USING AUGMENTED REALITY IN VOCATIONAL EDUCATION PROGRAMS TO TEACH OCCUPATIONAL HEALTH AND SAFETY

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ABSTRACT

USING AUGMENTED REALITY IN VOCATIONAL EDUCATION PROGRAMS TO TEACH OCCUPATIONAL HEALTH AND SAFETY

While augmented reality enables us to attach images and information from virtual environment into the real world; technology and computer science enables us to go beyond our limits of visual perception through showing us the world with the information which was not there before. The aim of this research is to design a system that will enhance the awareness of the vocational education students over the topic of occupational health and safety. With the augmented reality system projected on the work surface, the students will be warned when they perform actions that pose a risk, needs caution and may result in accidents. As they are doing it, therefore, they will understand the faultiness of the actions again.

In this work, augmented reality is chosen based on two advantages; students will be able to access the information needed, in this project warnings, without looking at directions other than the work surface and there exists lack of study in the topic of augmented reality in the field of industrial design.

The research involves a literature review and two case studies in Konak Çınarlı Mesleki ve Teknik Anadolu Lisesi with high school and university students. A system is designed according to findings from these studies. As the result, students' caution was got and the number of mistakes was decreased. This resulted in decrease in the number of occupational accidents, deaths and financial loss. The project may also become a new method of teaching occupational safety and operation of the machines.

ÖZET

MESLEKİ EĞİTİM PROGRAMLARINDA İŞ SAĞLIĞI VE GÜVENLİĞİNİN ÖĞRETİLMESİNDEARTTIRILMIŞ GERÇEKLİĞİN KULLANILMASI

Arttırılmış gerçeklik, gerçek dünyaya sanal ortamdan imgeler ve bilgi eklememize olanak sağlar. Teknoloji ve bilgisayar bilimi, daha önce orada olmayan bilgileri bize görünür kılarak görsel algımızın sınırlarının ötesine geçmemize imkân tanır.

Araştırmanın amacı bir sistem tasarlayarak mesleki eğitim öğrencilerinin iş sağlığı ve güvenliği konusundaki farkındalıklarını arttırmaktır. İş yüzeyine yansıtılan arttırılmış gerçeklik sistemi ile öğrenciler, tehlike oluşturacak hareketlerde bulundukları, dikkatli davranmaları gereken ve kazaya sebebiyet verebilecek durumlarla karşılaşmaları halinde hatayı yapmakta oldukları anda uyarılacak, hareketlerinin sakıncalarını göreceklerdir.

Arttırılmış gerçekliğin avantajları sayesinde öğrenciler ihtiyaç duydukları bilgiye, bu projede uyarılara, çalışma yüzeyinden gözlerini ayırmadan ulaşabileceklerdir. Diğer nedenler ise, endüstriyel tasarım alanında bu konunun yeterince çalışılmış olmaması, yeni bir konu olması ve henüz çok sayıda uygulaması olmamasıdır.

Araştırma, arttırılmış gerçeklik ve iş sağlığı ve güvenliği hakkında kaynak taraması ve Konak Çınarlı Mesleki ve Teknik Anadolu Lisesi'nde uygulanmış lise ve üniversite öğrencilerini kapsayan iki vaka çalışması içermektedir. Kaynak taraması ve vaka çalışmasından elde edilen sonuçlara göre sistem geliştirilecektir. Bu çalışmanın sonucu olarak mesleki eğitim gören öğrencilerin hem öğrencilikleri süresince hem de devamında iş hayatlarında dikkatli davranmalarının sağlanması hedeflenmektedir. Bu, iş kazalarının azalmasıyla, dolayısıyla daha az ölüm ve maddi kaybın yaşanmasıyla sonuçlanacaktır. Başarılı olunması halinde sistem iş sağlığı ve güvenliği ve makine operatörlüğü eğitimlerinde yeni bir yöntem olarak kullanılabilecektir.

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CHAPTER 1

INTRODUCTION

This chapter will explain the basis and the aims of the research. Therefore, definition of the problem, aim, route, method and the significance of the study is explained and open questions asked at the beginning of the research, and the structure of the thesis is summarized.

1.1. Definition of the Problem

The problem that is stated in this thesis tackles with the lack of courses and inability of the teaching of occupational health and safety (OHS) for occupational and industrial education. The causes of the lack of OHS in vocational education are explained in the literature review section in detail, however, it will be explained briefly here.

Occupational health and safety is an issue that needs to be thought early in professional life, in order to explain the worker, or in this case future professional, the consequences of their actions. Otherwise, the worker becomes experienced and starts working as a form of a reflex, which may result in the false belief of being safe without the precautions. Although it is true that the inexperienced ones are the most to be involved in work accidents, experienced workers also make mistakes that results in their injuries.

Occupational health and safety is seen as a burden by both the employers and employees. Employers consider it as a financial burden and time consuming, since there are inspections and trainings. The employees consider the gear needed make them incapable of working freely and the trainings are not needed. This information has been gathered mostly in the 8th International Conference on Occupational Health and Safety (TIOSH) in Istanbul in 2016 where there were many complaints from the OHS experts and professionals[1]. Although it is hard to convince these people to understand the

[1] TIOSH 2016 Conference, 8-11 May 2016, Istanbul

importance of the topic and for them to gain a positive approach towards OHS, this research also provides interest about it and hopefully will show people how it is not a burden but to ignore safety is.

1.2. Aim and the Route of the Study

The study aims:

- To create a guideline for industrial designers to start researching on OHS and augmented reality systems
- To design a system of education for teaching of occupational health and safety in vocational schools
- To create a discussion topic on OHS and what can be accomplished by it
- To understand the effect of augmented reality systems in the field of education

Regarding to these aims:

1- Literature review on occupational health and safety, vocational education and augmented reality are conducted in order to give an insight on these topics

2- A fully operational prototype is designed and completed in order to do usability tests on students to understand the effects on them

3- Ideas on what else can be changed in order to avoid accidents in vocational schools are discussed. Hazardous actions and situations are examined

1.3. Method of the Study

This research consists of two parts; a preliminary study to understand the problem and approximate solutions for this problem. The second part is the main study, which is the case study of the developed system in industrial education. Preliminary study consists of literature review and surveying, therefore, its method is qualitative while the main study has a systematic data collection and analysis, which makes it available to be analysed as both qualitative and quantitative research. However, during the case study, problems in the workshop have been examined and analysed as a qualitative research. The case study experimental comparative results are examined with quantitative methods. This makes this research a mixed method research.

Data collection and analysis methods used in case study are explained in detail in Chapter 3. Data collection in literature review has been done through the Izmir Institute of Technology's library, TÜIK (Turkish Statistical Institute) databases, and SGK (Social Security Institution) databases and through researcher's personal library.

1.4. Research Questions

The research questions that were asked at the beginning;

- What is the condition of Vocational Schools in terms of OHS?
- What design or engineering applications are done in order to maintain safety in lathe operations?
- What can be accomplished in OHS training in order to catch young students' attention?
- Which applications can be done with augmented reality in OHS training?

1.5. Significance of the Study

This research is clarifying the significance of occupational health and safety, guiding the designers into a different path and a way of thinking in order to design systems to help teach the students OHS. Augmented reality has been used in education although this technology has not been implied into vocational education other than showing information about material and assembly. (Mura et.al, 2016)

Occupational health and safety training had been a matter of professionals, however today it had become more important and thought more thoroughly. Even The Ministry of Education in Turkey had given orders to employ OHS experts in every department. These experts inspect schools and other educational areas, such as courses, in terms of safety and have the authorisation to take the needed action in order to make the surrounding safe enough for the students, teachers and the other people using these premises.

The main difference of this research is that this does not rely on the technology or the innovations of the machines that make them safer to operate, rather relies on the learnability of occupational health and safety in the early stages of professional life or even while studying.

Another difference between a person which can be the teacher in school and OHS inspector in a work place is that this system cannot be tricked and it is always there, watching the mistakes, while teachers and inspectors move around controlling everyone. It also cannot be hacked while most machines in small businesses are hacked by either the workers or the employers in order to get more products in the same time period, disabling the OHS systems in the machines.

Simulators are safe devices to learn to use a machine or a vehicle. Although lathes have virtual simulators, they lack physical interaction devices. This also shows that an educational system for safety in lathe is needed.

1.6. Limitations of the Study

Case study is conducted in Çınarlı Technical and Industrial Vocational High School. Although lathe is used in many applications today in industry, most of the students of the high school do not get the necessary education to be a lathe operator and the demand for these courses are decreasing every year. Teachers stated that there are only two classes who are in this curriculum and last year there were five. Because of that, the test was conducted with 14 high school student participants.

In order to increase the number of subjects and have reliable results that are needed in between-subjects design of experiments that depend on quantitative analysis, Dokuz Eylül University Mechanical Engineering students were included in the study as a second case.

