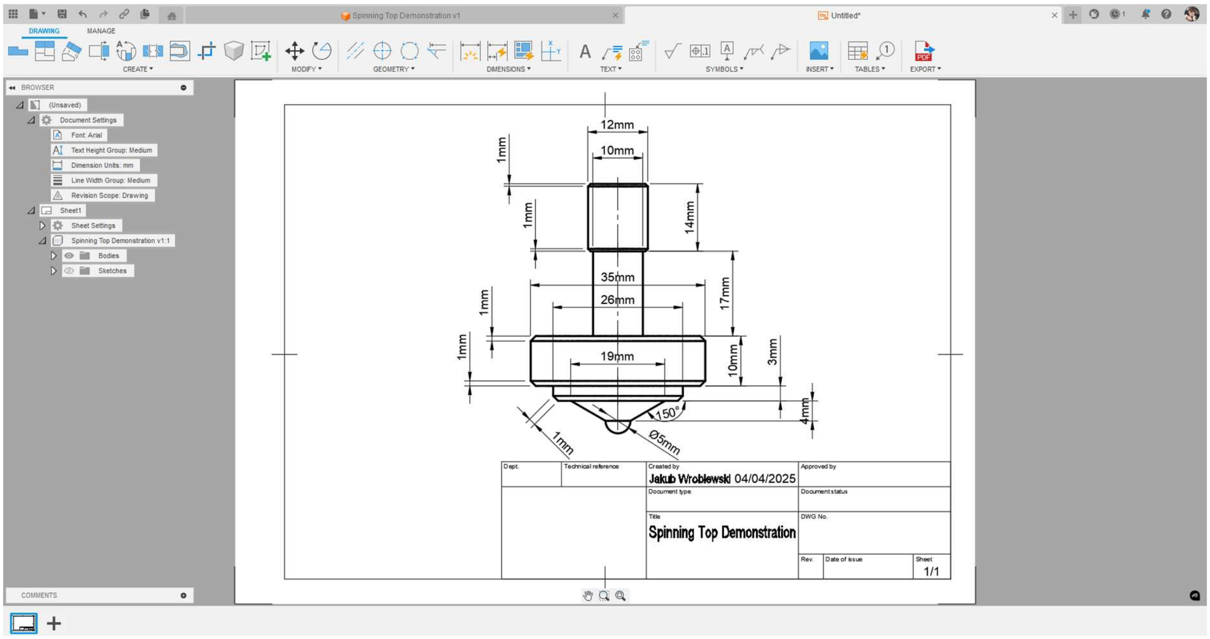


Figure 0-7 Spinning top drawing with dimensions.

The final step of the designing process is to create a drawing of the spinning top profile with accurate dimensions. This drawing will be used as a guide for the dimensions during the programming session, which is why accurate dimensions are needed. This is done by clicking on the button in the top left corner of the workspace; this will be labelled 'Design'. Next, in the dropdown menu, select 'Drawing' and then 'from design.' This will take you to the drawing workspace. Once in the drawing workspace, the base view needs to be placed. This is done by clicking in the centre of the page, as seen in Figure 6. At this step, the size ratio may also be changed. To add dimensions to the drawing, select the dimension tool from the dimension section and select the edge that requires a dimension.

Figure 7 shows the spinning top drawing with dimensions applied so that the dimensions of all the areas are known.

This is a necessary step to make the programming step later much easier, as this drawing will act as a guide for how the profile should look and what the dimensions are.

Any angled or sloped segments must be given an angle dimension, not including chamfers, and the diameters of all the segments must be shown.

Figure 6, however, shows a drawing with inaccurate dimensions. This is because the program is set to automatically round any values to zero decimal places. This is visible in the difference in size of the chamfers despite them all being dimensioned at 1mm. Figures 7-9 show how to solve this issue.

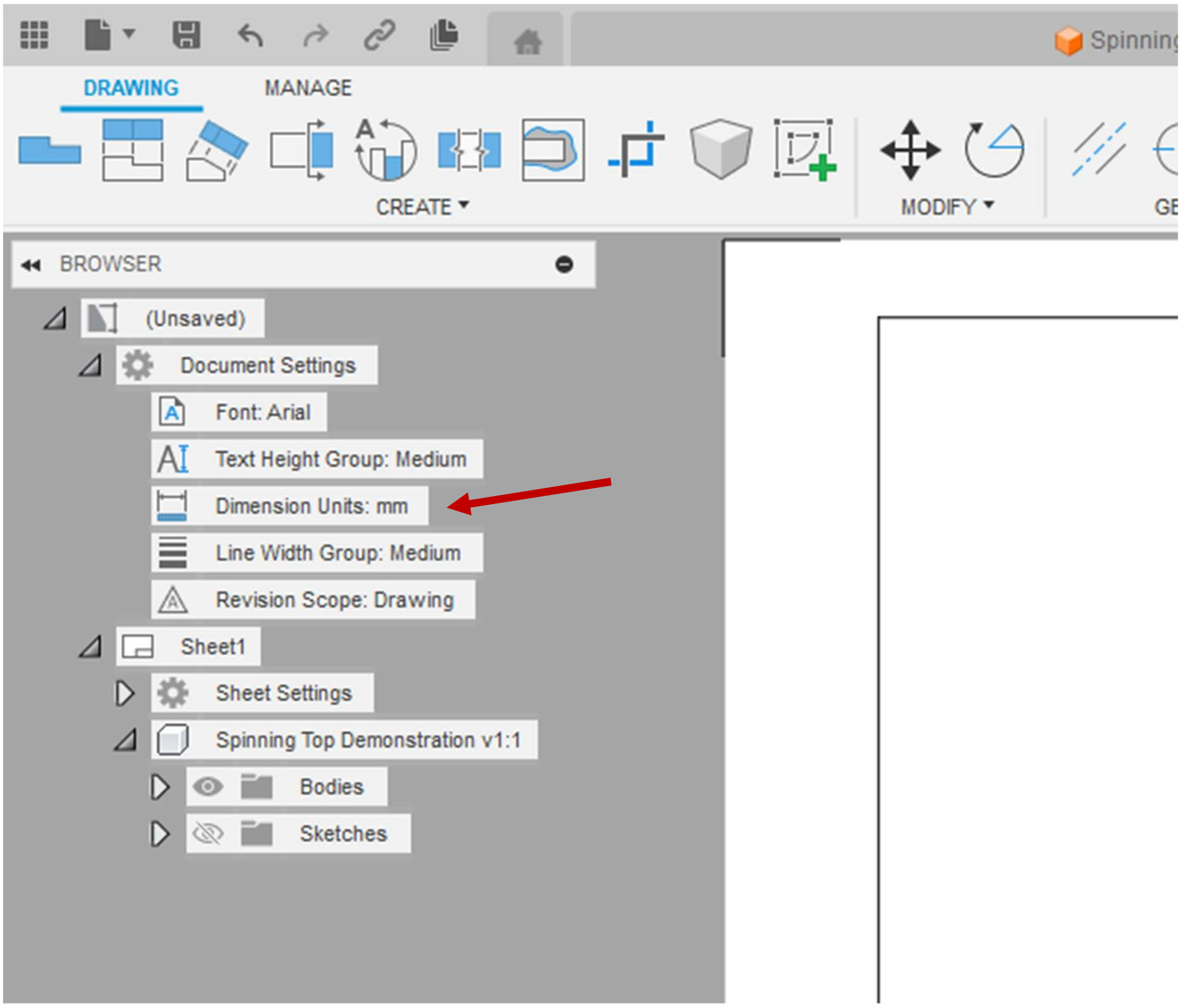


Figure 0-8 Demonstration of the dimension unit setting being changed (part 1).

To increase the accuracy of the dimensions, the amount of allowed decimal places must be changed in the dimension units settings. To do this, click on the small icon that appears when the mouse is hovered over the dimension units shown in Figure 8.

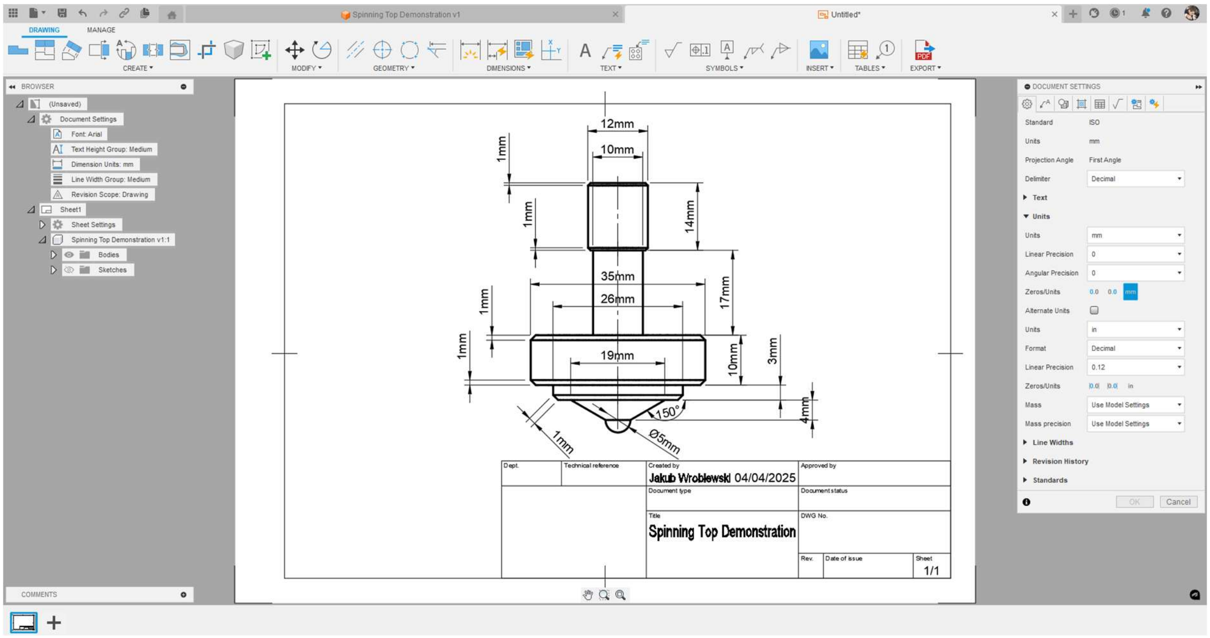


Figure 0-9 Demonstration of the dimension unit setting being changed (part 2).

A window will open to the right of the screen shown in Figure 9.

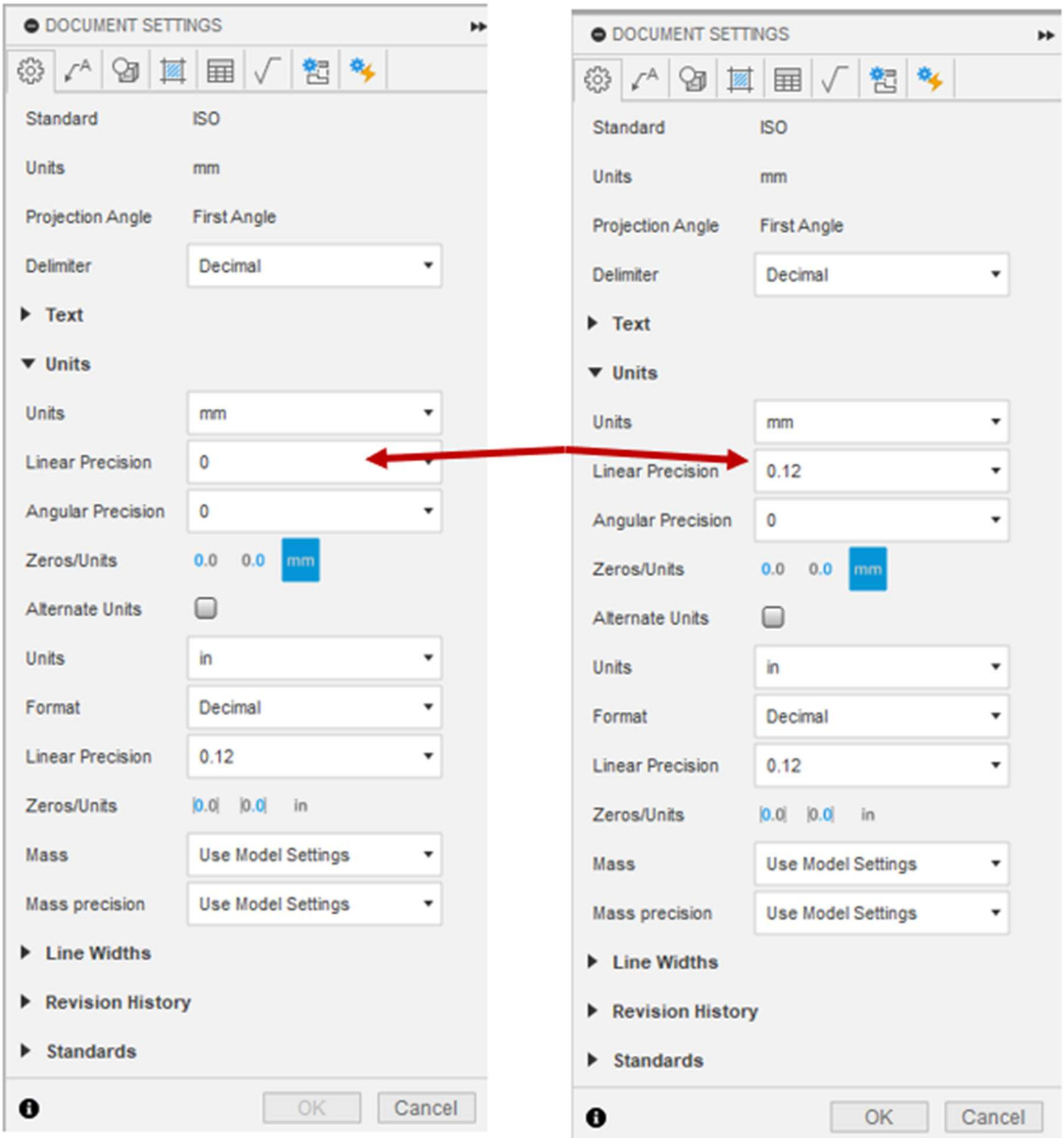


Figure 0-10 Demonstration of the dimension unit setting being changed (part 3).

