Clocks as a Learning Tool

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Introduction

Using horology as a learning tool in schools is a current PhD research project at Loughborough University being developed with the BHI. The aim is to make horology more accessible to newcomers by providing modern resources and use it as a platform for the teaching of science, technology, engineering and mathematics (STEM) in schools.

The benefit of increasing interest in clock making is that it attracts all and will pull through and develop interest in STEM areas as well as pure Horology. There are two issues to overcome: most children's experience with clock making is in schools designing a face and fixing a quartz mechanism to the back, with no further learning of horology; secondly making mechanical kits is not interesting to children in the world of computers and digital games. If we cannot get children interested in clock making with current methods then we must alter clock making to make it more accessible, as the current level of activity shows traditional tools and concepts are presented in a manner not directly available to children.

The modern school environment

The appreciation of the modern school environment results in an approach that engages the facilities and resources available in schools. Traditional manufacturing processes and techniques, such as turning and milling, are no-longer available in a lot of schools, as they are unable to provide the required level of support. Youth training on machine tools is decreasing as costs rise and teaching resources become more limited. This is leading to fewer secondary school pupils having skills and familiarity with traditional machinery and it highlights how it would be difficult to make horology accessible in a school.

The school Design and Technology environment has changed, the lathes and milling machines have been replaced with computers attached to laser cutters and additive manufacturing machines as these are much more suited to the modern curriculum and current resources available in schools. These digitally driven resources are comfortable and familiar to today's pupils and provide a more immediate gratification of work done which is essential to capture the attention of the "Gameboy generation".

School children are just as curious as always but now they investigate and consume information in a different way. Solutions to this problem can be observed inside and outside of the school environment. Other areas of teaching have adopted digital resources to aid teaching and museums have changed their content displays to provide instant access to children through the use of interactive computer software and planned and guided learning activities.

Clocks as a Project Environment

In the Department of Mechanical and Manufacturing Engineering at Loughborough University there has been an undergraduate project which has been running for more than fifteen years. It sets out to utilise modern design tools, limited to laser fabrication equipment to allow final year engineering degree students the design freedom to produce their own working mechanical clock within a twenty-four week project.

The students that take on this project have no background or knowledge of horology and so the problem is undertaken from an engineering perspective. The reason for this is that the student is not guided by any previous guidelines about horology; they must tackle the problem using modern manufacturing design tools and methodologies. These tools include the use of Computer Aided Design software to model and simulate parts before manufacture and the use of laser cutting machines to manufacture a variety of materials very quickly. Manufacturing methodologies such as design for manufacture and design for assembly create new solutions to design problems. The consolidation of these projects has resulted in a toolbox of approaches. Examples of previous clocks are shown which include recoil and grasshopper escapements, non-standard gear sizes, Geneva mechanisms and cruciform cross sectional shafts with threaded ends and materials such as MDF,

Acrylic and Kevlar. All of which are cut from sheet materials by a laser within a matter of minutes.