Another limitation for this research is again the case study. Since there is only one vocational school available in Izmir which teaches how to produce and machine moulds for injection moulding which is the one this study is conducted. For further study in vocational education, other cities must be visited and cases of other schools must be conducted.

The suggested system is intended to be used for educational purposes, therefore, it has been tested with students only. However, as further study, it can be tested with professionals working with lathe machines.

Due to this study being in the field of industrial design only, interactive and automated system could not be constructed and tested. Therefore, the system is tested with an operator dependant prototype.

1.7. Structure of the Thesis

This thesis consists of the following parts;

First chapter is Introduction where the definition of the problem, aim, route, method, limitations and the significance of the study and research questions are summarized and explained. Second chapter is the theoretical research conducted with literature surveys, research on occupational health and safety products and legal regulations on this matter. Also vocational education is explained in this chapter with its importance and its practice in Turkey. Augmented Reality is surveyed with its current and future uses, methods, applications and its technology. This also explains how this technology and the used method is selected for this research is discussed with examples of the applications and their advantages and disadvantages. Lastly, designer’s role in occupational health and safety is explained with the current practices such as prevention through design and the design of safety gear.

Third chapter is the case study. In the case study chapter, conduction of the test and the results of the observations in the workshop are explained in details. Information about the test includes how the students have been chosen and how the prototype has been prepared for the test of the system. Also details about data collection and analysis, methods which are used in these are explained in detail.

Fourth chapter is the results chapter, which includes the data gathered from the experiment in Çınarlı, comparative results of the students’ work with and without the projected OHS education system and this data’s analysis. It also includes the results of the field observations about the condition of school in terms of OHS.

Lastly, fifth chapter is the conclusion chapter, which interprets the outcomes of the research.

CHAPTER 2

THEORETICAL BACKGROUND

This chapter will explain the theoretical background and review the research done so far in the topics mentioned in Chapter 1. With the findings from this chapter, the system to be tested in the case study was designed.

2.1. Occupational Health and Safety

According to International Labour Organisation (ILO) Occupational Health and Safety is the science of expectation, acknowledgment, decision and control of dangers emerging from the workplace itself or the work, which has a negative impact on the health of the labourers.

2.1.1. Causes of the Accidents

Causes of the accidents in workplaces are broad concept. Therefore, in this research, firstly general causes of accidents will be mentioned and secondly, accidents in lathe work will be analysed since the case study is conducted in the lathe machine. The main causes of accidents in a machining plant will also be explained, with examples given in lathe only in order to keep this research on a focus. Safeguards regarding to the types of accidents are also explained at the end of every paragraph for lathe work.

Chips are a main cause of injuries in lathe work. Long string-like chips and flying chips cause danger of getting in the eye, sticking on the skin and burning the skin layers. As mentioned in the following chapters, metal chips have been found to be a main cause of injury in Çınarlı too. These accidents are avoided by using chip pullers in order to cut the chip before it gets dangerously long and chip shield in order to keep the flying chips in the area around the work piece.

Rotating chuck is a cause of hazard like every other rotating piece in every machine, which has human access. In order to avoid contact with rotating chuck, chuck guards are used. This enables the operator to work chose to the work piece without the danger of getting pulled into the machine by this rotating part.

Loose or incorrectly fastened work pieces cause hazard with the possibility of getting free of the grip or the tool bit crashing into the chuck. There are no precautions in place to prevent operators from this kind of hazard. The avoidance relies on the experience of the operator.

Accidental start-ups cause the operator to get pulled into the machine since the operator is most probably adjusting the work piece when this type of accidents happen. This can be caused by the operator whose limbs got too close to the machine or when the operator leans on the machine to do maintenance, cleaning or adjusting of the work piece. These types of accidents can be avoided by using recently manufactured machines since they have sensors that allows the machine to start only when all precautions are in place, such as chuck guard and chip shield. However, even when the safeguards are in place, the operator's limbs may still be close to rotating parts. As a result, accidental start-ups can only be avoided with proper OHS training of the lathe operator.

Entanglement of the work piece is another cause of hazard in lathe operations. This may be caused by the wrong choice of tool bit, which is unsuitable for the material that is machined, too much chip depth, loosely fitted parts etc. In the event of the work piece causing danger to the operator, lathe operation can be stopped immediately with emergency stops. However, stopping the operation may not be quick enough to avoid the accident. In order to cover these situations completely, experience of the operator and the proper OHS training on how to avoid these accidents, is crucial.

Handling of heavy work pieces can cause accidents by falling if not only causing uneasiness. Even when there is no accident occurring, these actions will definitely cause work related illnesses in long term such as rupture. Since OHS is against both accidents and illnesses, proper OHS training of a lathe operator should include the handling of objects, work pieces and tools. An OHS trained lathe operator avoids handling heavy work pieces, instead uses hoist and lifting cranes.

Rotating cranks with handles cause accidents by catching loose clothing and continuing rotating. Automatic feeding systems consist of these parts since the feeding is done both manually and automatically with the same system. The danger caused by these parts can be avoided by OHS training that includes the proper working outfit and how to take care of this certain uniform.

2.1.2. Precautions

Preventing work accidents need a systematic approach just like preventing car accidents. Although legal regulations that are mentioned in the following section are effective methods, non-punitive methods are also used. The most important non-punitive methods are OHS education or training, Prevention through Design and different approaches for controlling the OHS practices of the workers such as INFO cards and checklists to make sure all measures for safety are taken (Jørgensen, 2016). These applications are called as injury and illness protection programs.

Safeguards in machines and systems that prevent the worker to get into the dangerous zones have been found to be useful. For example, the number of injuries in power-presses went down after the installation of two hand operating systems (Suokas, 1983). Similarly, accidents and injuries in lathe operations have decreased in great numbers with the improvement of lathe safeguards (Varonen, 1995). However, using safeguarded machinery is not legally obligated and accidents that could have been avoided by simple guards happen every day.

Since the legal precautions in Turkey are not enough and specific enough yet, the non-punitive methods are the primary type of precautions, which depends on the decisions of the employer or the managers.

2.1.3. Legal Precautions

Regulations have been made in order to avoid accidents in workplaces. There are different types of legal precautions; ones that are voluntarily which is obtaining certifications such as OHSAS, and there are obligatory precautions defined by work laws. Although voluntarily precautions may not seem as a matter of this chapter, these certificates became a must in most sectors in order to be able to find customers. If a manufacturer does not have a certificate defining that they meet universally approved standards in occupational safety, they may get rejected by clients.

The social security law that secures worker's right explains the procedures to be applied in case of an accident or the precautions to be made in order to avoid the accidents. Since Turkey has not been known with their well-adjusted occupational safety system, these laws are still not enough to stop the deaths at work that could have been avoided by taking the right steps in OHS ladder. However, law number 6331 which is occupational health and safety law, does have improvements in order to maintain a better workplace and it points out the responsibilities of the employer as the main person to keep the workplace safe. According to this law, even when an OHS service is bought from another company, the employer's responsibility is not transferred to another person. This law also explains how a work accident is defined and it is important. It counts every action made at work or during the time to come to work as work accident, without seeking for a relation between the cause of the accident and work related actions. Moreover, with this law, hiring OHS experts and specialists in order to make workplace and work actions safer have become obligatory. This created a new line of work for many technical personnel such as engineers. However, hiring an OHS expert have brought ethical questions, would the hired employee of the company give bad credit to the workplace and shut it down in order to take precautions of would they be worried about their pay check. The law has an assurance for this action, stating that their licenses would be cancelled if the OHS expert's fault or deficiency is proven in case of a work accident.

The law number 6331 also states that it is the worker's responsibility to use the required safety gear and following the rules of an operation. It is also the worker's responsibility if they hack a system in order to work easily and make the system lack the required OHS precautions and measures. This shows that even with the regulations, if the worker is not well educated about their own safety, accidents will continue to happen as a cause of the thought "it won't happen to me". This also justifies this thesis' aim to teach the students who are young enough to learn the dangers without getting into any.

2.1.4. Losses

Losses in work accidents are divided in two; human loss and financial loss. Although they are thought separately, most of the time human loss or an injury results in financial losses due to accident benefits given to the injured worker or in case of loss of life the worker's family, stopping the manufacturing in a factory and long term effects such as the workers' unions demanding higher wages in order to work under dangerous circumstances.

Even when the worker is not dead, but suffering from the accident, permanent or transient incapacity report is given (Özdemir, 2015). This is a burden to the system. It also is a loss for the company if the worker is not replaceable. If the damage is permanent, the worker does not stay in the company, they become incapable, thus, retire due to disability and cash retirement salary from the social security system. This shows that the financial losses of working accidents are not limited to the worker or the company but also are a burden to the social security system which in Turkey belongs to the government. Therefore, government does take precautions about work safety. When the worker dies while being a social insurant, their family also benefit from the situation, both an accident benefit from the company or the owner of the cause of the accident (in some cases the manufacturer of a faulty machinery used by the deceased that caused the accident) and also from the social security system, as monthly payments and the expenses of the funeral and also a wedding grant for the daughters of the deceased.