In this window, the linear precision needs to be changed to at least ‘0.1’ or ‘0.12’, which is 1 decimal place and 2 decimal places, respectively. The angular precision can also be changed

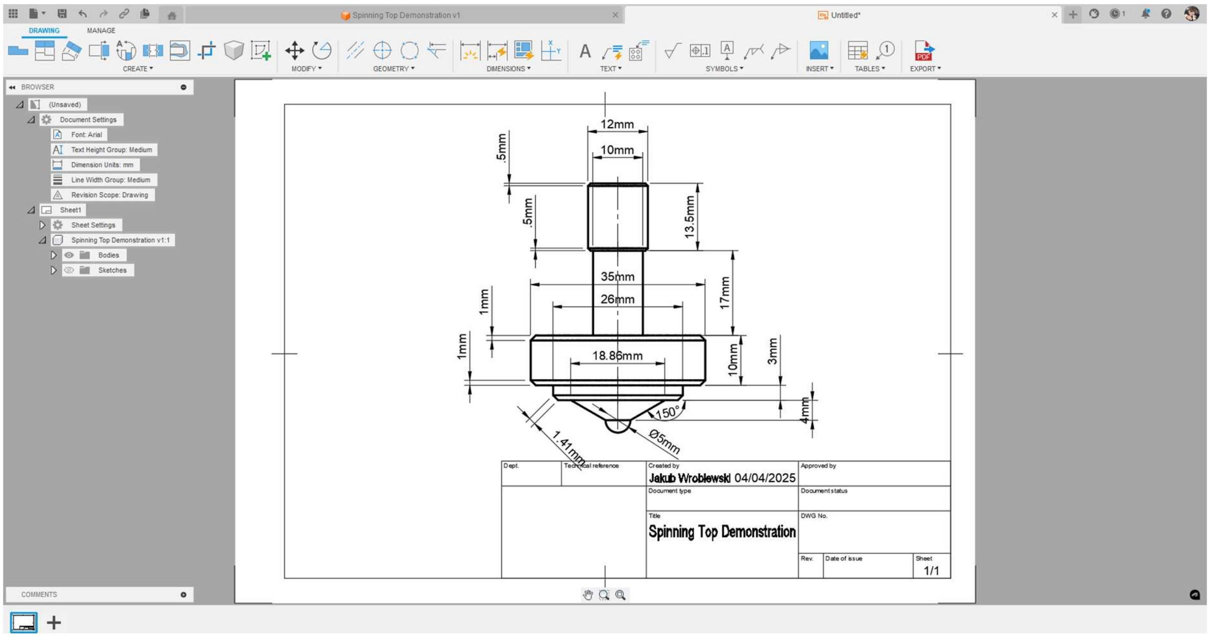


Figure 0-11 Spinning top drawing with correct dimensions.

Figure 11 shows the drawing of the spinning top profile accurately dimensioned.

In Figure 11, the chamfers are both dimensioned vertically and angled. This is because, due to it being an equal distance chamfer, the angled, vertical, and horizontal lengths will all be the same and having them spaced out as in Figure 11 makes the drawing dimensions easier to read.

To be best used as a guide during programming, the drawing can either be exported as a PDF or be taken as a screenshot; all that is important is that the measurements are easily read. To use as a guide during programming, ensure that the spinning top drawing can be viewed easily. This could mean having it downloaded on a smartphone, having a printed copy or having it stored in the cloud so that it can be accessed easily on any device.

13.4 Appendix 4: Programming Teaching Aid.

ProtoTRAK software programming.

These sets of instructions should be accompanied by a live demonstration from the teacher so that the following literature can be properly understood and any questions can be answered.

A properly dimensioned drawing of the student's spinning top is necessary for this activity to use as a guide when programming the software.

This activity can be performed using the CNC lathe's interface or a computer with the software installed; however, when using the computer and not the lathe, there is a necessary step that cannot be completed: linking the tools used to the tool table. This cannot be completed on the computer because the tool table is not available on the computer. The importance of this step and how the issue is overcome will be described in greater detail at the end.

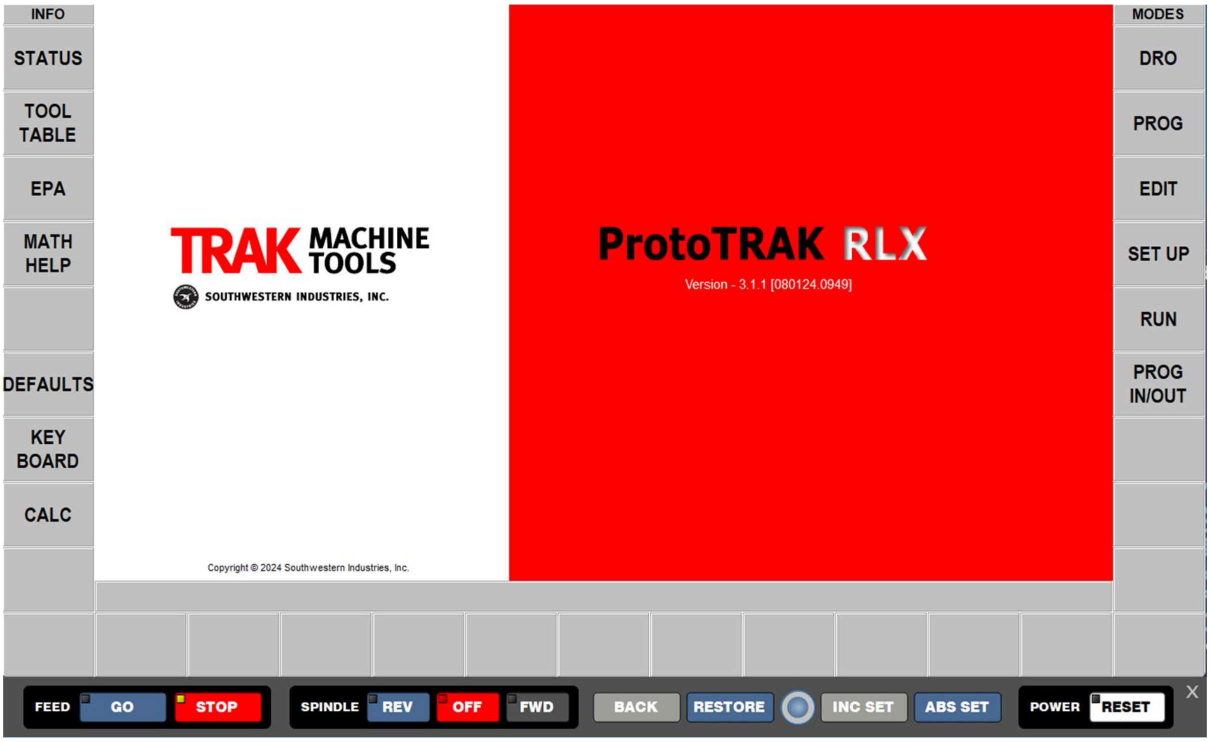


Figure 0-12 ProtoTRAK software main menu.

Figure 1 shows the main menu of the software; this will be the default screen once the program is loaded up. To open this program, first open the TRAK machine tools software, and where it asks for milling machine or lathe, select lathe and confirm. Once the program reloads, click and hold the reset button found on the toolbar until the small square on the button lights up. In Figure 1, the tool bar is located at the bottom of the screen; however, this may not always be the case. Once the square on the reset button lights up, the options on the right side of the screen will appear, as shown in Figure 1.

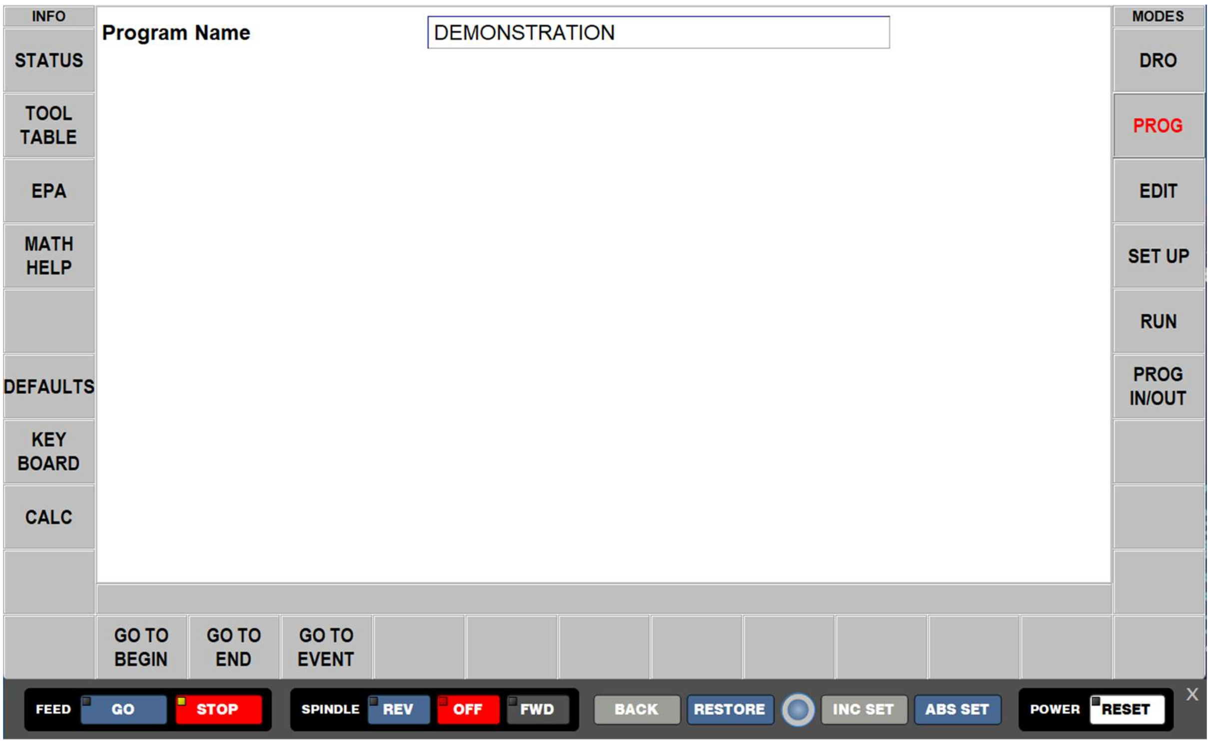


Figure 0-13 ProtoTRAK software program naming.

Now press the 'PROG' option on the right side of the screen. The interface will change to what is shown in Figure 2. This is where the name for the program file is set, this should be set to the student's name. To proceed to the next step, click and hold on the right side of the white area and drag to the left. Drag from just before the edge of the white area shown in Figure 2, not from where the 'Modes' are displayed.

The interface should now display a black screen on the left with 'X' and 'Z' marked on it and a white screen on the right with the heading 'Event 1' at the top. Along the bottom, there should be options to choose an operation. The first operation for machining the spinning top is going to be a cycle in which the turning down of the point will be programmed. Select 'Cycle.'