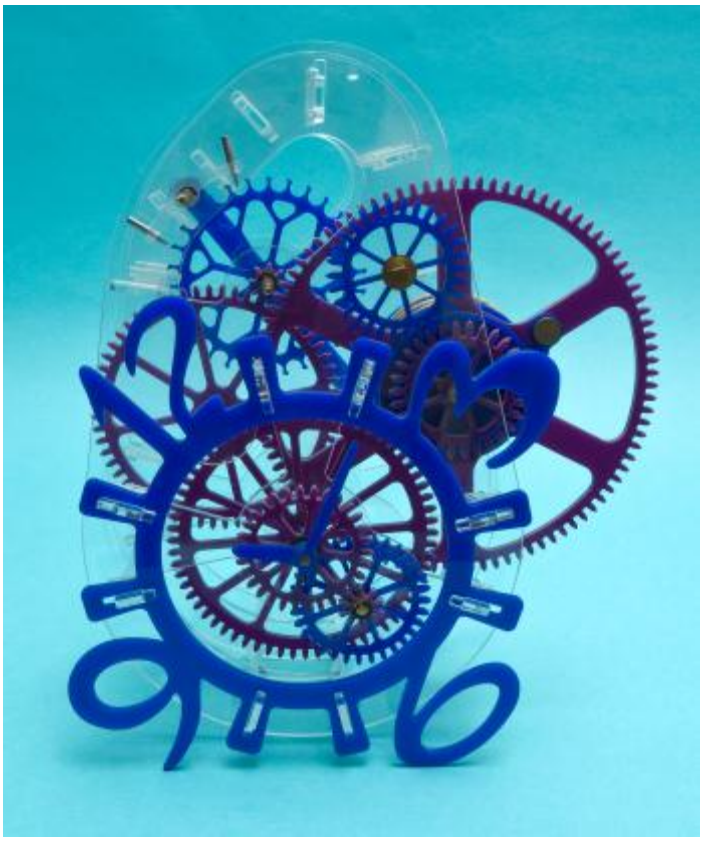

Figure 1 Deadbeat escapement

Figure 2 Grasshopper escapement and skeletonised gears

Figure 3 Grasshopper escapement with Acrylic and Kevlar gears

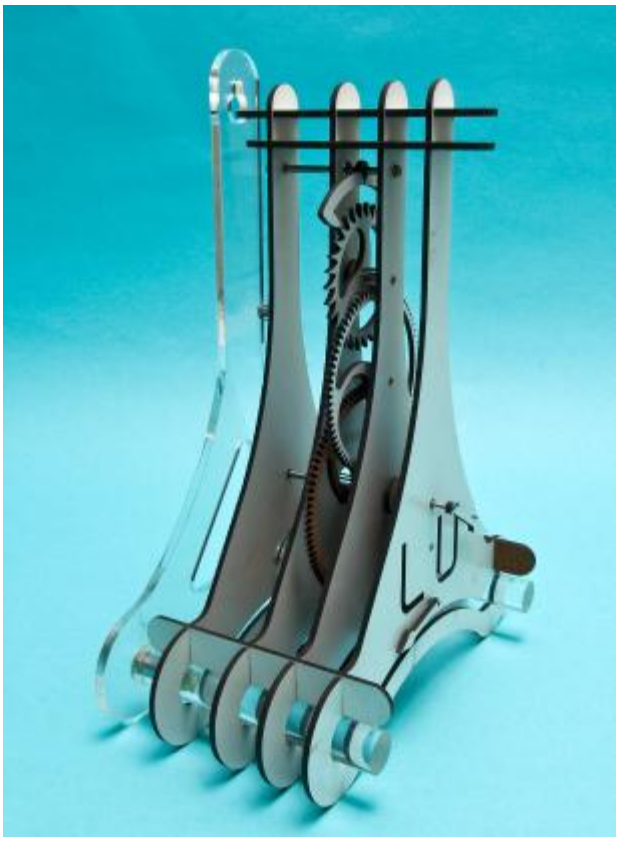

Figure 4 Fibreboard construction with lantern pinions

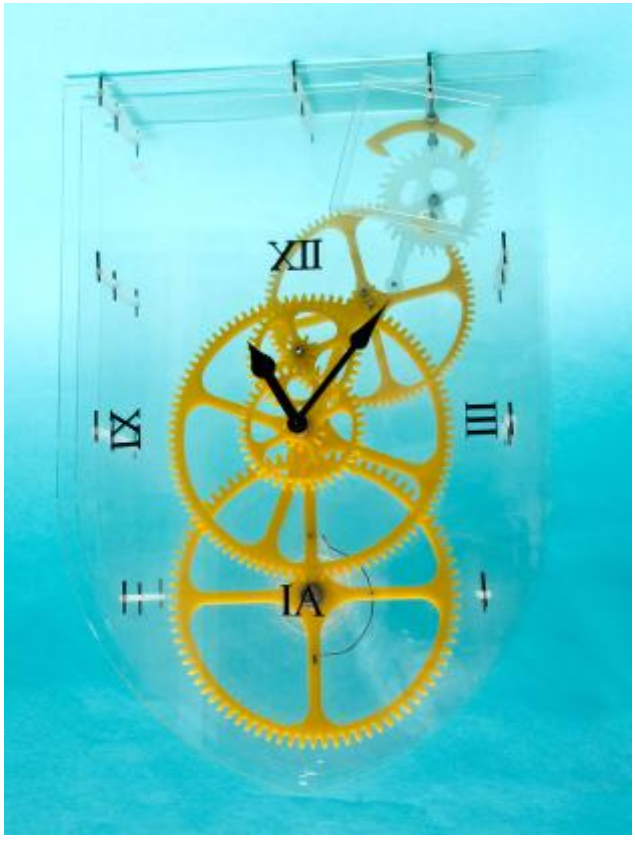

Figure 5 Design incorporating animated university logo

Figure 6 Geneva mechanisms create a digital face

The several week initial computer aided design phase of this project is common to all these designs, this allows a prototype of a complete clock to be manufactured and tested. The advantage of having the design fully in CAD and being able to send this data directly to a laser cutter is that any modifications required to the clock that are developed through testing can be changed and recut within a few minutes. This includes major design changes for example, completely different gear ratios; the ability to select cycloidal rather than involute gears; alterations of the escapement wheel or remanufacturing the clock in another material. The speed with which parts can be cut by the laser allows a fast iteration process where new ideas and solutions can be implemented without requiring any changes to tooling.