Accidents cause financial loss with a different issue as well, the employer of a high risked factory will find the workforce they need hard since workers would not want to be there anymore.

2.1.5. OHS in Turkey

OSH gained importance in Turkey after the incidents in Tuzla shipyards in 2008. Enforcement law regarding to work accidents and occupational safety were accepted in the Turkish parliament with an omnibus bill afterwards. This law, the law number 6645, included the obligation to have the necessary training or education for dangerous work fields or jobs that require training in order to work safely. These educations have certificates, which are called as professional competence certificate that are given by the vocational qualification authority in The Ministry of Education.

EUROSTAT data shows that Germany, UK, Norway, Finland and Ireland have the least amount of deaths at work, with numbers varying from 1.0 to 1.8 in 100,000 while it is 12.3 in 100,000 in the same year, 2007, according to SGK database. This indicates that the OHS is not as settled in Turkey as in these other countries, while one of them, Germany, have more production than most of the other countries in the world and is the biggest producer in European Union. These numbers do need to change as a figure to show that the country do care about human life. Even though the death by accident numbers are high, occupational diseases are reported as very low in Turkey. This is the result of the lack of control and since these diseases happen even years after the work, the connection is not found by doctors. This problem needs new regulations, however work related diseases are not a matter of this research.

According to the data obtained from the report of SGK, in 2014; main metal industry and metal product manufacturing are the most dangerous economic activities in case of the number of accidents and the number of days spent in recovery. According to TÜİK's report on work accidents and work related medical problems, dated 2014, the second most dangerous line of work is manufacturing, however the most accidents did happen in this line of work. In the same report, it can be seen that the most accidents happened among machine operators and assemblers with 4.8%, which is more than twice as much as the average of 2.3%. The average of 3% of all workers encountering an accident in last 12 months have decreased from the 2007 report however it is still above the desired level. The same report states that the eye strain and visual focusing is a highly encountered problem among the workers with the 10.4% of all workers contributing the survey.

In order to teach safety in vocational education, 11^{th} grade students are given at least 8 hours of OHS education. This course does have certification. Their education also includes a career development course in 9^{th} grade, which also includes OHS education. Also, in order to make schools safer, OHSAS 18001 certificates will be obtained with the realization of the safety obligations.

2.2. Vocational Education

Vocational education is crucial for developing countries. It provides qualified manpower needed for the production. Vocational education costs 2 to 4 times more than the mainstream education (Psacharapoulos, 1997). It also has another financial negative effect, which is to the students themselves, by not allowing them to work on this period by taking their time with courses. However, this financial burden is paid back accordingly since educated and qualified manpower earn more and work more effectively. The important issue in this matter is not letting the qualified manpower to drop out of the system due to an accident. This can be achieved through giving proper work safety and health education to these people during their time in the vocational education therefore not getting more of their precious time.

Students with the lowest high school entrance exam grades apply to vocational schools, therefore, going to a vocational school is mostly not a choice of the student or the parents but an obligation in order to continue the student's education. The choice of vocational schools are not made by the students since they do not know their fields of interest nor do they know themselves completely. This choice is made with the guidance of the parents, the grades they took in the exams and their success in courses before (Hepkul, 2014). According to a study conducted with technical high school students in Bursa, Turkey; these students see themselves capable of understanding technical and mechanical matters although they think they are incapable of the social skills (Bağatır et.al, 2004). This also shows their sense of self is affected by their education and their choice of high school.

According to Andersson et.al. (2015), vocational school teachers teach OHS based on their own experiences. They found out that only a few of teachers search for teaching materials for this subject. Vocational education teachers depend on their own, self-taught methods. This kind of education bases itself on the risks; teachers warning the students according to what have happened to them in their profession or their own training phase. This reveals the lack of pedagogical methods, therefore may result with the student not understanding the subject, or the importance of the OHS. Andersson et. al. (2014) mentioned in a previous study that an OHS education based on teacher's experience results in the student believing they are the only responsible people and the key for avoiding accidents, which is a false belief and this belief itself may cause accidents since it eliminates the risk analysis that can be done by the workers, in this case students.

2.3. Augmented Reality

Augmented reality enables us to attach computer generated elements from the virtual environment into the real world environment (Graham et. al, 2013). Technology and computer science enables us to go beyond our limits of visual perception through showing us the world with the information which was not there before. As for the inventor of augmented reality, Ivan Sutherland, it can be considered AR if these terms are met; connecting virtuality with reality, real time interactivity and three dimensional space.

Augmented reality is a fairly recent technology, although it has been thought and the first applications have been made years ago. Due to the level of technology needed, it has gained the importance after the year 2010, after the release of Microsoft Kinect which is an input device for such systems.

Reality-virtuality continuum is the visual method of showing the range from completely real to completely virtual. In this scale, first used by Paul Milgram, Augmented Reality is positioned in mixed reality, close to reality rather than virtuality.

Most known and most recent application using augmented reality is Pokémon GO, which is a smartphone application that enables the gamers to see virtual Pokémons in the real environment through the screen of their phones and interact with them by catching them with what is called Poke-balls, which is also a virtuality adapted into reality.

Figure 2.1. Milgram's Reality–virtuality continuum

2.3.1. Technology

There have been many technological improvements enabling augmented reality applications. These are;

- See through displays: Although this technology cannot be considered as new, easier methods for creating such displays have been discovered. With these advancements, transparency does not have to be provided by the material, rather the image from the other side of the display now can be projected into the screen by using cameras as input devices.
- Projection displays: When thought about, projection is not a recent technology, however it must be considered that some of the head mounted devices and head

up displays, such as Google Glass also use projection in order to project information on the goggle's surface.

- Motion tracking: This may include the input technologies such as Kinect, high resolution cameras
- Smartphones: Although smartphones were not an enabling technology for augmented reality, they have made it possible to have a huge audience. These are the most used technological devices in the world. By 2017, 2.6 billion people will be using smartphones.
- More powerful processors than ever enable the computers to produce such images that can adjust to differentiating input as the result of the rough surfaces. They also enable accurate 3 dimensional models to be created.

2.3.2. Uses of Augmented Reality

Augmented reality is used in many fields from education to tourism, medical applications to military ones.

Educational use of the augmented reality is the most important topic in this section for this research is about OHS education. Therefore, augmented reality applications and literature on this topic is reviewed. Uluyol and Eryılmaz (2015) have studied this technology's use as "Examining Pre-Service Teachers' Opinions Regarding to Augmented Reality Learning". The research with 51 pre-service teachers revealed that the teachers look positively on the use of augmented reality in education. Participants expressed the opinion of augmented reality to be an enabler for learning. They also mentioned that AR will increase the motivation and the class time will be more enjoyable. Teachers stated that they believe augmented reality will be used in the future classrooms. A different approach has been made by Serio et al. (2013) and the effects of augmented reality in education have been tested on and then asked to the students. These students claimed that these methods are more stimulating than the traditional education methods. Other researches have supporting results that find out the use of augmented reality and sensors to be positive as for awaking students' attention (Endyeny et al., 2012; Kamarien et al., 2013). Augmented reality enriched textbooks are proven to catch students' attention, make the class more enjoyable and arouse the curiosity for the courses. However, augmented reality's use in education is limited to the enrichment of the teaching materials. According to the predictions made by Abdoli-Sejzi (2015), it will be used in occupational health and safety in the future however there are not enough research conducted on this matter yet.

2.3.3. Current Methods

There are different applications of augmented reality. As the uses are explained briefly in the previous section, different applications of the augmented reality in general will be examined here, without limiting it to a certain type such as head mounted.

The method used in the case study section is called as spatial/projected augmented reality meaning the images are reflected into the real world therefore everyone in the room, without needing another device, can see the visualisation of the virtual world. This method has a limited use since it relies on high powered projectors and control of room's light. It also relies on a surface it is projected therefore need a smooth surface with right choice of material for readable/understandable images. The legibility depends on both material, text font, text size and the surface of the material, either it is smooth or has a 3rd dimension (Donato et.al. 2015) Although it has these disadvantages, projected augmented reality has many advantages which made it the right choice of technology for this research. While head mounted augmented reality devices cause visual problems such as problem in adapting, focusing from the near image to the real world image, tunnel vision; projected augmented reality is free of these problems that imitate visual impairments. (Sabelman and Lam, 2015).

Spatial of projected augmented reality is another method of creating a mixed reality. Bimber and Rascar (2005) provided the definition of spatial augmented reality in their book. According to this definition, spatial augmented reality does not need intermediary materials or screen since the augmented images are projected into the real world. Projector can be fixed, as in this project, or mobile as in LuminAR project. Another known application of spatial augmented reality is Microsoft's IllumiRoom. With the IllumiRoom's technology, the room is modelled in the computer by the data gathered from Microsoft Kinect and the extensions of the image on the television are projected into the room, widening the visual experience. Images can be altered and even the room itself can be distorted through this technology. CAVE, which is the acronym of cave automatic virtual environment, is another application of augmented reality which combines spatial augmented reality and head mounted devices.