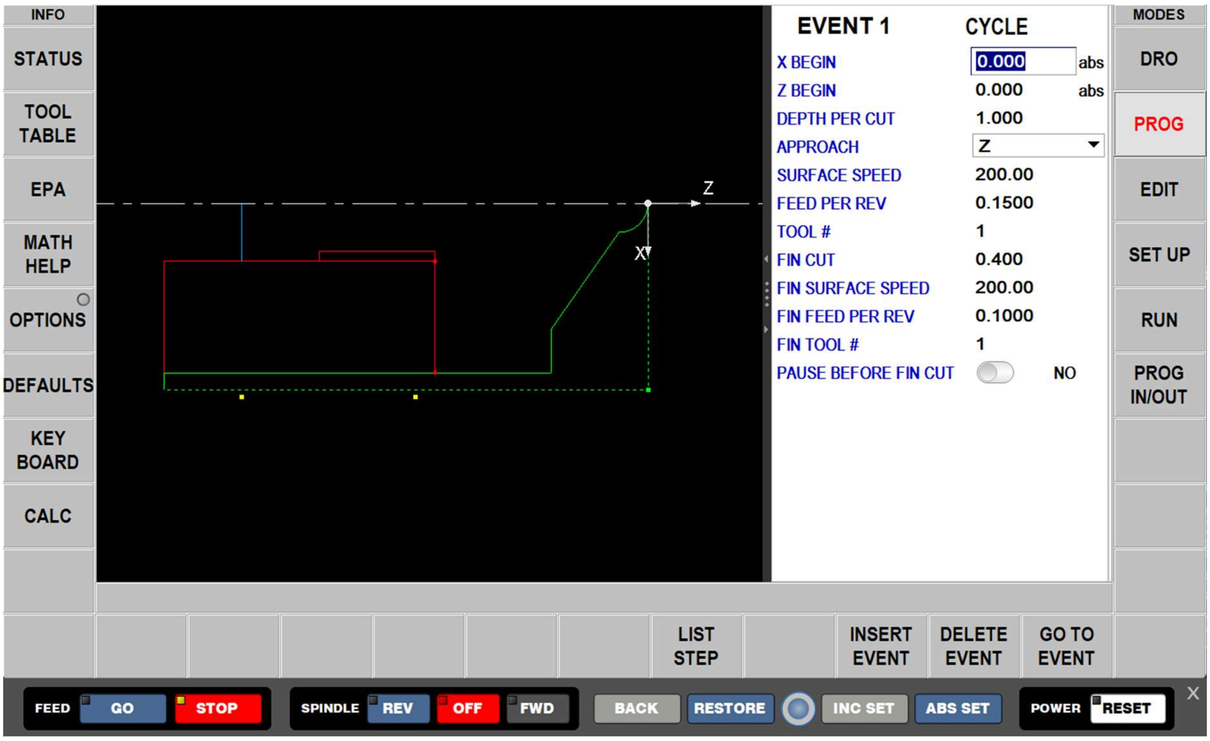


Figure 0-14 Program event 1 cycle beginning.

Figure 3 shows the cycle event being created. In this step, values for the cycle are input. Figure 3 shows a simulation of the spinning top on the left side. This will be used to demonstrate actions in the next events; however, this screen will just be black when writing the program for the first time until all event values are added.

The cycle starts at absolute zero for both the X and Z values, this can be done by typing ‘0’ and clicking the ‘ABS SET’ button on the toolbar. The rest of the values for this cycle are all specific to the tool being used. The tool used for this operation will be a general turning/facing off tool labelled 104. This number will be important once in the workshop and when using the lathe. For this tool, the values are:

- Depth per cut: 1
- Surface speed: 200
- Feed per revolution: 0.15
- Finish cut: 0.4
- Finish surface speed: 200
- Finish feed per revolution: 0.1

The ‘TOOL #’ or tool number in the program refers to which tool you are using. This means that as this is the first tool used, the tool number remains as 1, and so does the finish tool number, as the same tool is being used for the finishing and roughing cuts. When another tool is used, that tool will be named tool number 2 and so on. This is later put into the tool table, where all the available tools are registered, and the tools being used are labelled 1,2,3, etc. This is where the earlier number 104 becomes important because this is the number that tool can be found under in the table. However, as mentioned at the beginning, this can only be done once on the lathe as the tool table is not available on computers.

Once all the values are filled out, drag from the right, as in the previous step, to advance to the next event.

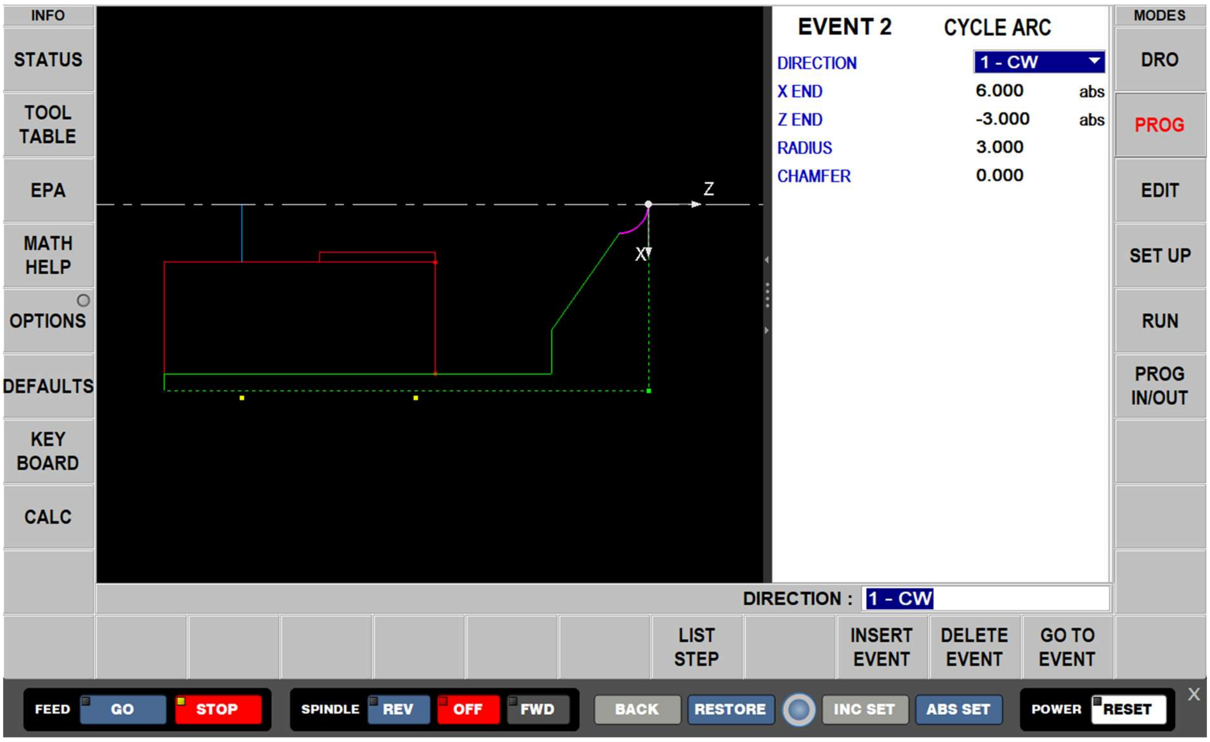


Figure 0-15 Program event 2 cycle arc

The next step for this demonstration spinning top will be turning the ball point tip of the spinning top. This will be an arc, so select cycle arc.

The cycle arc or event 2 is shown in Figure 4. To program this arc, the end point on the x and z axis need to be known, along with the radius of the arc. Because this point is a hemisphere, the ‘X END’ and ‘Z END’ are easily found. The x-axis is always considered in diameter. The x end will be the diameter of the hemisphere. The z end will then be the radius of the hemisphere or half the diameter; however, it is important to remember that the z is zeroed at the very point, and the positive direction will be to the right of that point. Because of this, all z dimensions will be negative. So, the 'X END' 'Z END' and radius are all input using the abs set.

Chamfer is set to 0, this is because there is no chamfer on this part.

Now, again, proceed to the next event by dragging from the right.

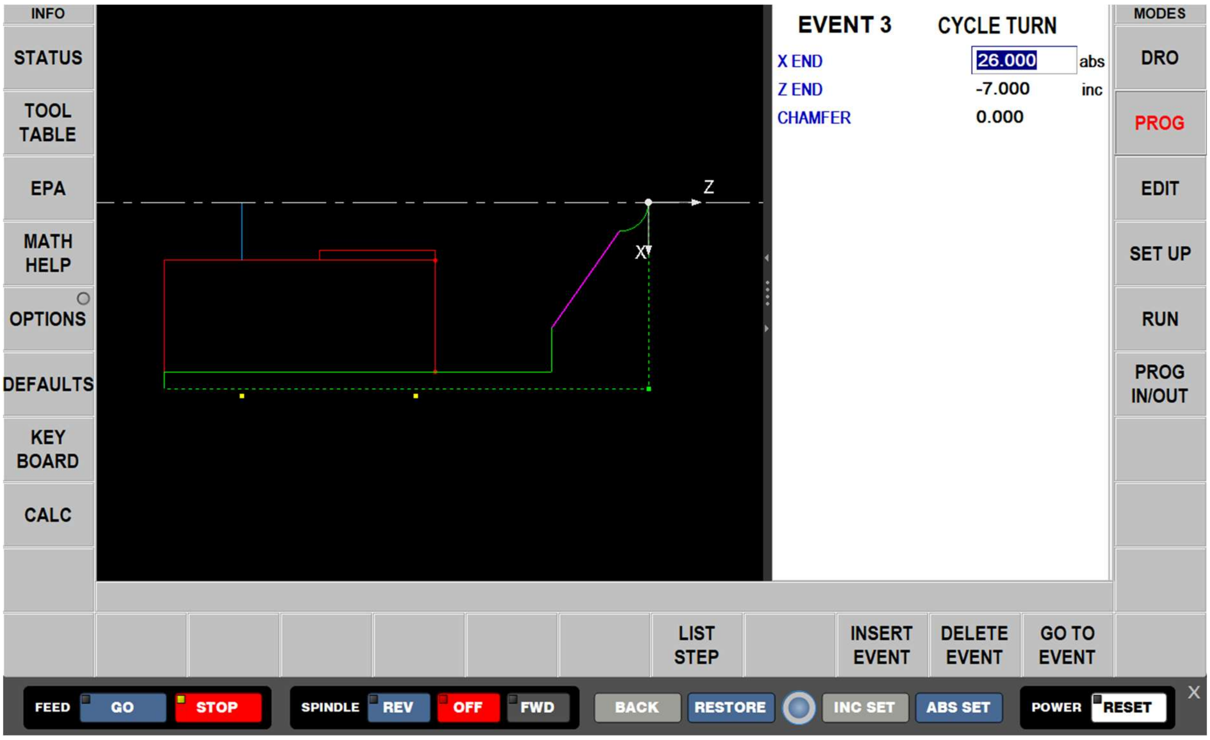


Figure 0-16 Program event 3 cycle turn.

The next event will be a straight line, so it will be a cycle turn. Select the cycle turn, and the screen should look like the one shown in Figure 5. The first point of the line will start at the end of the last event or arc. The second point of the line will be placed by inputting the 'X END' and 'Z END'.

The x end point will be 26 absolute set; remember that this x value is always considered as diameter.

The z end point located 7mm behind the ball point tip, this means that it makes it easier to write –7 and set it using the 'INC SET' button, this means incremental set and will set the z end –7 from the last z value rather than the absolute value which is always from the z true zero. This value could also be set to the z of the ball point tip '-3' added to the z depth of this line '-7' so it could also be set at '-10' abs set. Inc set is used because if the ball point tip's z is changed by 3 mm for example the z for this turn will remain 7mm behind the new value automatically however if it were set absolutely it would remain at '-10' z so the turn would only be 1mm away from the ball point tip.

Now proceed to the next event.

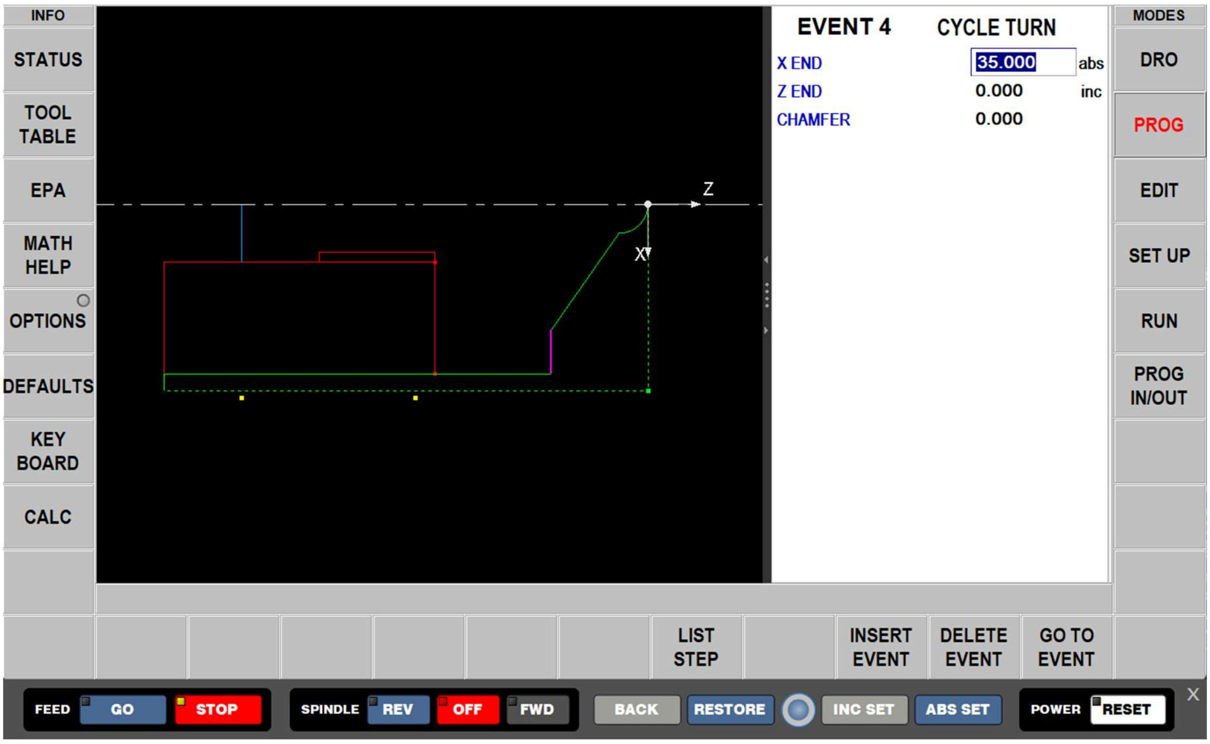


Figure 0-17 Program event 4 cycle turn.