The most recent project was also selected as the winner in a Loughborough University clock design competition, shown in Figure 7. This allowed the development of this particular design to be taken further to produce a 30 hour mechanical clock that is completely manufactured using a laser cutter; which with some help and guidance from BHI members is to be hung in the refurbished university council chambers.

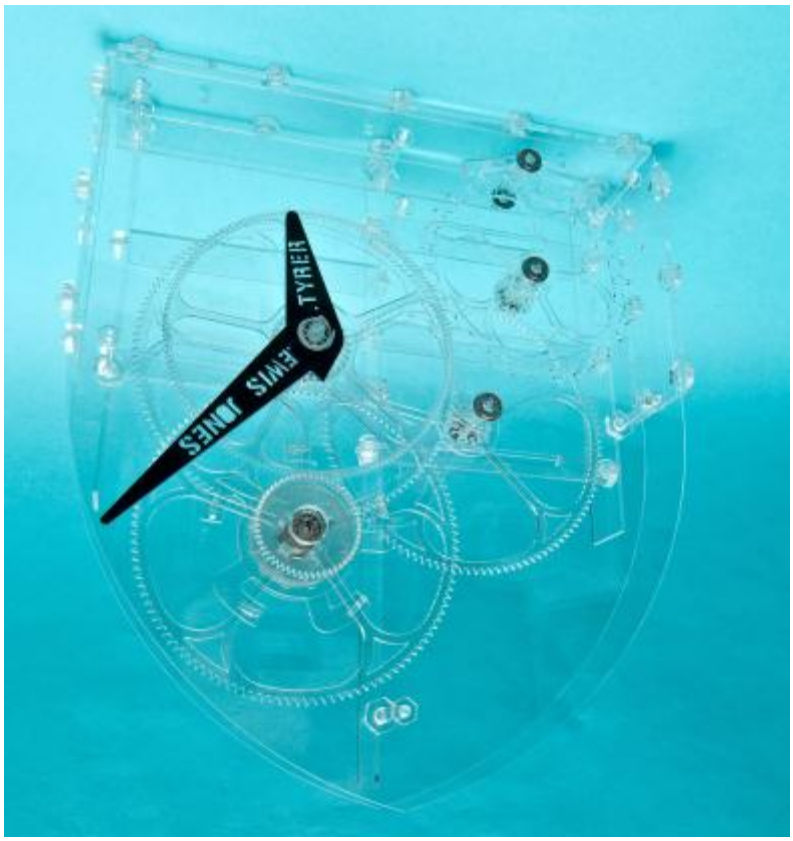

Figure 7 University competition winner features compound acrylic shafts

The manufacturing process and materials create different challenges to the design. Complex geometries, spacing of features and alignment are all very simple using CAD and a laser cutter but the strength and rigidity are inferior to metals. The cross sectional structure of the frame is designed to reduce bending moments which would be less of a concern with a solid metal frame. Features of this design include compound shafts which are the solution to cutting rotary shafts from sheet material. The shaft is assembled in two halves to form a cruciform cross section. This has the benefit of being easy to assemble and the profile created prevents radial and axial movement. The design also has 2D thread tooth forms that are cut into the frame with the same process that cuts out the rest of the frame, this allow the threaded pegs to be used with standard nuts as location and fixing features.

The awareness that has been created by project has shown the opportunity for revitalising youth interest in horology and making the techniques we have developed more accessible. The success of this technology approach was proven when design improvements and suggestions made by a range of people at the Upton Hall

workshop allowed for a complete redesign and manufacture of the clock within a week of the visit.

Clocks in Schools

To get clock making effectively into schools it must be accessible to teachers, be suitable for their resources and budget and also be a viable project from the curriculum perspective. Although there is a vast wealth of horological knowledge in books and there are many support communities it is not available in a project suitable for teaching in secondary schools, it would be a large undertaking for a teacher to put this all together, forgetting that schools do not have the correct manufacturing equipment for clock making.

Positioning the Design and Technology Teacher community with easily accessible resources such as digital designs and plans, assembly instruction packs and properly formatted information, clock making in schools would be transformed. Students would be able to actually manufacture and understand the mechanical mechanism behind the face they designed. This type of resource would instantly increase the popularity of horology; also the complex nature of the mechanisms provides a broad range of teaching opportunities. Since such a mechanism can be rapidly manufactured all the pupils in a class can quickly make one and begin to investigate the features of a clock.