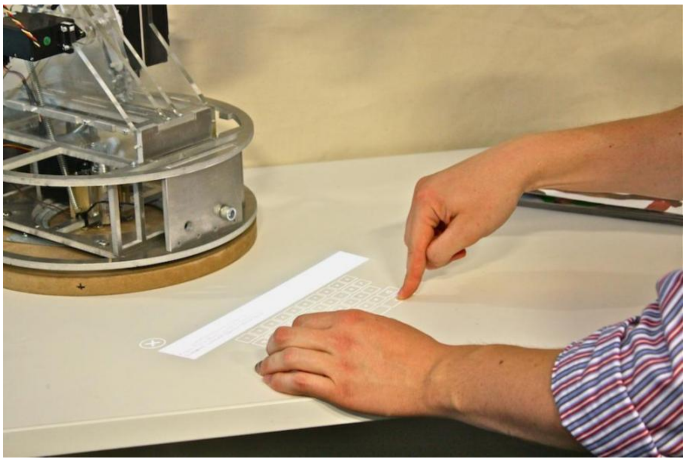

Figure 2.2. LuminAR project of MIT

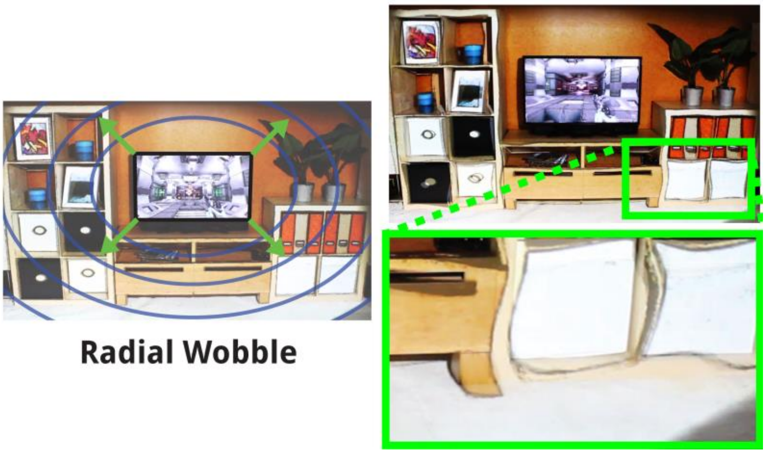

Figure 2.3. IllumiRoom project of Microsoft

Security is more and more of a person’s concern, since today’s world has become a more connected one. Every piece of information is now accessible on the internet. People give their personal information to companies in order to be a part of the social networking. Credit card information is stored on the devices in order to use them easily and quickly. With this information, security and privacy of online being is a new field of problems. Augmented reality is not free of these problems. The first ethical question asked when Google Glass was announced was if it is right to record people with a goggle without their consent. However, augmented reality can also enable online security to be more private, such as private information that can only be seen by the wearer of the device. (Roesner et. al, 2014)

Recently, Radowski et al. (2015) have created a system that helps assembly making for machine parts by guiding with visual hints. However this system does need a screen to show the hints therefore needs the person to look in another direction than the assembly/work surface. This needs the looks to travel between the screen and the working surface. Another application of helping making assembly is done by Mura, Dinni and Failli (2015) who used Quick Response (QR) codes in assembly stations. This research involved head mounted displays.

2.4. Designer's Role in Occupational Health and Safety

Designers, as industrial designers, have been uninvolved in the Occupational Health and Safety matters. However, this has not been their choice since this field considered to be engineers', architects' and technical professionals' field. Even medical doctors have been involved in the OHS practices with occupational illnesses. This section will guide the design professionals into the OHS practices with the explanation of what is done by other designers at present.

2.4.1. Prevention Through Design

Prevention through design (PTD) is a fairly new method in OHS. It is also called as "Designing for safety" (DFS) in some literature. PTD is a principle for the planning of operations, facilities and equipment to help conserving human life. (Walline, 2014) Prevention through design is about avoiding the hazardous action or the situation at the first place. For example, if there is a falling hazard because of working on a high ground, traditional OHS preventions are safety gear and railings, while PTD offers to avoid going and working on the high ground, taking the operations on the ground level thus eliminating the risk of fall. It also enables the worker to work without personal protective equipment (PPE), which need constant control and mostly, especially in Turkey, not used with the excuse of it disabling moving freely.

PTD is getting more and more popular and the executers of it are designers, architects, engineers and OHS professionals.

The negative side of the PTD is that it is most cost effective at the planning, it requires a huge budget and time if it’s done in an operational factory. It adds cost at the planning too, although it costs less than fixing those mistakes later or than the costs that will occur when an accident happens. And the cost of human life is unmeasurable.

Application of PTD in Turkey is carried out as Safe Design or Safety Design, mostly in the field of civil engineering and architecture. It is similar to PTD by eliminating the sources of hazard that are caused by the faults or inadequacies in design such as working on a job on high ground that can be done on surface or working with moving ladders rather than fixed ones. The most used models in Safe Design are called STAGE, CHAIR and GUIDE which are abbreviations.

2.4.2. Design of Safety Materials and Gear

Safety materials and safety gear designing process involve professionals from different expertise such as mechanical, chemistry, material sciences and industrial designers. Designers deal with the usability of the gear. Although these instruments were not well designed to fit human use, they are getting more efficient and easier to use. Even the easiest, lightest and the most comfortable safety gear will create discomfort. Prevention through Design is the field which deals with the elimination of the threats therefore eliminating the need for special equipment.

Safety signs’ effectiveness can be discussed although they are well accepted OHS materials. Safety signs and posters are designed mostly by graphic designers, however their physical features are also important, in this case industrial designers should take their parts. Material of the sign should be suitable for the workplace and the atmosphere, chemical or sun exposure if present, sign itself should not put the workers in danger by distracting their attention nor by falling out of its place or having dangerous edges. These should be easily understood and should get the attention of the desired audience.

CHAPTER 3

CASE STUDY

This chapter of the thesis consists of two experiments and their results; a case study conducted in Konak Çınarlı Mesleki ve Teknik Anadolu Lisesi (Konak Çınarlı Vocational and Technical Anatolian High School) with the high school's students in May 2016 and a second case with Dokuz Eylül University Mechanical Engineering students who have completed their second semester and now are participating in Workshop course conducted again in Çınarlı in August 2016. Konak Çınarlı Vocational and Technical Anatolian High School is located in Izmir, Turkey. School has been open since 1958 and one of the largest vocational high schools in Izmir. It currently has 2826 students and 231 teachers. Dokuz Eylül University is also based in Izmir and its Mechanical Engineering Department has had 210 enrolled students in 2015. 28 of the students enrolled in the Workshop course are included in the second case study.

Case studies have been conducted in order to find out what can be done to increase occupational safety without changing the setups of the machines or the workplace and without adding extra safety materials or machines other than the ones in use. This method is studied in both vocational high school and university students in order to understand its applicability in different educational background groups. In case of success, this method can be used in different groups such as factory workers, and in different setups such as drilling operations.

While working on the system conducting the case study, data to understand the workplace hazards have been gathered by photographing and interviews with teachers of the vocational school. This data also helps us to understand how accidents can be avoided in such environments where the operators are not professionals. This data, without previously though, also helped us make a guideline to make better machines in terms of safety, not by adding safety barriers or sensors but with changes in design that can again be attached later on the system, but intended to be on the original machines in the future. Further information regarding this matter will be given in results and conclusion chapters.

3.1. Population and Sample

Students to participate the test have been chosen randomly among the technical high school students and industrial high school students. 14 students have been randomly divided into two equal numbered groups. First group, which is the test group, used the test setting and got the warnings from the machine rather than the teacher. Second group, which is the control group, did not use the test setting and the students have been warned by their teacher when they make mistakes. Both groups' mistakes and the incidence frequencies were noted down. A week later, the same students were gathered again, this time without the test setup. Their mistakes have been noted down again. Both weeks' results were compared in order to see if the system has made a difference in the behaviors of the students.

The experiment was repeated with Dokuz Eylül University Mechanical Engineering students as a second case to confirm the results. 28 students participated in this second study. All steps of the previous experiment were repeated.

Students were expected to machine the parts given to them by their teachers as a part of their term projects or for university students, parts given by their instructor and the experiment was conducted while they were machining these parts. All parts and tasks given to the students were similar, the only difference is between the cases since the university students were not experienced therefore were not able to machine difficult geometries. Mechanical engineering students' have the same parts, given as technical drawings in their workshop textbooks written by Macit Buluç.