The next event will be another straight line, so another cycle turn. For this event, the x changes; however, the z does not, so the z is set as 0 'INC SET'.

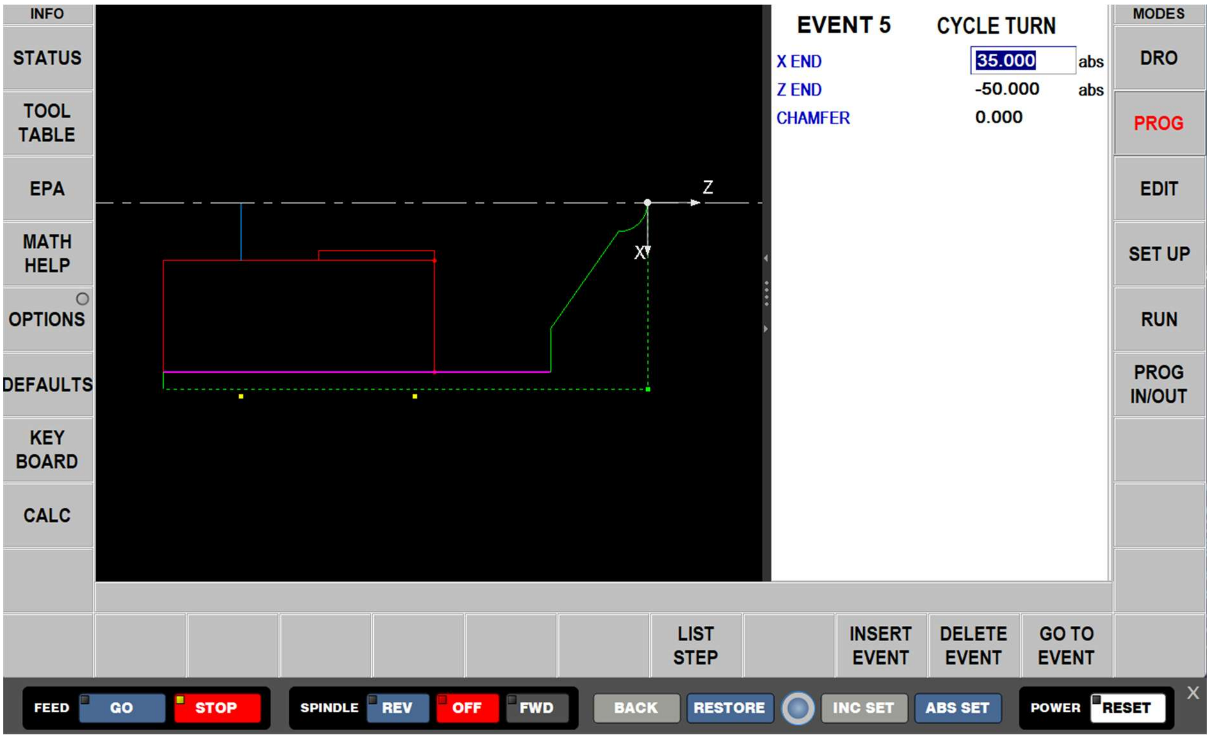


Figure 0-18 Program event 5 cycle turn.

This next event will be a cycle turn used to turn down the stock surface to the 35mm diameter used on this spinning top. The stock surface is not used for the final surface because it is uneven and marked and sometimes even dented from the fabrication process. This will also be turned beyond the end of the spinning top, shown in Figure 7 by the blue line. This is because the parting-off tool has a thickness of 3mm, which needs to be added on to the end of the part. The part is designed to be 42mm in length, plus the 3mm from the tool is 45mm. This was then rounded up to 50mm for safety.

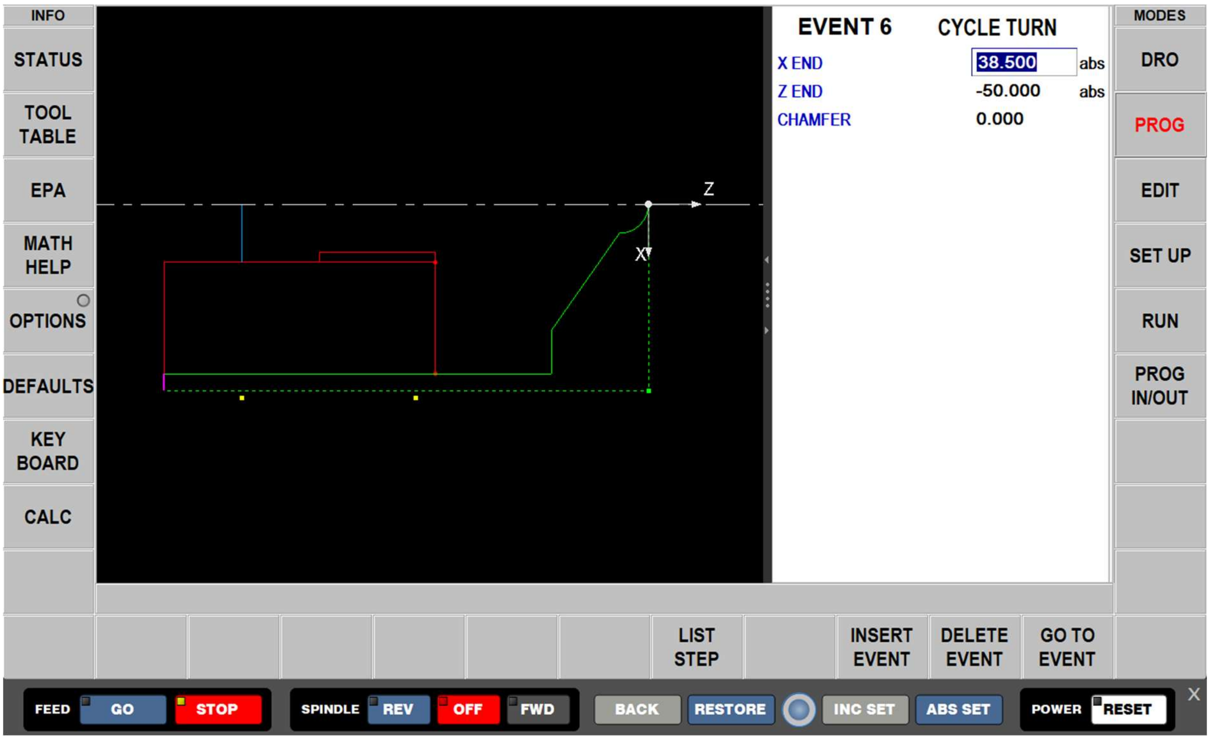


Figure 0-19 Program event 6 cycle turn.

Event 6 will be the final cutting operation of the cycle; this is another cycle turn. This is needed because the stock is around 38mm in diameter but not at all points, so the final cut is performed out of the spinning top from 35mm to 38.5mm. 38.5 is used for the x instead of 38 to account for the irregularities of the stock surface. The z end does not change, so the same value as the last one can be abs set as seen in Figure 8, or it could also be set as 0 inc set.

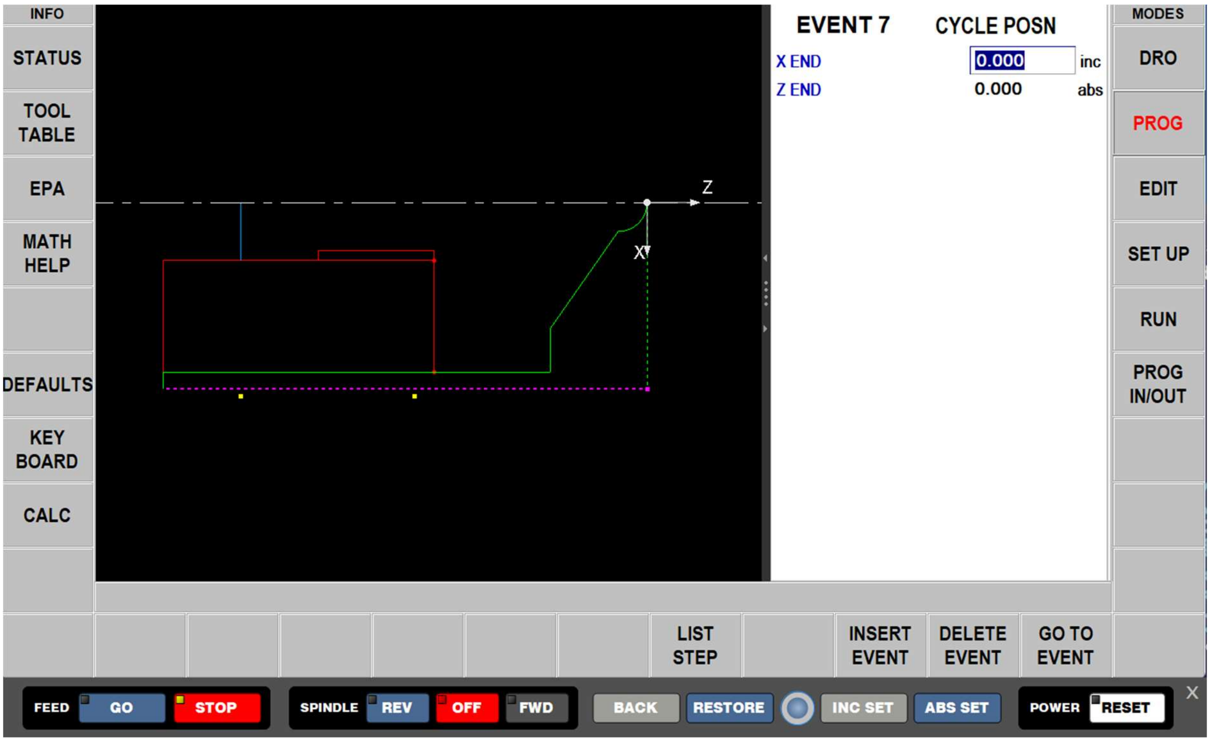


Figure 0-20 Program event 7 cycle position.

The next event will be a cycle position. This is something that is not on the design; however, it is needed to outline the area that will be turned away during the cycle. The x value does not change, so 0 inc set is used, and the z will be the absolute zero of z, so abs set is used.

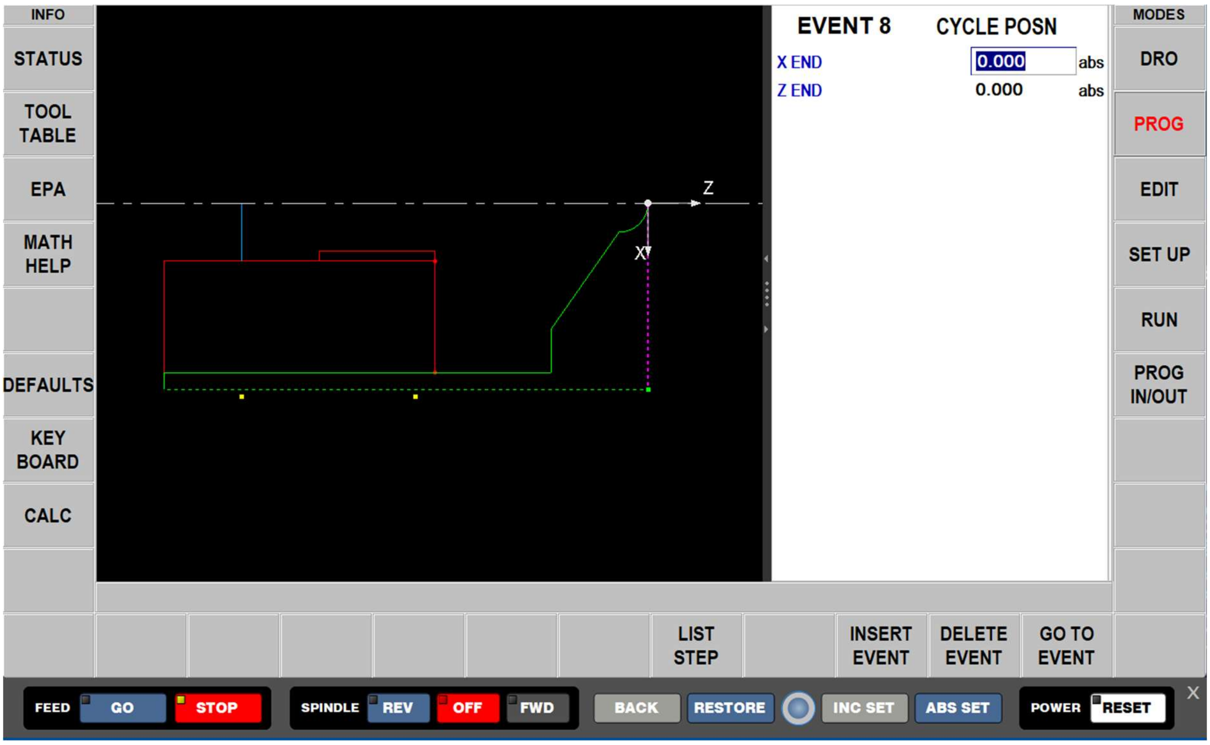


Figure 0-21 Program event 8 cycle position.