The initial project that has been developed is a mechanical timer that can be made from MDF on a laser cutter and then assembled using stationary pins and shown in Figure 8. It features a simple recoil escapement and a single gear reduction to produce a mechanical timing mechanism that students can transform into a product such as an egg timer. The ½ second pendulum and escapement pallets are combined to reduce parts and the frame and shafts are constructed using the same techniques as the laser made clocks. Paper clips are used as pins for the bearings, to reduce costs, which sit in laser cut holes. These holes are self-lubricated, a benefit of the dark graphite surfaces produce by laser cutting MDF. The all of the MDF parts are laser cut from a single sheet with a total cutting time of seven and a half minutes.

Figure 8 MDF timer mechanism to be produced in schools

This timer will not be able to turn children into horologists but by giving them access to building these types of mechanisms it will get children interested in schools, and those students who wish to take it further can be developed with supplementary resources.

To ensure that this timer resource is well grounded in pedagogic theory and can deliver all the required teaching requirements the project is also being developed with Loughborough University's Design Education Research Group. This will ensure that the resource is properly integrated into the national curriculum so that it can be used as project in a normal class and not just as an extra-curricular activity. This will ensure both a good teaching of engineering principles and access to a large audience for encouraging interest in horology and STEM.

Pedagogic features of the resource include its ability to be rapidly manufactured and investigated before pupils suggest their own design improvements. This is known as Problem Based Learning and this technique helps pupils to discover and develop their own deep knowledge of a problem by experimenting and experiencing the information before reflecting and conceptualising on it. It has been shown that pupils

gain knowledge in one subject but are unable to apply this knowledge in another area. The research project will investigate that by learning about mechanical systems with a working practical example pupils will be able to transfer their knowledge to other classrooms and other situations. The resource will also be developed to make it easier for teachers to deliver engineering content in their classes. It is developed with an understanding of the types of knowledge teachers have, and how they use their own curriculum and pedagogical knowledge to deliver specific content knowledge to students. This is achieved through matching specific elements of the design to curriculum requirements, such as gears and complex mechanical systems.

This project has already begun; currently there are 4 schools in Leicestershire and Nottinghamshire where they are using a Laser Made Timer mechanism to teach STEM and Horology in the Design and Technology classroom. This initial trail will not be completed until the end of this academic year and results of this project in schools will be reported in the Horological Journal.

Modern Horological Resource

The primary outcome of this work is to garner interest in STEM and horology through the teaching of this mechanism. However the laser made clock project in schools is not the end of this outreach activity it is also a conduit to make Horology accessible and therefore draw in new people. The aims beyond a teaching project are to create and provide a modern horological resource for students as a follow up to completing the project in school and to create an open-source community where horologists provide non-horologists with appropriate and accessible resources.

This resource will take the form of a website with free information available to download and use. Digital plans to build clocks that are formatted for use with commonly available software and are suitable for people to build with resources that are accessible to them. This will require input from the British Horological Institute membership; experience from those who have developed projects for children and the sharing of information on designs and features suitable for schools and children to build.

The information gathered for the resource will be organised and formatted, the objective is to modularise clock design such that students in this age group could interchange components or utilise other components to construct their own clock. By creating modules of components, escapements, going trains, gear profiles, drive mechanisms etc… the information will become easy for new youth horologists to discover and digest the large amount of information available. The online resource will make more information than laser made clock parts available. It can provide a horology education for those more interested, for example allowing the teaching of more professional and traditional techniques and the history of horology and exciting timepieces. The website will also function as a platform for communication, promoting other sites and available resources and allowing interaction between schools and local horologists to give examples of industry and aid school clubs in building clocks.

The goal is to be able to run competitions with schools for them to produce their own clocks and judge and present awards with sponsorship from interested professional horologists and the BHI all as part of creating a new youth community.

Conclusions

The intention is to use the timer as the start for capturing interests and delivering mechanical timing systems to a large number of D&T students. There will be a percentage of enthusiastic students who may wish to further this interest and make clocks. Some of those will then follow up and if they are provided with resources and links from this project they will have a suitable path to expand their knowledge base. The target is that students can deliver working clocks to their parents and relations that they have manufactured in school, with acknowledgement to the equipment, resources and limits of the modern classroom. The aim is to let the timer provide linkage to other parts of the teaching curriculum and generate interest so that students can be motivated to download further designs and enable clock making to be undertaken by those individual students. Hosting design competitions can be used to further enhance this process. Also if interest is shown then short courses will be held at Loughborough University for Design and Technology teachers to further extend laser and clock manufacturing knowledge.

The project wants to involve the readers of this journal and seeks your interest in being involved in this work. If students at schools get motivated conceivably links can be established between such schools and local BHI members who might like to further student interest. Would readers be interest in providing input to the resources provided by the web site given below and would you like to contribute designs which could be made available to this community?

The research project and the mechanical timers will be on display at Upton Hall for the BHI Annual Show. For more information and to download the timer plans visit **clocks.lboro.ac.uk**