3.2. Experimental Setup

Device planned to be used if the prototype is found effective is an autonomous device, meaning it will decide if the student is making a dangerous move or an action and warn them. Although there are many options to automatize this device, the most effective option would be machine learning. The first reason for choosing this method is that it takes less coding and any dangerous move can be added to the system easily even after the setup has been finished. This will be helpful if another dangerous action has been spotted among the students or if there is a fault or a missing part in a machine that the students need to be careful about. The second reason would not be needed in a perfectly functioning maintenance system however, as it was explained, these vocational schools in Turkey have the financial problems, preventing them from taking needed measures when a system or a machine is not functioning properly. However, a drawback of the use of machine learning in such system may be the dangers caused in the programming and teaching process. These can be prevented by different methods such as not operating the machine at the time, programming the computer to give the warning when the machine is operating, rather than not working as in the teaching process. These are the matters of programming the final system, therefore will not be explained further.

Examples of this kind of systems in Turkey can be seen in portfolio of “Hedef Sıfır” (Aim: Zero) projects, which aim to end deaths at work. They produce machine learning based OHS systems in which the computer does the control of the workers with use of cameras as input devices. These cameras send the information to a computer which detects a hazardous move or action done at the worksite and warn or even shut down the systems, which are working. Another project of this group detects worker’s outfit to find out if it’s correct for their line of work, with safety guards and equipment. This system also works with machine learning, as for teaching the computer which kind of visual is the correct and if the computer does not perceive this image, it gives a warning.

Software used in the prototype, called “red-dot” named by the programmer, is programmed for this project. This software is produced with Unity. It enables the user of the computer or a smartphone to put a red dot on the screen where they click or touch, depending on the device. The red dot on the screen can be erased by the tester after the student realizes and corrects his or her mistake. With this software, prototype was controlled by the researcher and the warnings were projected on the working surface by the projection device hanged above the lathe. Color of the light in this prototype is chosen according to the accepted color norms in machinery; as for blue machines having orange warnings and green machines having red warnings, due to the negatives of the colors. Most of the lathe machines in the Çınarlı technical high school are green with some exceptions of blue. This system is tested on a green lathe. Additionally, the software can produce warnings of different sizes, for example a small dot is needed for a precise warning and a big red dot for getting too close to the machine which is an instant and a whole body mistake.

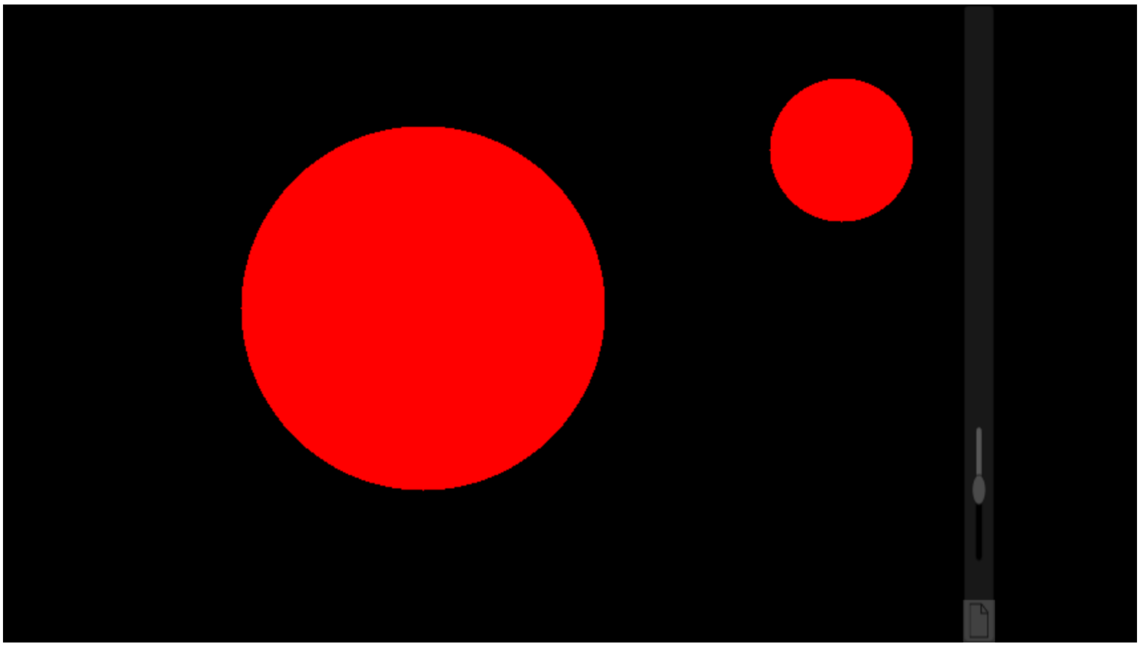

Figure 3.1. Screen capture of the Red-Dot Software

Projector used is chosen according to the uncontrollable lighting conditions in the workplace. From the recent projects LuminAR and MARIO it has been noticed that the use of high resolution projector is not necessary. Attention is only paid for the projector to have a high lumen number in order to be visible in the highly sun lighted workshop in Çınarlı. Choice of the projector made the system advantageous financially and affordable for the vocational schools. Although the prototype involved a projector and these projectors are affordable, a more cost efficient alternative with LEDs is presented as the final product with the ability to do the same warnings as the projector, the red dot in the place of the mistake or hazard.

In the test made with the prototype; visibility, usability and utility of the system is tried. Automatisation and image processing is not tested since the prototype does not involve these features.

Figure 3.2. Experimental setup in Çınarlı Vocational High School

Figure 3.3. Warning seen on chuck

Final product is intended to be encased and the casing is industrially designed with information of appointed elements that will be used. The system as a product is intended to be used at vocational training.

Final product is planned to be consisted of the following parts:

- Single Board Computer: this part is for the Automatisation of the system. Single board computers, in this case, Raspberry Pi, are cost effective and small, which qualities make these the right choice for such systems. Since the system will be encased and mounted on a ceiling or a similar higher ground, the whole encased materials need to be small and light in weight.
- Camera: in order to capture the movements of the students and to the motion tracking, a camera is needed. To make the system cost effective and lightweight, a web camera is intended to be used in the final form of the system. Camera is an input therefore will be treated as a sensor with the data coming from it to the computer, where it is processed.
- Sensors: these are needed to sense the mistakes. Recent machines with CE certification do have sensors that disable the starting of the machine if there are missing precautions such as a chuck guard not being placed. The sensors that will be attached to this system will be dependable, it can be altered with the needs of the machine. If the lathe does not have certain sensors then the system needs to have them. Sensors will be; heat sensors for sensing the heat of the work piece so that the worker or the student will be warned not to touch it when it is hot , angular velocity sensors in order to sense if the velocity is too much (this will be decided by the teacher, since different materials can be machined with different speeds), knock or impact sensors to sense if there is an impact caused by falsely or off-centred work piece, vibration sensors to sense if there are unwanted vibrations or a danger of resonance, proximity switches that can be triggered when an undesired object is apparent such as standing too close to the machine or tool bit coming too close to the rotating chuck. Sensors can be altered, increased or decreased depending on the preferences. Microphones and other alternatives may be used in order to find out problems in machining that cause unexpected noise.
- Smartphone: Although smartphone is not a constant part of the system, it is needed to control the system, as for enabling or disabling certain warnings for different materials or different types of machining with a software. Since the single-board computer does have Bluetooth communication, connecting the smartphone to the system is wireless. The alternative for the smartphone is a

computer screen. With a computer screen, the system can be monitored and changes can be made with inputs through a keyboard, a mouse or both. However, adding another vulnerable system in a corrosive working environment is not the right solution since the screen and the inputs have to be dust-proof and vandal proof in case the students do arm to these objects. Dust and vandal proof systems are more expensive than the normal ones.

- Projector/Directed LED: There are two options in the device that is used to direct the warning to the desired area; first of them is projector and the second is a LED system which can be directed into positions. A projector's advantage is its ability to direct any image to anywhere in the projection area. Therefore, different types of warnings can be projected and even information about the mistakes can be projected where the student can read it or see the image assigned for that precise mistake. However, the downside of the projector is its cost and it being heavy and big in volume. Although there are lighter and smaller projectors today, the intended light for a not fully controlled lighting workplace is more than these mini or nano projectors' provision. Therefore, in today's technology, big projectors are suitable for this kind of project. Since there is no need for a high image quality, cheaper options are available in the market and these low-quality projectors are getting cheaper with the development of new technologies. The other option, LED, is a more recent technology. Although LEDs are around for many years, they becoming cheaper and the application area getting wider, LEDs became the light source of our decade. From the LED light bulbs to our TV screens, LED technology is universally used. With LED directed in the direction of the warning, the red dot can be made visible. However, a disadvantage of using this technology in such project is the need of another system attached to it and the software needed to control these LEDs while there is no need for an additional software for the projector since it gets the data directly from HDMI or VGA output. The advantages of using LED in this system are the low costs and lightweight structure.
- Case: The encasement of the system is crucial since it is intended to be distributed to schools by the government. The case of the system must cover all the instruments in the system and it also needs to be dust and corrosion proof since the workshops are such environments. Since the students will not

be able to touch the system the case does not have to be vandal-proof, the selection of normal materials lowers the cost rather than vandal-proof ones. The ventilation is a problem in the case since it both needs to be dust-proof and the projector needs to be ventilated. The solution for that are filters used in ventilation.