The final position of the cycle will end at 0,0; this means that both x and z are set at 0 absolute. Now drag from the right to progress to the next event and select 'END CYCLE.'

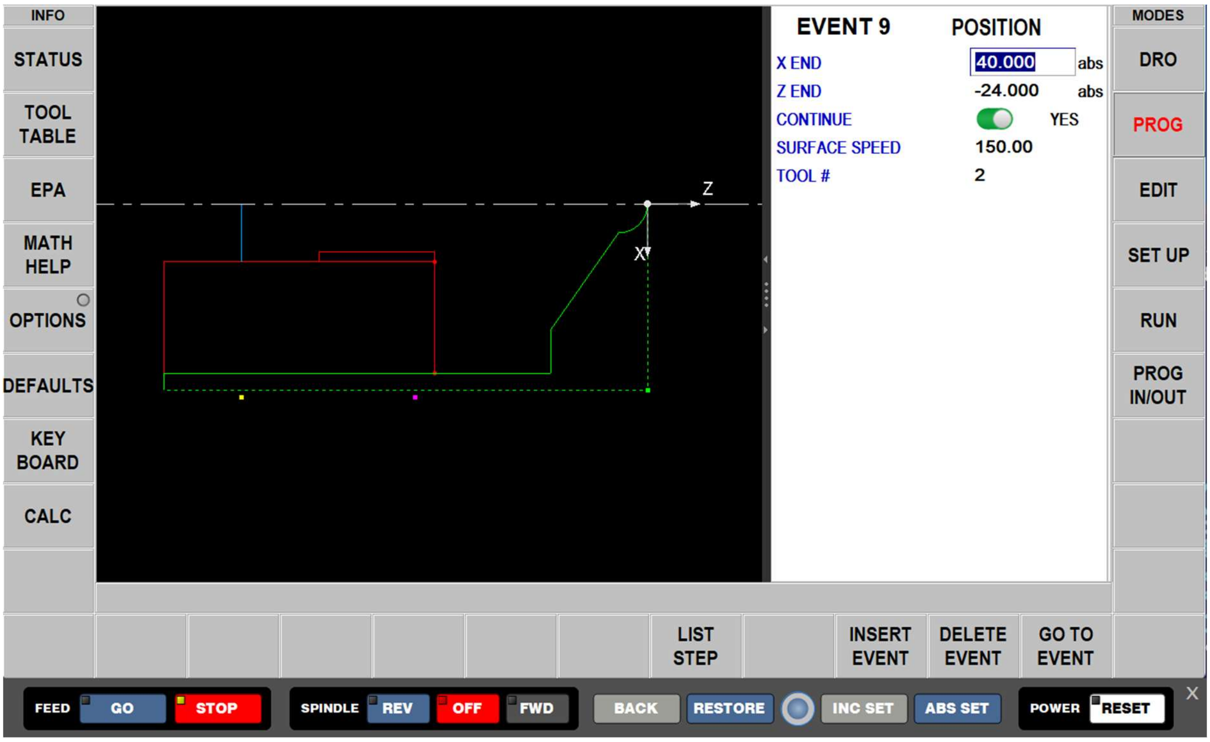


Figure 0-22 Program event 9 position.

The next cutting operation will be a groove; however, before this can happen, the tool needs to be positioned so that it does not collide with the spinning top, as the machine is not aware of where the spinning top is. This is done by selecting the position operation from the bottom.

As seen in Figure 11, the position is different from the cycle position used earlier. This event needs a few more values. The tool used for the groove, which is the next operation, is the grooving tool. As mentioned before, the surface speed and other values needed later are all dependent on the tool; the surface speed for this tool is 150. This is a new tool, so the tool number is now changed to 2 as this is the second tool. The x end is set to 40mm diameter, which is larger than the diameter of the stock because the tool needs to hover over the surface and not collide with it, so the x is rounded up for safety. The z also does not need to be exact if it is between the left side of the widest part and the right side of the end of the piece; for this purpose, 24 abs set is perfectly fine. The 'CONTINUE' slider needs to be put to 'YES' so that the tool stays in that position for the next event rather than going back to 0,0 before the next event, which would defeat the point.

Now, progress to the next event.

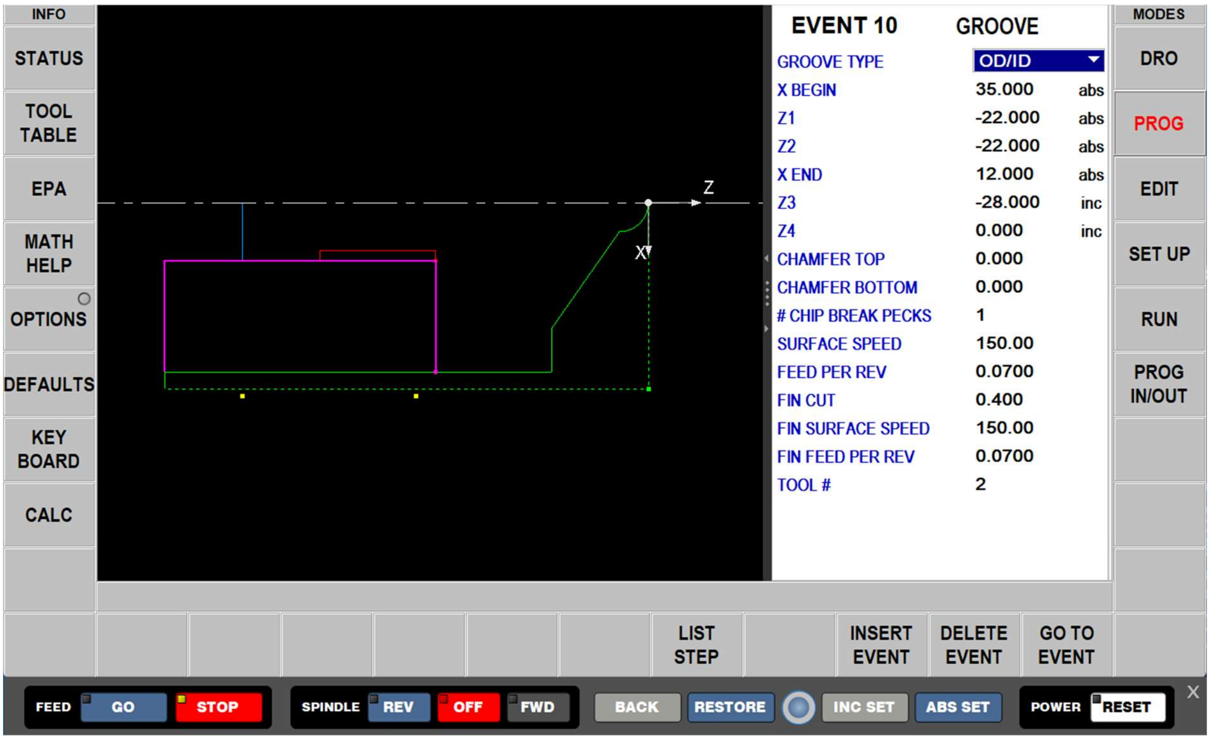


Figure 0-23 Program event 10 groove.

Event 10 will be the larger groove, as seen in Figure 12. This groove will create the widest part of the handle. The length of the groove is determined by the length of the spinning top's handle plus an additional 3mm to account for the width of the parting-off tool rounded up to 5mm to leave a bit of extra space for safety. The groove type should be OD/ID, the x begin should be the diameter of the widest part (35mm) as this is where the groove will begin to cut, and the x end should be the diameter of the widest part of the handle, in this case, 12mm. If the left and right sides of the groove are to be at a right angle, then the z1 and z2 should match, or z2 should be 0 inc set and similarly with z3 and z4.

- Chip break pecks: 1.
- Surface speed: 150.
- Feed per rev: 0.07.
- Fin cut: 0.4.
- Fin surface speed: 150.

- Fin feed per rev: 0.07.

The tool number should be set to 2, as this is the second tool used.

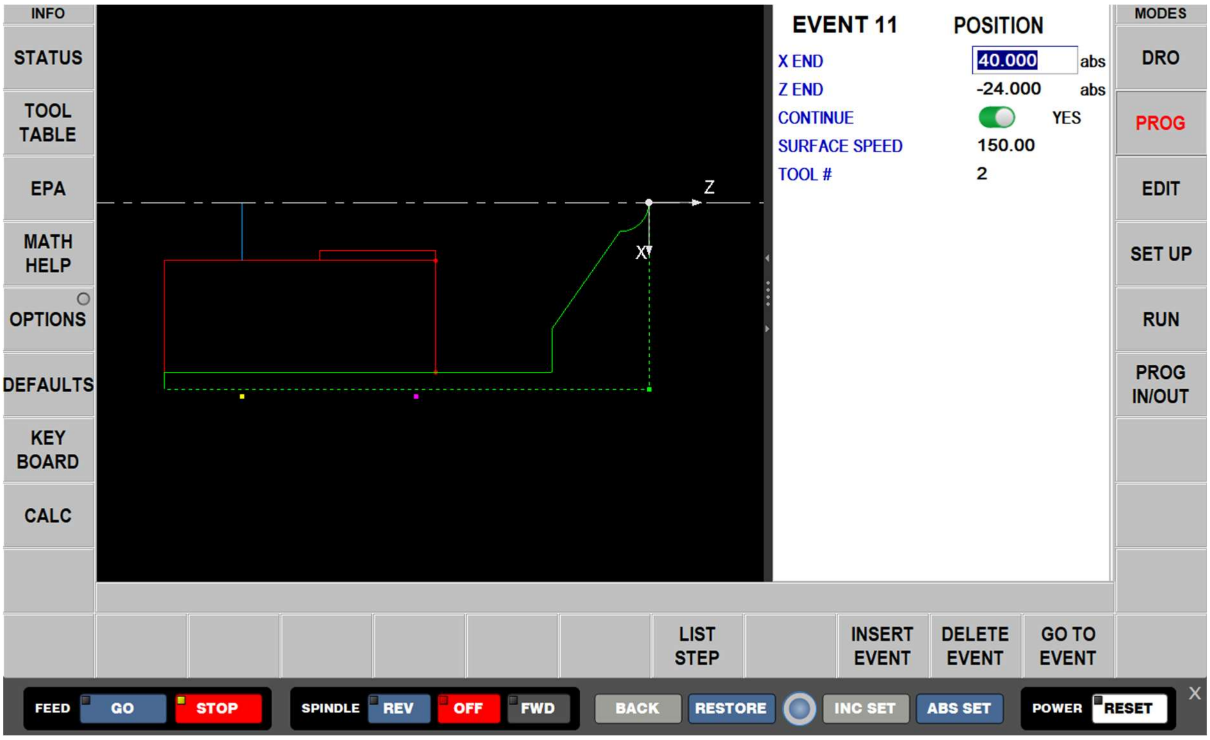


Figure 0-24 Program event 11 position.

Now, for event 11, another position is needed in the same place as the last, for the same reason: to stop collisions.

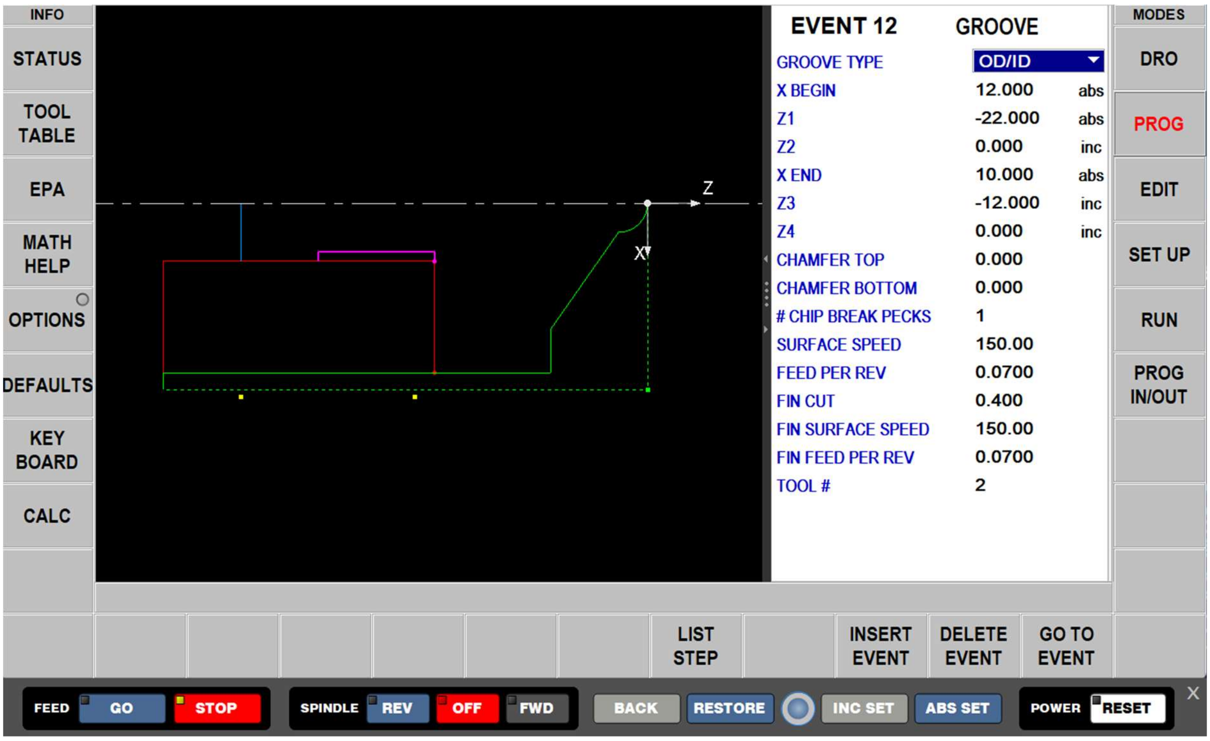


Figure 0-25 Program event 12 groove.

Event 12 will be the final groove. This groove will cut the thinner part of the handle. The reason the handle is cut with two overlapping grooves like this rather than one deeper on the right and one shallower next to it on the left is because manufacturing it using that method creates a small disk in between the grooves where, due to the way the grooves are cut, the material becomes so thin and wide that it bends away from the tool rather than being cut by it.

This groove will start at the diameter that the last groove cut and end at the diameter of the thinnest part of the handle. The z positions should start at the right side of the spinning top's 'weight' and end at where the grip of the handle begins, as shown in Figure 14. The rest of the settings should remain the same as the other groove.

This step is not necessary if the spinning top's handle remains at a constant diameter through its length.

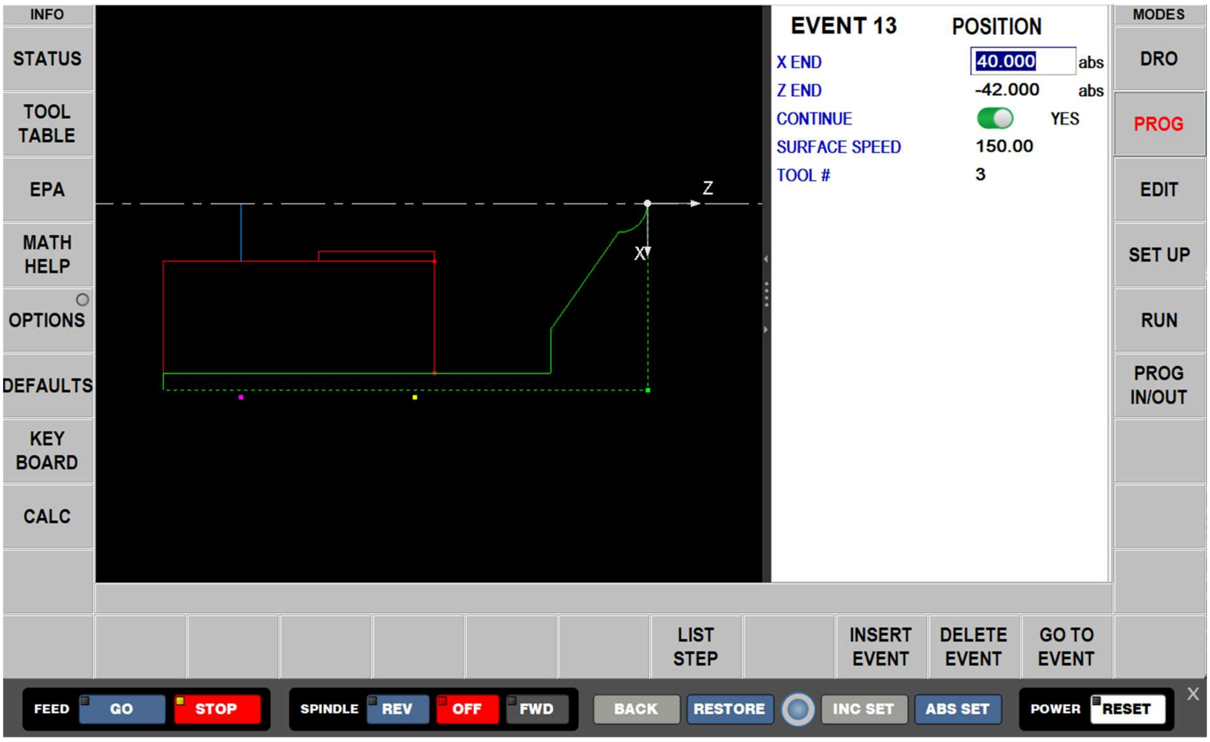


Figure 0-26 Program event 13 final position.

Event 13 will be the final position. This position will be before the final operation, which will be parting off. This means that the tool number must change to 3 as the parting-off tool is seen by the program as a different tool even though the grooving and parting-off tools are the same tool. The surface speed remains at 150. The continue slider should be put to yes so that it does not go back to 0,0 between this event and the last. The z end should be the length of the spinning top, and the x end should be 40mm again so that it hovers over the part further out than the width of the largest segment.

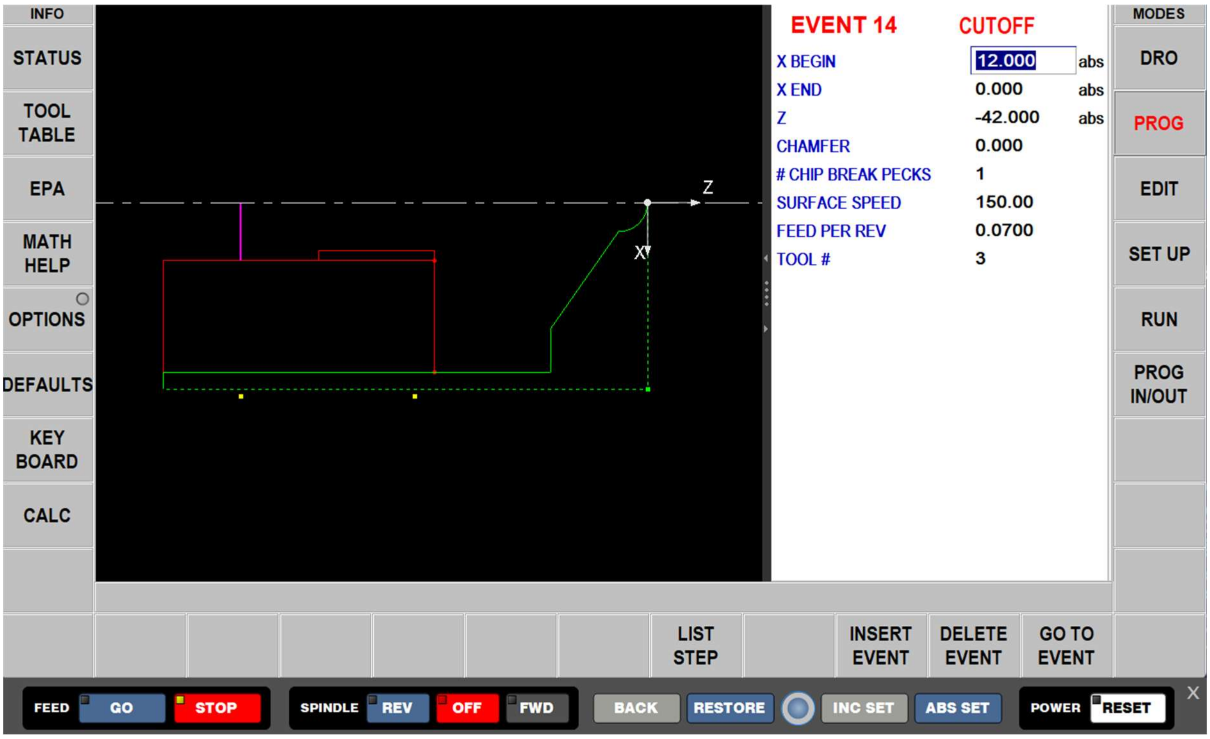


Figure 0-27 Program event 14 cutoff final event.

Event 14 will be the final operation: parting off. This means that the part will be cut away from the stock. Select the cutoff operation found in the 'more' section of the operation selection bar. The x begin should be the diameter of the end of the spinning top, as seen in Figure 16; this is the handle grip. The x end should be set to 0 as it will be completely severing the part from the stock. The z end should be set to the length of the spinning top.

- Chip break pecks:1
- Surface speed: 150
- Feed per rev: 0.07

As stated in the previous step, the tool number should be set to 3.

13.5 Appendix 5: Workshop Session Teaching Aid.

Workshop Instructions

The workshop session will be carried out under the instruction and supervision of the technical skills specialist. The technical skills specialist will conduct this lesson and provide all necessary instructions on how to machine the part; however, this is what is expected to occur during the workshop session.

To safely participate in the workshop session, the following measures must be considered and followed before attending the session:

- The student should wear steel-toe cap boots or shoes. This is to prevent injuries caused by dropping heavy materials or tools on the toes. If the student does not own any steel-toe shoes, then protectors will be provided by the workshop, however, the shoes must still be sensible, for example, no open-toed shoes.
- The student should wear overalls. This is to protect them and their clothes from cutting oils, fluids, and other similar substances. If the student does not own overalls, then they should wear any old clothes that they do not mind getting dirty or stained.
- The student must tie up any long hair so that it cannot be pulled into the lathe. For the same reason, the student must also remove anything dangly, such as lanyards or dangling jewellery. The student's sleeves must similarly not dangle so that they cannot be caught on the machines.
- Goggles must be worn during the operation of the machines; however, they will be provided in the workshop.

Setup

After the technical skills specialist finishes the safety talk, describing what to do in case of fire, etc, the first step will be setting everything up for the machine. This will involve:

- Finding and preparing all the tools used during the program.
- Turning on the machine.
- Preparing all the equipment, such as the chuck key and measuring tools.
- Loading up the program on the lathe’s computer.
- Setting the tool table in the program.

- Putting the stock into the chuck and leaving the proper amount sticking out of the end of the chuck.

After all these steps have been completed, the final setup can begin. The final setup step is to set the Z and X offsets on the machine. To do this, the machine must first be put into DRO mode, which allows the lathe to be used like a regular manual lathe. The computer must be told the tool number before beginning so that it knows the offsets of the tool. The tool used for setting material offsets will most likely be tool 104. The tool number is not the same as the tool number used during the programming stage, but rather the number the tool is labelled as in the workshop. Now set the spindle to 1000 rpm and start it.

To set the Z offset face off around 1mm of material, back off the tool but only in the x direction, not the Z. Once the tool is backed off from the material, turn off the spindle, then select 'Z' and ABS set, this will set the z offset to 0.

Now to set the X offset, turn down roughly 1cm around 1mm of material deep, this will give room to measure, now back off the tool only in the z direction. Once the tool is backed off, stop the spindle and, using a micrometre, measure the diameter of the turned-down section. Now select 'X' and enter the value measured. Now turn down the bar again using the readout on the screen to turn it down to a round number, for example, if the measurement was 37.7654mm, turn down to 37mm and once again back off the tool in the z direction only. Measure the new diameter of the turned-down part, and if the measurement is the same as the readout on the screen, then the x offset is correctly set; however, if the measurement is different, repeat this process until the x readout matches.

Once both offsets are set, the coolant jets must be set up so that they properly spray onto the tool and part. After all of this is complete, it is time to begin machining.

Machining

To begin machining, switch back to PROG from the DRO screen and select run. This starts the setup, and once that is complete, there will be instructions on the screen to click go. All the instructions on the screen must be followed. Once it is ready, turn on the spindle and select tracking. This will allow the student to control the tool as it goes through the first cut by turning the z-axis wheel. Once the first cut has been performed, the program should be set to CNC. This is done by first pausing the program by hitting the start-stop button, then choosing the 'CNC RUN' option. Once the start-stop button is pressed again, the CNC will start.

Whenever it is desired to lift the cover of the lathe after it has been running, it must first be given 30 seconds so that the coolant mist can settle.

After the program stops and asks for a tool change, and the 30 seconds have passed, the tool can be changed; however, due to the new tool, the coolant jets need to be reset so that they are hitting the tool and part correctly.

After this is complete, the same steps should be followed for the next operations, first tracking, then CNC RUN. Once the program has run its course and the 30 seconds have passed, the technical skills specialist can use a special cut-proof glove to retrieve the part from the swarf bin.

13.6 Appendix 6: Knowledge Questionnaire Pre-Project.

Spinning Top CNC Project Questionnaire

This is a quick questionnaire that gives the teacher a baseline of your and your class's current knowledge about the subjects covered in this project. This is so that your learning can be adapted to best fit you and your class. This same questionnaire will be used at the end of the project as a method of feedback and also to reflect on what you have learnt. This shouldn't take more than a couple of minutes to complete. The answers will not be shared with the class, only the teacher will have access to them.