The block diagram of the prototype is as following and the system are presented in Figure 3.4 and Figure 3.5, respectively.

Figure 3.4. Block diagram of the prototype used in the case studies

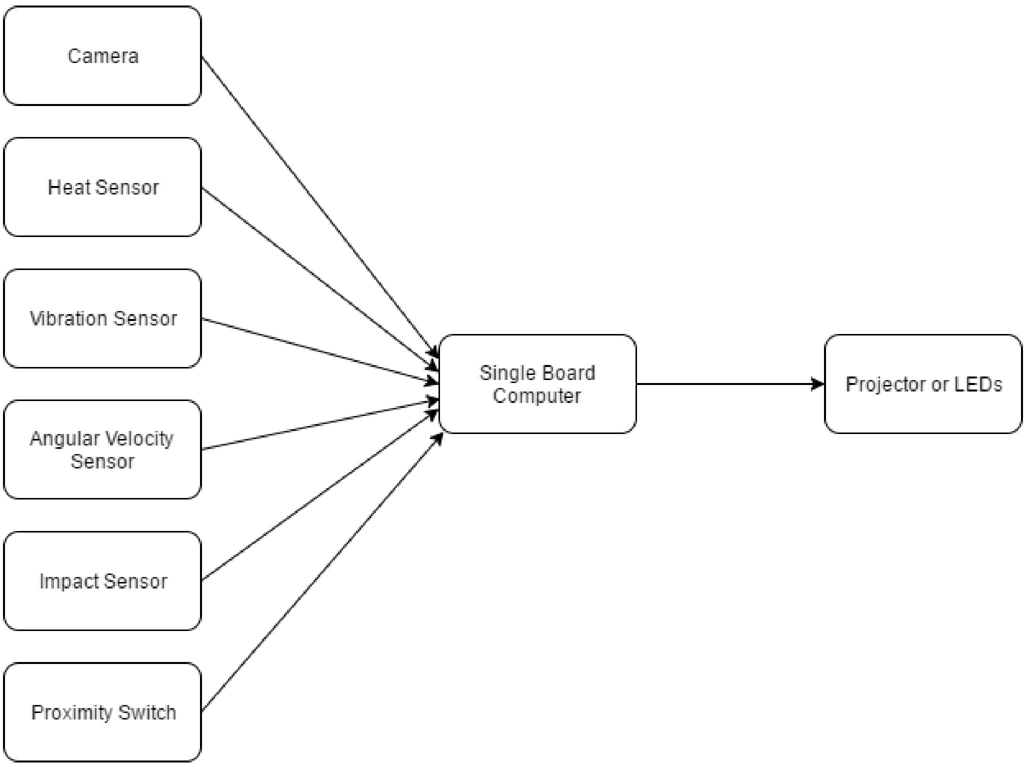

Figure 3.5. Block diagram of the system

As it can be seen in the block diagrams of both the prototype and the system, the prototype is operator-dependent while the system will be independent. The input in the system will be sensors. In order to avoid the mistakes or overlooking by the researcher, the teacher also watched some of the subjects, without warning them. No problems in terms of noticing the mistakes were encountered in both cases.

In order to make an educational kit, industrial design of this system needs to be a guide to understand how it works. As Donald Norman suggested in his book *Design of Everyday Things* (1988) an object of use should not need instructions. Therefore, only in this project will be given as assembly manual for the system. Instructions to use the system will be given only to the teachers and this will be done through troubleshooting and frequently asked questions in the smartphone application. This will prevent paper waste and the risk of losing the manual. Since the manuals are mostly skipped and neglected, troubleshooting is a more convenient method in such system. The case of the system will not have interaction with the user, therefore it will only have a switch and a reset button at the back, near the power supply.

There has not been any alterations done on the machine, neither will be done with the actual system designed. The machines in the vocational school are old, conventional and lack some important safeguards. According to the teachers in the school, the changes that need to be done in order to fit the regulations that will be obligatory from next semester on are impossible to cover because of the lack of income and the funds to the school.

Experimental setup is based on between-subjects design, which is a commonly used method in psychology and especially in education. This method requires at least 20 participants for each group and is based on changing only one factor at once, in this study's case, the source of the warning, whether it is the teacher or the machine. Although between-subjects design is limiting by its nature and within designs have more power, between designs conserve the information, while within designs cause perplex (Charness et. al, 2012). Therefore, between-subjects design is chosen rather than within design and the combination was not used since it does require high number of subjects.

3.3. Data Collection

Prototype, testing setup intended to have a camera to record the hazards and movements of the student but due to nervous behaviours of the students and their unwillingness to be recorded while working, camera was detached from the device. Recordings was done with another camera by some of the participants.

During the test and also during the no test setup in the workshop; student's behaviours, hazardous moves, hazardous actions and surroundings, simple mistakes that are not hazardous by nature were observed and noted down.

Photography is another method used to gather data, especially when the student continued to make the dangerous action. This method was also used to gather data around the workshop in order to find the mistakes made about occupational health and safety in terms of surroundings and machinery.

Think aloud comments of the teachers are also considered in this research. They were not recorded by a device however have been noted down. These comments were mostly about the school's and students' conditions, rarely about the device itself since they did not interact with the device themselves. Both teachers and students were nervous about their actions being recorded since they believed that the system does have a camera while it did not.

Data collection has been made throughout the days, experiment was not conducted in a specific time of the day.

3.4. Data Analysis

Data gathered from the 2 days of studies with each groups of students are organised as day 1 and day 2, which is the mistakes they do in the first day: for test group the mistakes they do with the system working and for control group a normal working setup; and the mistakes they do on the second day, both groups with normal working setup, without the aid of the system. Results have been covered in tables to understand the changes in the student's behaviour about occupational health and safety. Usability tests are done in order to understand the effects and the problems of using a product, in this case, this system. Data is analysed in order to see if it is an efficient method of teaching high school students about OHS and the problems that are confronted. As mentioned before, data was obtained with between-subjects design, therefore the only parameter that was different between control and test groups was the source of warning.

Data has been converted to qualitative data in order to make a qualitative analysis. The mistakes have been given numbers and symbols.

CHAPTER 4

RESULTS

Results of the case study conducted are given in this chapter, the analysis of the data is presented afterwards.

The information and insight gathered with the literature review suggested that most of the accidents are avoidable through taking proper precautions and with the use of required safety gear. Although real accidents, appearing without any warning and even with the use of all safeguards, might have happened, no such incident occurred during the case study. All hazardous moves and incidents were caused by the students and the way of they work.

The problems in using the system were also detected, including unseen problems while planning and irrelevant problems to the students or the teachers.

First and most important problem with using the system was the chip guard, blocking the red dot to be seen on the work piece. This resulted in the students not understanding where they did wrong since the light reflects on the chip guard. However, this problem can be neglected since the more recent chip guards are transparent and the older ones can be read as the problem is on the work piece or the tool bit (the machining parts).

Visibility has been encountered as a problem with only one student, who was Bahadır in Çınarlı High School Students group. He once was unable to see the warning, however this problem was not encountered again, remaining as a one-time complication.

Data about the students' physical features and their mistake frequencies was not gathered systematically, however, no sign of correlation between physical features such as weight and height, and frequency of mistakes was found in the observations.

Experiment has not been performed in a specific time of the day and no sign of differentiation within the frequency of the mistakes regarding to the time of the day has been encountered.