* Required

1. Student first name *

2. Student last name *

3. Student ID number *

4. Have you used CAD before? *

○ Yes

○ No

5. How confident are you with using CAD? *

○ Extremely confident

○ Somewhat confident

○ Neutral

○ Not very confident

○ Extremely not confident

6. Do you know what CNC is? *

- Yes
- No

7. How experienced are you with CNC machinery? *

- Very experienced use them all the time
- I have used one before but not a lot
- I have seen someone use one but have not personally used one
- I have never used one

8. Do you know what a centre lathe is? *

- Yes
- No

9. Do you have any experience with lathes? *

- Very experienced use them all the time
- I have used one before but not a lot
- I have seen someone use one but have not personally used one
- I have never used one

10. Have you ever designed to a specification before? *

- Many times
- Once or twice
- Never

11. How confident are you with creating a design to a specification? *

- Extremely confident
- Somewhat confident
- Neutral
- Not very confident
-

Extremely not confident

12. Have you got any experience programming CAM machinery? *

- ◯ Very experienced
- ◯ I've programmed once or twice
- ◯ I've seen someone program but never done it myself
- ◯ Zero experience

13. How confident are you with programming CAM machinery? *

- ◯ Extremely confident
- ◯ Somewhat confident
- ◯ Neutral
- ◯ Not very confident
- ◯ Extremely not confident

14. How confident would you be undertaking this project from start to finish? *

- ◯ I could confidently complete this project alone
- ◯ I would feel confident only if there was someone there to supervise
- ◯ I would require lots of help and would not feel confident taking control

---

13.7 Appendix 7: Knowledge Questionnaire Post Project.

Post Spinning Top CNC Project Questionnaire

This is a quick questionnaire that gives the teacher a baseline of your and your class's current knowledge about the subjects covered in this project. This is so that your learning can be adapted to best fit you and your class. This same questionnaire will be used at the end of the project as a method of feedback and also to reflect on what you have learnt. This shouldn't take more than a couple of minutes to complete. The answers will not be shared with the class, only the teacher will have access to them.

* Required

1. Student first name *

2. Student last name *

3. Student ID number *

4. Have you used CAD before? *

○ Yes

○ No

5. How confident are you with using CAD? *

○ Extremely confident

○ Somewhat confident

○ Neutral

○ Not very confident

○ Extremely not confident

6. Do you know what CNC is? *

- Yes
- No

7. How experienced are you with CNC machinery? *

- Very experienced use them all the time
- I have used one before but not a lot
- I have seen someone use one but have not personally used one
- I have never used one

8. Do you know what a centre lathe is? *

- Yes
- No

9. Do you have any experience with lathes? *

- Very experienced use them all the time
- I have used one before but not a lot
- I have seen someone use one but have not personally used one
- I have never used one

10. Have you ever designed to a specification before? *

- Many times
- Once or twice
- Never

11. How confident are you with creating a design to a specification? *

- Extremely confident
- Somewhat confident
- Neutral
- Not very confident
-

Extremely not confident

12. Have you got any experience programming CAM machinery? *

- ○ Very experienced
- ○ I've programmed once or twice
- ○ I've seen someone program but never done it myself
- ○ Zero experience

13. How confident are you with programming CAM machinery? *

- ○ Extremely confident
- ○ Somewhat confident
- ○ Neutral
- ○ Not very confident
- ○ Extremely not confident

14. How confident would you be undertaking this project from start to finish? *

- ○ I could confidently complete this project alone
- ○ I would feel confident only if there was someone there to supervise
- ○ I would require lots of help and would not feel confident taking control

15. Would you say you feel as though you have learnt from this program? *

- ○ Yes
- ○ No

16. Describe one thing you have learnt if you can. *

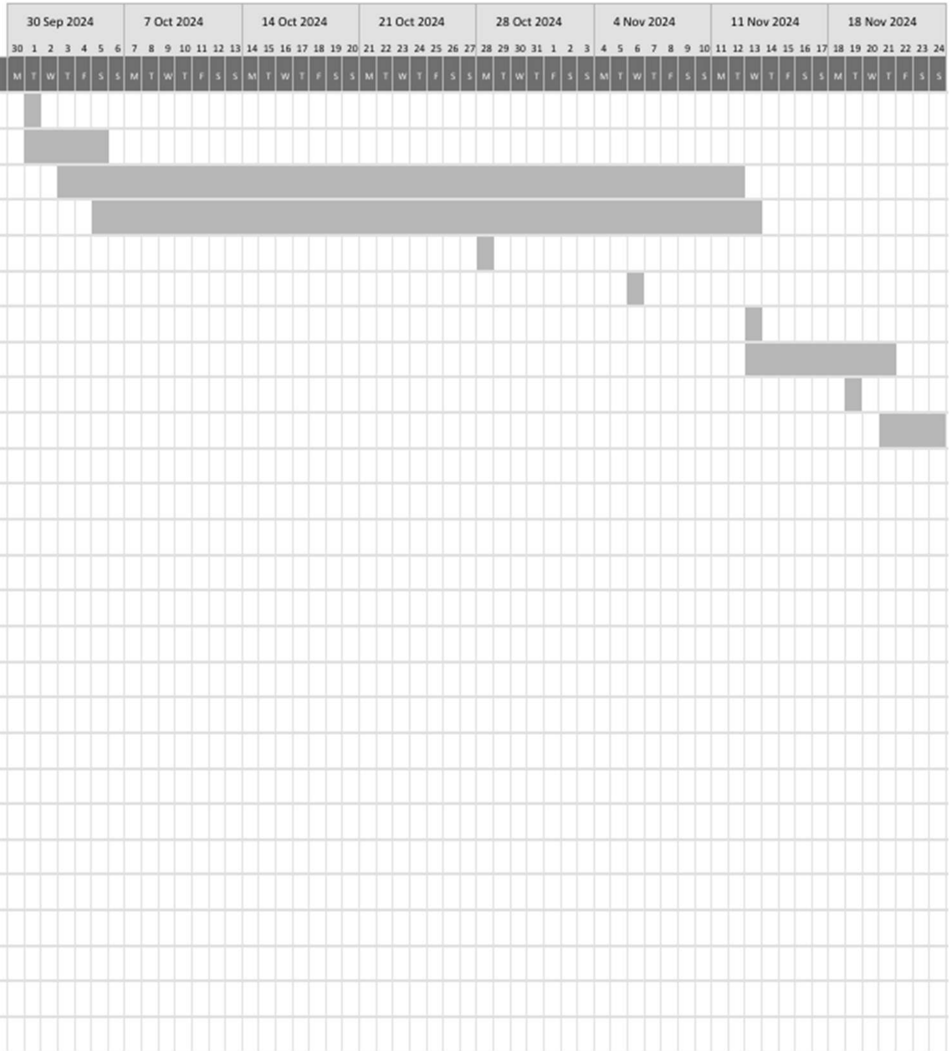
13.8 Abstract 8: Gantt Chart.

Idividual Engineering Project
Jakub Wroblewski

Project Start: Tue, 01/10/2024

Display Week: 1

TASK	PROGRESS	START	END
Project Supervisor Form	100%	1/10/24	1/10/24
Project Supervisor Form	100%	1/10/24	5/10/24
Ethics Form	100%	3/10/24	12/11/24
Risk Assessment	100%	5/10/24	13/11/24
CNC Lathe Induction	100%	28/10/24	28/10/24
Meeting With supervisor	100%	6/11/24	6/11/24
Meeting With supervisor	100%	13/11/24	13/11/24
Proposal	100%	13/11/24	21/11/24
Meeting With supervisor	100%	19/11/24	19/11/24
Journal Learning action plan	100%	21/11/24	7/12/24
Journal ethical conduct in engineering	100%	7/12/24	23/12/24
Journal legal requirements	100%	23/12/24	8/1/25
Create an IPDS for the product	99%	4/1/25	5/1/25
Journal intellectual property	100%	8/1/25	24/1/25
Journal initiative and problem solving	100%	24/1/25	9/2/25
Research VARK learning theories	100%	5/2/25	14/3/25
Research curricula and lesson plans	100%	5/2/25	14/3/25
Research differences in teaching 1980-2025	100%	5/2/25	14/3/25
Journal project management	100%	9/2/25	25/2/25
Journal sustainable design	100%	25/2/25	14/3/25
Create prototypes in workshop	100%	7/3/25	7/3/25
Create a step-by-step teaching aid for CAD	100%	14/3/25	2/5/25
Create a step-by-step teaching aid for programming	100%	14/3/25	2/5/25
Create a step-by-step teaching aid for machining	100%	14/3/25	2/5/25
Start trial run by having the participants answer the questionare	100%	2/4/25	3/4/25
Perform CAM programming workshop with participants	100%	8/4/25	8/4/25
Perform mancining workshop with participants	100%	11/4/25	11/4/25

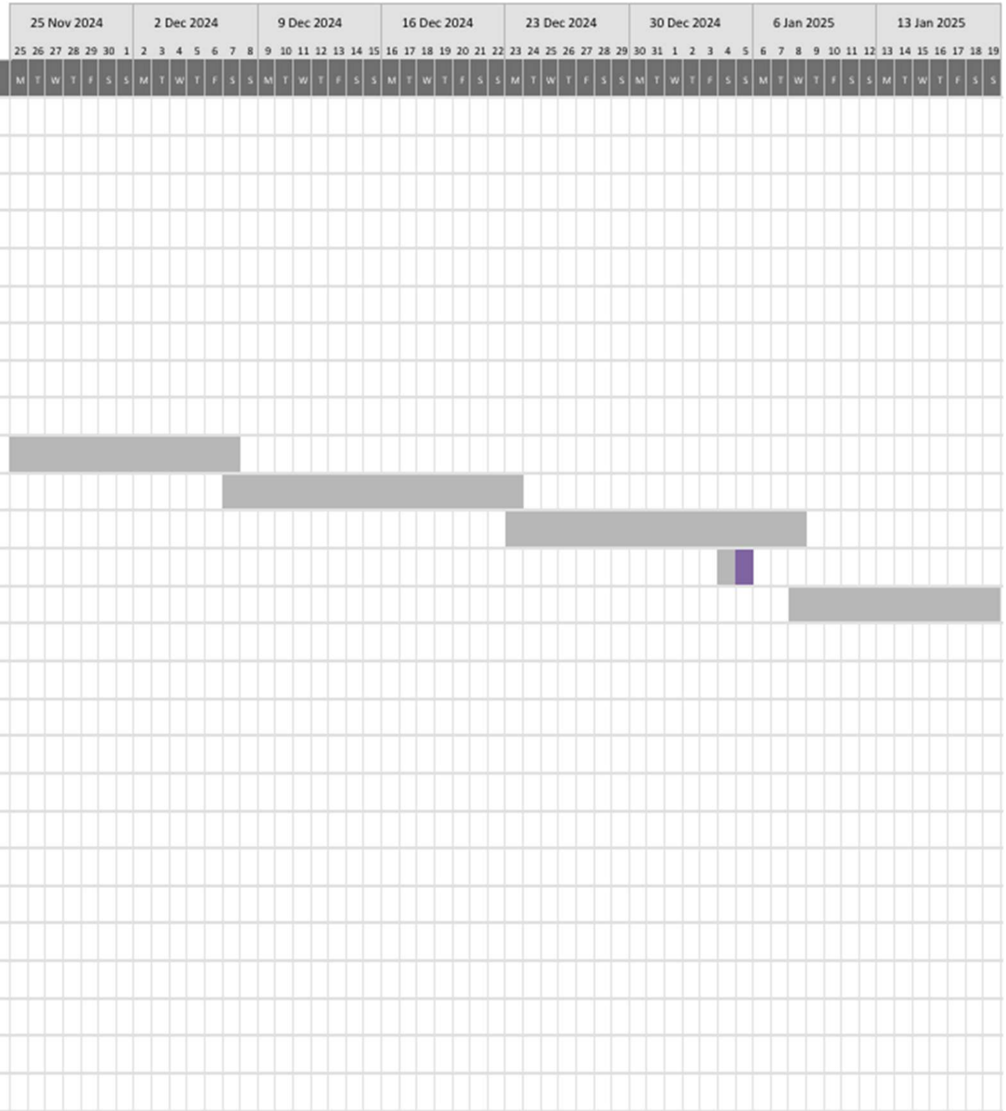


Idividual Engineering Project
Jakub Wroblewski

Project Start: Tue, 01/10/2024

Display Week: 9

TASK	PROGRESS	START	END
Project Supervisor Form	100%	1/10/24	1/10/24
Project Supervisor Form	100%	1/10/24	5/10/24
Ethics Form	100%	3/10/24	12/11/24
Risk Assessment	100%	5/10/24	13/11/24
CNC Lathe Induction	100%	28/10/24	28/10/24
Meeting With supervisor	100%	6/11/24	6/11/24
Meeting With supervisor	100%	13/11/24	13/11/24
Proposal	100%	13/11/24	21/11/24
Meeting With supervisor	100%	19/11/24	19/11/24
Journal Learning action plan	100%	21/11/24	7/12/24
Journal ethical conduct in engineering	100%	7/12/24	23/12/24
Journal legal requirements	100%	23/12/24	8/1/25
Create an IPDS for the product	99%	4/1/25	5/1/25
Journal intellectual property	100%	8/1/25	24/1/25
Journal initiative and problem solving	100%	24/1/25	9/2/25
Research VARK learning theories	100%	5/2/25	14/3/25
Research curricula and lesson plans	100%	5/2/25	14/3/25
Research differences in teaching 1980-2025	100%	5/2/25	14/3/25
Journal project management	100%	9/2/25	25/2/25
Journal sustainable design	100%	25/2/25	14/3/25
Create prototypes in workshop	100%	7/3/25	7/3/25
Create a step-by-step teaching aid for CAD	100%	14/3/25	2/5/25
Create a step-by-step teaching aid for programming	100%	14/3/25	2/5/25
Create a step-by-step teaching aid for machining	100%	14/3/25	2/5/25
Start trial run by having the participants answer the questionare	100%	2/4/25	3/4/25
Perform CAM programming workshop with participants	100%	8/4/25	8/4/25
Perform mancining workshop with participants	100%	11/4/25	11/4/25



Display Week: 9

TASK	PROGRESS	START	END
Have the participants retake the questionare to show development	100%	13/4/25	13/4/25
Thesis	100%	14/3/25	2/5/25
Presentation	0%	2/5/25	9/5/25

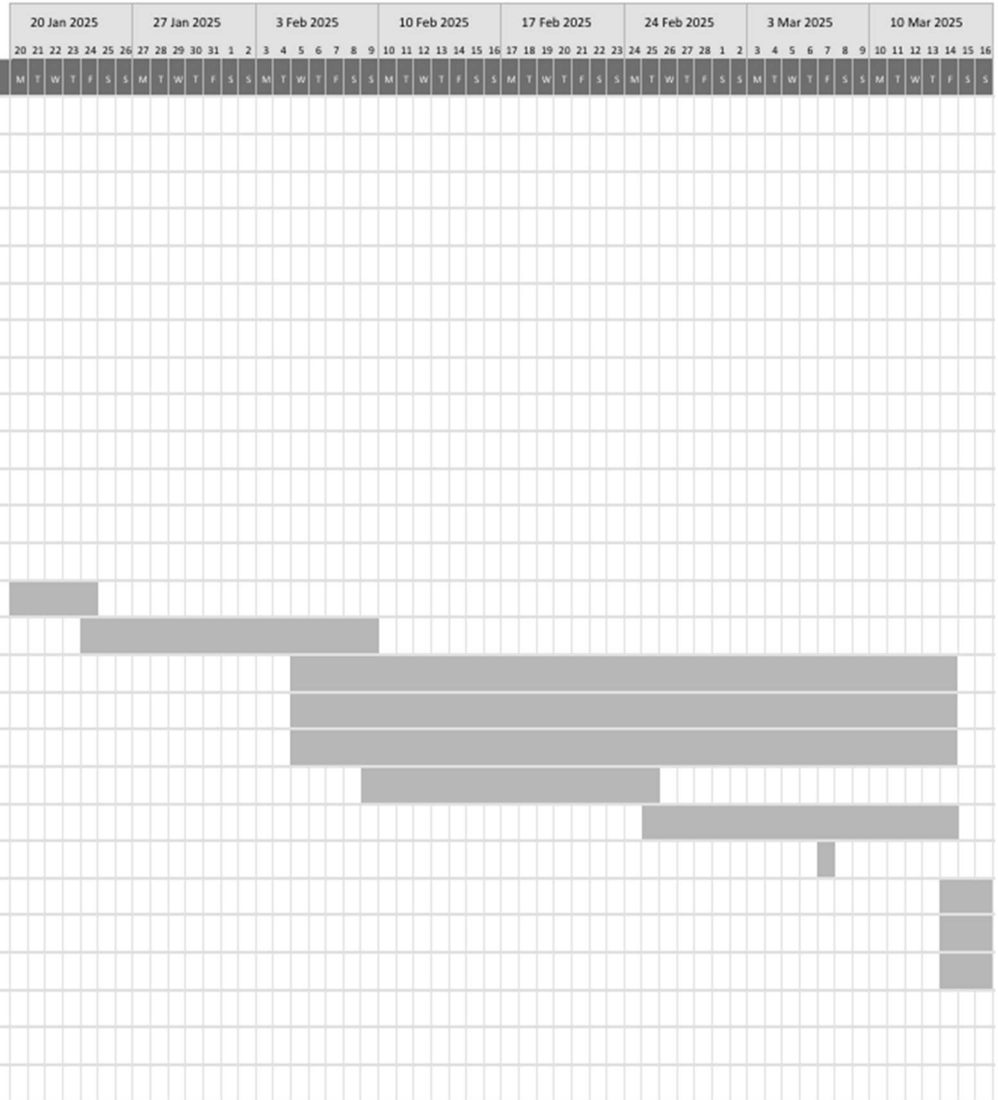
25 Nov 2024	2 Dec 2024	9 Dec 2024	16 Dec 2024	23 Dec 2024	30 Dec 2024	6 Jan 2025	13 Jan 2025
25 26 27 28 29 30 1	2 3 4 5 6 7 8	9 10 11 12 13 14 15	16 17 18 19 20 21 22	23 24 25 26 27 28 29	30 31 1 2 3 4 5	6 7 8 9 10 11 12	13 14 15 16 17 18 19
M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S	M T W T F S S

Idividual Engineering Project
Jakub Wroblewski

Project Start: Tue, 01/10/2024

Display Week: 17

TASK	PROGRESS	START	END
Project Supervisor Form	100%	1/10/24	1/10/24
Project Supervisor Form	100%	1/10/24	5/10/24
Ethics Form	100%	3/10/24	12/11/24
Risk Assessment	100%	5/10/24	13/11/24
CNC Lathe Induction	100%	28/10/24	28/10/24
Meeting With supervisor	100%	6/11/24	6/11/24
Meeting With supervisor	100%	13/11/24	13/11/24
Proposal	100%	13/11/24	21/11/24
Meeting With supervisor	100%	19/11/24	19/11/24
Journal Learning action plan	100%	21/11/24	7/12/24
Journal ethical conduct in engineering	100%	7/12/24	23/12/24
Journal legal requirements	100%	23/12/24	8/1/25
Create an IPDS for the product	99%	4/1/25	5/1/25
Journal intellectual property	100%	8/1/25	24/1/25
Journal initiative and problem solving	100%	24/1/25	9/2/25
Research VARK learning theories	100%	5/2/25	14/3/25
Research curricula and lesson plans	100%	5/2/25	14/3/25
Research differences in teaching 1980-2025	100%	5/2/25	14/3/25
Journal project management	100%	9/2/25	25/2/25
Journal sustainable design	100%	25/2/25	14/3/25
Create prototypes in workshop	100%	7/3/25	7/3/25
Create a step-by-step teaching aid for CAD	100%	14/3/25	2/5/25
Create a step-by-step teaching aid for programming	100%	14/3/25	2/5/25
Create a step-by-step teaching aid for machining	100%	14/3/25	2/5/25
Start trial run by having the participants answer the questionare	100%	2/4/25	3/4/25
Perform CAM programming workshop with participants	100%	8/4/25	8/4/25
Perform mancining workshop with participants	100%	11/4/25	11/4/25



Display Week: 17

20 Jan 2025 | 27 Jan 2025 | 3 Feb 2025 | 10 Feb 2025 | 17 Feb 2025 | 24 Feb 2025 | 3 Mar 2025 | 10 Mar 2025

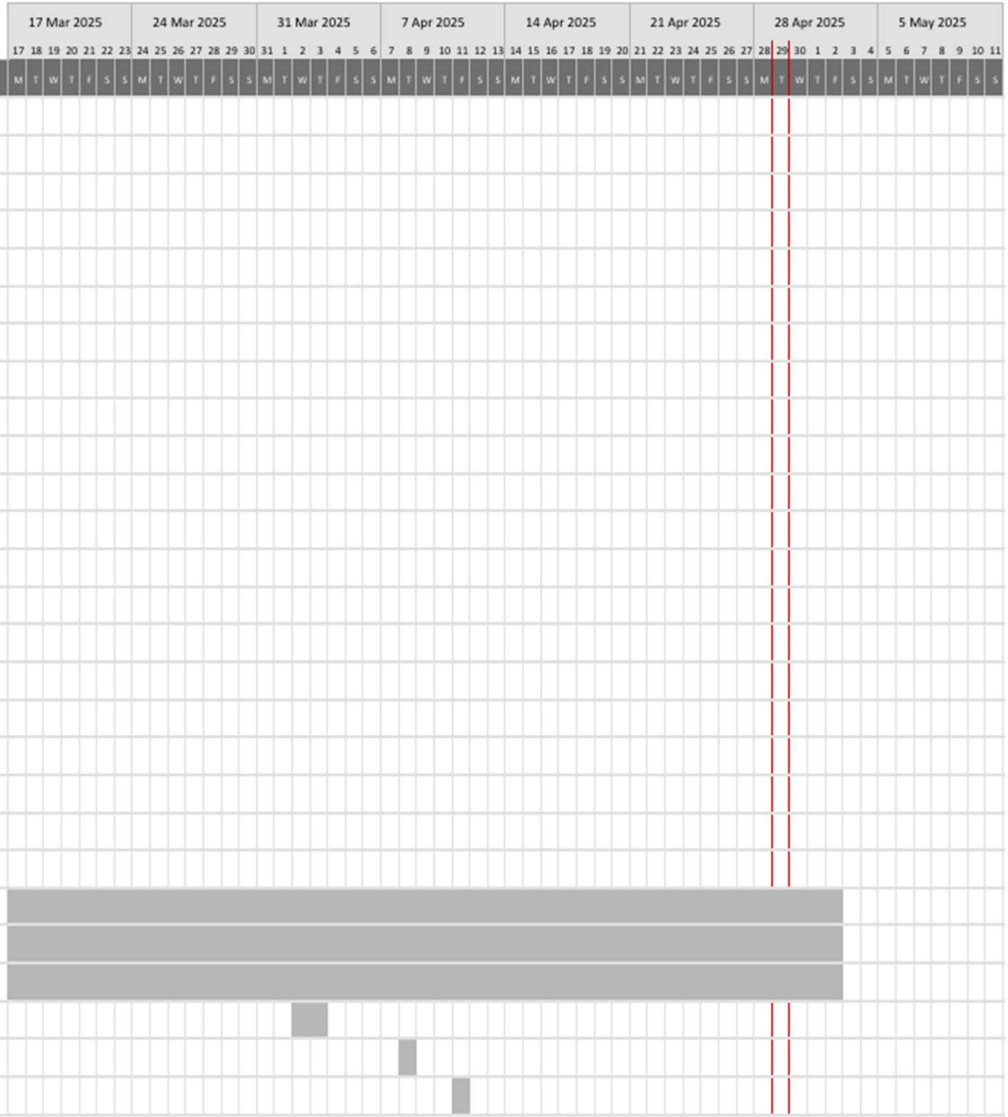
TASK	PROGRESS	START	END
Have the participants retake the questionare to show development	100%	13/4/25	13/4/25
Thesis	100%	14/3/25	2/5/25
Presentation	0%	2/5/25	9/5/25

Idividual Engineering Project
Jakub Wroblewski

Project Start: Tue, 01/10/2024

Display Week: 25

TASK	PROGRESS	START	END
Project Supervisor Form	100%	1/10/24	1/10/24
Project Supervisor Form	100%	1/10/24	5/10/24
Ethics Form	100%	3/10/24	12/11/24
Risk Assessment	100%	5/10/24	13/11/24
CNC Lathe Induction	100%	28/10/24	28/10/24
Meeting With supervisor	100%	6/11/24	6/11/24
Meeting With supervisor	100%	13/11/24	13/11/24
Proposal	100%	13/11/24	21/11/24
Meeting With supervisor	100%	19/11/24	19/11/24
Journal Learning action plan	100%	21/11/24	7/12/24
Journal ethical conduct in engineering	100%	7/12/24	23/12/24
Journal legal requirements	100%	23/12/24	8/1/25
Create an IPDS for the product	99%	4/1/25	5/1/25
Journal intellectual property	100%	8/1/25	24/1/25
Journal initiative and problem solving	100%	24/1/25	9/2/25
Research VARK learning theories	100%	5/2/25	14/3/25
Research curricula and lesson plans	100%	5/2/25	14/3/25
Research differences in teaching 1980-2025	100%	5/2/25	14/3/25
Journal project management	100%	9/2/25	25/2/25
Journal sustainable design	100%	25/2/25	14/3/25
Create prototypes in workshop	100%	7/3/25	7/3/25
Create a step-by-step teaching aid for CAD	100%	14/3/25	2/5/25
Create a step-by-step teaching aid for programming	100%	14/3/25	2/5/25
Create a step-by-step teaching aid for machining	100%	14/3/25	2/5/25
Start trial run by having the participants answer the questionare	100%	2/4/25	3/4/25
Perform CAM programming workshop with participants	100%	8/4/25	8/4/25
Perform mancining workshop with participants	100%	11/4/25	11/4/25



By J Wroblewski

Display Week: 25

TASK	PROGRESS	START	END
Have the participants retake the questionare to show development	100%	13/4/25	13/4/25
Thesis	100%	14/3/25	2/5/25
Presentation	0%	2/5/25	9/5/25