4.1. Data Gathered from the Experiment

4.1.1. Çınarlı Vocational High School Students

4.1.1.1. Test Group

Students who operated the machine with the warnings by the system rather than the teacher have made the following mistakes in two different days (see Table 1.1);

Table 1.1. Çınarlı Vocational High School Test Group Results

Name of the Student	Mistakes and dangerous behaviours they made during the operation of the test setup (first week)	Mistakes and dangerous behaviours they made without the test setup (second week)
Ismail	• Did not detach the unused tool bit; it may have caused injury by cutting his hand or arm. • Did not attach the tool bit properly; tool bit hay have caused injury by getting free of its grip	• Worked without the proper outfit, did not wear smock • Cleaned the tool bit from metal chips by hand; it may have caused injury by cutting his hand and fingers
Hüseyin	• Did not attach the tool bit properly; tool bit hay have caused injury by getting free of its grip • Too many tools were on the tool kit platform; they may cause injury by dropping on the work piece while the machine is operating or it may block the worker from stopping the machine in an emergency situation	

(Continues on next page)

Table 1.1. (Continuing)

Bahadır	• Used the wrench as a hammer • Did not use safety goggles and was warned by the machine 4 times • Forgot wrench on the chuck; it is one of the most dangerous mistakes done while operating lathe, wrench will fly off the chuck on a really high speed and will injure the worker or a person standing at the other side of the machine, depending on the rotation being clockwise or counter-clockwise.	• Did not attach the tool bit carefully, causing it to come dangerously close to chuck while operating
Ömercan	• Cleaned the metal chips off the material while the machine was operating. This action may have resulted in injury by getting caught by the rotating parts.	• Outfit not properly buttoned up

(Continues on next page)

Table 1.1. (Continuing)

Fırat	• Did not use safety goggles • Cleaned the metal chips off the material while the machine was operating. This action may have resulted in injury by getting caught by the rotating parts.	• Did not forget to use safety goggles this time, and warned his friends about it too but stood at the back of the machine (with his safety goggles on)
Gökhan	• Did not use safety goggles	
Fatih	• Did not use safety goggles • Cleaned the metal chips off the material by hand	

4.1.1.2. Control Group

Students who operated the machine with the warnings by the teacher have made the following mistakes in two different days (see Table 1.2);

Table 1.2. Çınarlı Vocational High School Control Group Results

Name of the Student	Mistakes and dangerous behaviours they made during the operation of the test setup (first week)	Mistakes and dangerous behaviours they made without the test setup (second week)
Mehmet	• Forgot wrench on the tool holder • Measured the work piece without drawing away the tool bit	• Cleaned off the metal chips while the machine was operating
Burak	• Held the work piece while it was hot • Too many tools were on the tool kit platform	• Got his hand too close to the rotating parts of the machine while it was operating • Too many tools were on the tool kit platform (made the exactly same mistake)
Ali	• Measured the work piece without drawing away the tool bit	• Measured the work piece without drawing away the tool bit (exactly the same mistake as the last week) • Cleared off metal chips from the tool bit by hand
Mustafa	• Got his hand too close to the rotating parts of the machine while it was operating • Cleared off metal chips from the work piece by hand	• Done adjustments on the tool bit while the machine was operating

(Continues on next page)

Table 1.2. (Continuing)

Berk	• Did not clean off the metal chips when he was done operating with the machine	• Too many tools were on the tool kit platform
Hakan	• Did touch and pushed the tool bit on its cutting edge • Did not use safety goggles, he rather put it on the tailstock	• Cutting depth of the chip was beyond the safe level, causing flying, hot metal chips that can cause burning on skin • Did not use safety goggles again and a metal chip got into his eye. Luckily no permanent damage was done.
Batuhan	• Held the work piece while it was hot • Did not clean off the metal chips when he was done operating with the machine; may cause danger to the next operator of the machine • Did not attach the work piece to the chuck properly; this may cause injury if the work piece lets itself free off the chuck by the vibrations	• Did not held the work piece but made his friend to do so, his friend got burned this time. • Outfit not properly buttoned up • Too many tools were on the tool kit platform

In control group, the students which were not wearing safety goggles but not got warned by the teacher about that were not noted down in order to understand the effect of the type of the warning.

One of the students (Bahadır) failed to see the red dot at his first hazardous action. Other students who were watching the test warned him about it since he did not stop working in order to correct his action. There was not ant other visibility problems at the test, showing the projection is a correct device to perform such project. However, since the school does not follow ideal lighting conditions for a workshop, afternoons were too much bright because of the side of the building the lathes are on. This problem was overcome by attaching cardboards to some of the windows. In ideal lighting conditions for a workshop or a factory, no such problem is foreseen.

Figure 4.1. Screen capture of the vocational high school student touching tool bit's cutting edge while talking to his teacher and meanwhile, getting a warning from the machine, from the video recorded during the experiment

4.1.2. Dokuz Eylül University Students

4.1.2.1. Test Group

Table 2.1 – Dokuz Eylul University Mechanical Engineering Test Group Results

Name of the Student	Mistakes and dangerous behaviours they made during the operation of the test setup (first day)	Mistakes and dangerous behaviours they made without the test setup (second day)
Mert	• Did not use safety goggles and was warned by the machine 4 times • Did not use chip guard • Forgot a wrench on the non-operating machine • Adjusted the cut depth while the piece was being machined	Teacher gave him a new pair of safety goggles and he did not take them of even when they are not necessary/while not machining However: • He rushed the work piece and tool bit ended up crashing to the bigger diameter part of the work piece
Büşra	• Accidentally started up the machine • Did not use chip guard • Did not use safety goggles	• Did not use safety goggles
Arda	• Did not use chip guard	
Murat	• Stood too close to the operating machine while his friend was working	
Necip	• Did not use safety goggles • Cutting depth of the chip was beyond safe level	
Utku		• Did not button up his smock
Taylan	• Too many tools were on tool kit platform	

(Continues on next page)

Table 2.1. (Continuing)

Sevgi	• Did not use safety goggles	
Enes	• Used the wrench as a hammer • Adjusted cutting depth while tool bit was on the work piece	• Too many tools were on tool kit platform
Diren	• Did not close chip guard	• Did not use safety goggles
Melike		
Duygu	• Did not button up her smock	
Hakan	• Cleaned the metal chips off the machine while it was operating	
Mustafa	• Stood too close to the operating machine while his friend was working	

4.1.2.2. Control Group

Table 2.2 – Dokuz Eylul University Mechanical Engineering Control Group Results

Name of the Student	Mistakes and dangerous behaviours they made during their first operation of the machine lathe (first day)	Mistakes and dangerous behaviours they made during their second operation of the machine lathe (second day)
Yüksel	• Did not pay attention to the machine while it was operating, looked the other way • Did not use safety goggles	
Eser	• Did not use safety goggles	• Operated the machine to the opposite direction
Volkan	• Handled the hot work piece • Did not use safety goggles	• Did not close chip guard
Barış	• Did not use safety goggles and warned by the teacher 2 times	• Did not close chip guard • Did not use safety goggles
Zihni	• Outfit not proper; smock's buttons are not tied and shoes are untied • Did not use safety goggles	• Did not use safety goggles
Osman Yiğit	• Did not close chip guard	• Did not close chip guard • Stood too close to the operating machine
Salih	• Did not wear smock • Did not wear safety goggles	• Wore jewellery on wrist

(Continues on next page)

Table 2.2. (Continuing)

Gündüz	• Did not close chip guard • Stood against the operating machine while his friend was working	• Did not pay attention to the machine while operating
Okan	• Did not wear smock	
Kaan	• Did not wear safety goggles	• Did not close chip guard
Eray	• Accidentally started up the machine	
İrem	• Stood too close to the machine while her friend was working	• Did not pay attention while operating the lathe
Deniz		
Şeyma	• Did not button up her smock	• Did not button up her smock

4.2. Experiment's Comparative Results

In this chapter Çınarlı vocational high school test and control groups will be discussed first and Dokuz Eylül University students will be discussed secondly. Lastly, both groups will be handled and analysed in order to understand the effect of the system on both cases.

The results of both groups, test and control, have been analysed in order to find out the effect of the system. The only thing that changed between these two groups was the source of the warning, in test group the warnings came from the system and in the control group they came from the teachers.

Çınarlı vocational high school students in the test group have shown positive reactions to the system. Their first reaction was investigating the system by putting their hands in front of the projector and asking questions about it such as "does this record our actions" or "will this affect our grades?" After gaining their trust about it not having any impact on their grades, they began to work with the system on without further concern.

Test group students did not repeat their mistakes, at least did not do the same mistakes again after working with the system's warnings. 4 out of 7 of them did not make any mistakes again. Every one of them started using safety goggles after being warned by the system. Although, one of the students, İsmail, failed to understand the hazards caused by the tool bit. He did not remove the unused tool bit and did not tighten the tool bit, got warnings from the system both times. Even when he did not do the exactly same mistakes, he cleaned the tool bit with his bare hands, without thinking about the consequences. This shows that such systems will need upgrades in order to teach the dangers of a certain part. A positive reaction towards the system was from Fırat, who was in test group. He warned his friends about the importance of the safety goggles after being warned by the system. He even demanded from his friends who were watching him while he was operating the machine, to put their safety goggles on.

Students in the control group did not put their safety goggles on even when they were warned by their teachers multiple times. They continued working without safety goggles and without closing chip shield, which was extremely dangerous for the sake of their eyes. Eventually, an incident happened within the observations done in experiment and a student, Hakan, had a flying chip got into his eye. Luckily, no permanent damage was done, however, he continued working without the safety goggles even after this accident. Mustafa, another student in the control group, failed to understand the dangers of getting his limbs close to rotating parts and standing away while the machine is working. He has done similar mistakes both days. Ali measured the work piece without getting the tool bit away both times, which indicates he did not learn from the warnings made by the teachers. Batuhan held the work piece with bare hands and burned his hand the first day, did not need warning from the teacher but should have learned from his mistake, he learned from his mistake and did not hold the hot piece next time, but he made his friend do so, which indicates he lacked discipline and failed to understand the consequences of his actions. The last student in control group, Burak, too made exactly the same mistake both days. He left too many tools on tool kit platform. Even when he was warned, he did the same mistake, failed to understand how these tools could cause hazards.

None of the control group students did avoid all incidents at the second day. This showed that the system is an effective method of warning the students and may be interpreted as the warnings from teachers not having enough effect on the students anymore. The students did not change their attitudes for the safety gear even after the teachers warned them. This may be the result of the teachers not using these gear too.

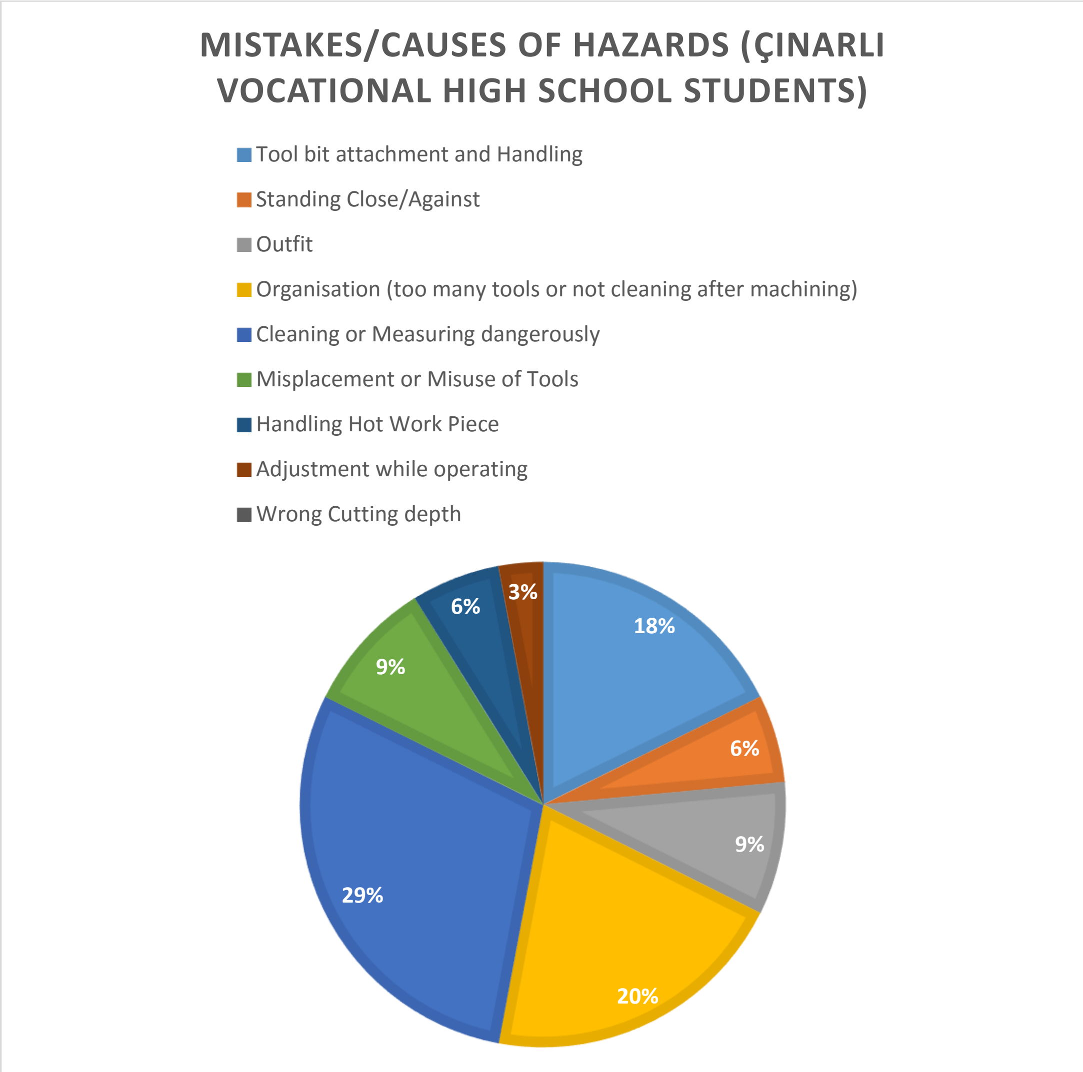

Figure 4.2. Mistakes/causes of hazards (Çınarlı Vocational High School Students)

Students of Dokuz Eylül University Mechanical Engineering have made different mistakes than the students of Çınarlı vocational high school. Since high school students were not warned about the safety goggles and chip guards, main mistake made by university students were forgetting these safeguards. Difference in these two cases can be explained by the students' level of expertise in terms of machining, none of the mechanical engineering students have worked on lathe before the first day of the case study. Therefore, the level of difficulty of the work pieces given to them are much lower than the vocational education students since they only work on one station for two days then move on to the other machines. However, these students are called as fast learners by the teachers of vocational school. Although they did not have an OHS training at school yet, these students are more aware of the hazards.

Safety goggles were forgotten to be used by 12 of 28 Dokuz Eylül students. Some of these students were warned by either the machine or the teacher more than once, one of them was warned 4 times. Total warnings for the goggles were 20. However, only 2 students in test and control groups forgot to use safety goggles on the second day. In test group these students are Büşra and Diren. Büşra is the only student in test group who forgot to wear goggles on both days. In control group, Barış and Zihni were warned on both days for not wearing safety goggles. Barış was warned 2 times on the first day by the teacher.

Second most common mistake made by university students was the mistakes in outfit which include not wearing a smock/work uniform, not buttoning up the outfit properly and wearing jewellery on the hands. Only Utku, in test group students, forgot to button up his smock properly on the second day. In control group, Şeyma forgot to button up her smock in both days even with the warning in the first day by the teacher.

Least common mistake in both groups was accidental start-ups with occurring only twice. However, this mistake often follows standing close to the non-operating machines. 4 warnings have been made for standing too close to the machine.

Technical mistakes are decided to be not counted in this case's conclusion since they are mainly caused by the lack of experience of students in lathe work. 7 warnings of technical mistakes that could have resulted in accidents were made.

Chip guards were forgotten to be used by 8 students out of 28 and these students have been warned 8 times, making this mistake only once. Kaan, Barış and Volkan in control group made this mistake on their second days. None in test group forgot to use thee chip guard on the second day.

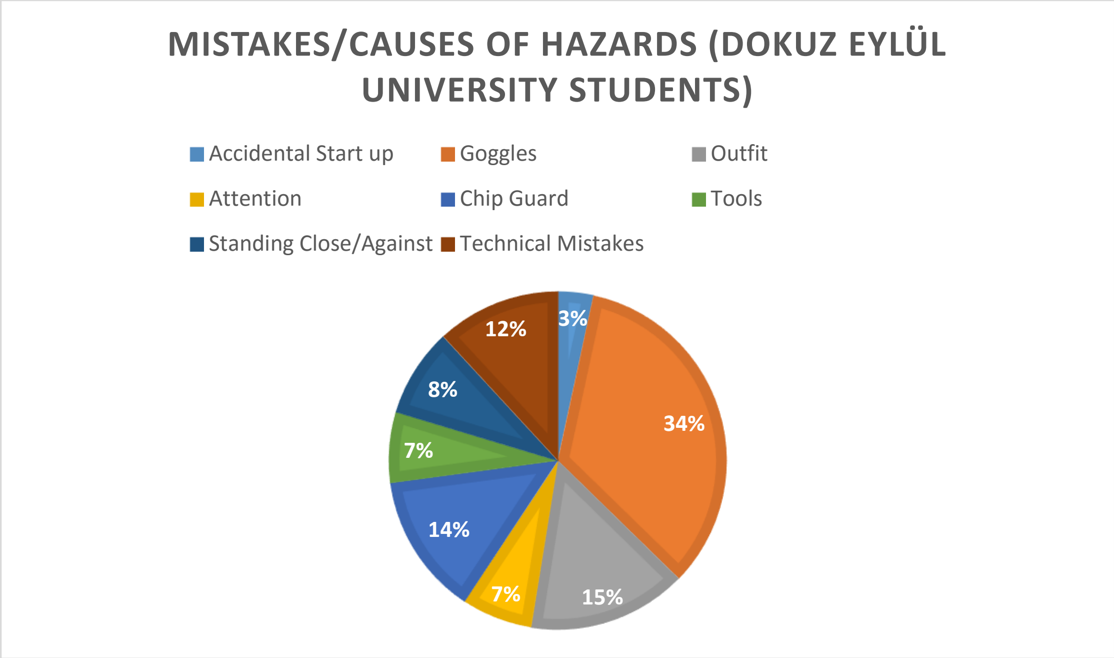

Figure 4.3. Mistakes/causes of hazards (Dokuz Eylül University Mechanical Engineering Students)

In order to understand the effectiveness of the system in both groups, having different number of subjects, average of mistakes made by students have been taken and systematically adapted into a graphic where test and control groups in both cases can be seen in the same image.

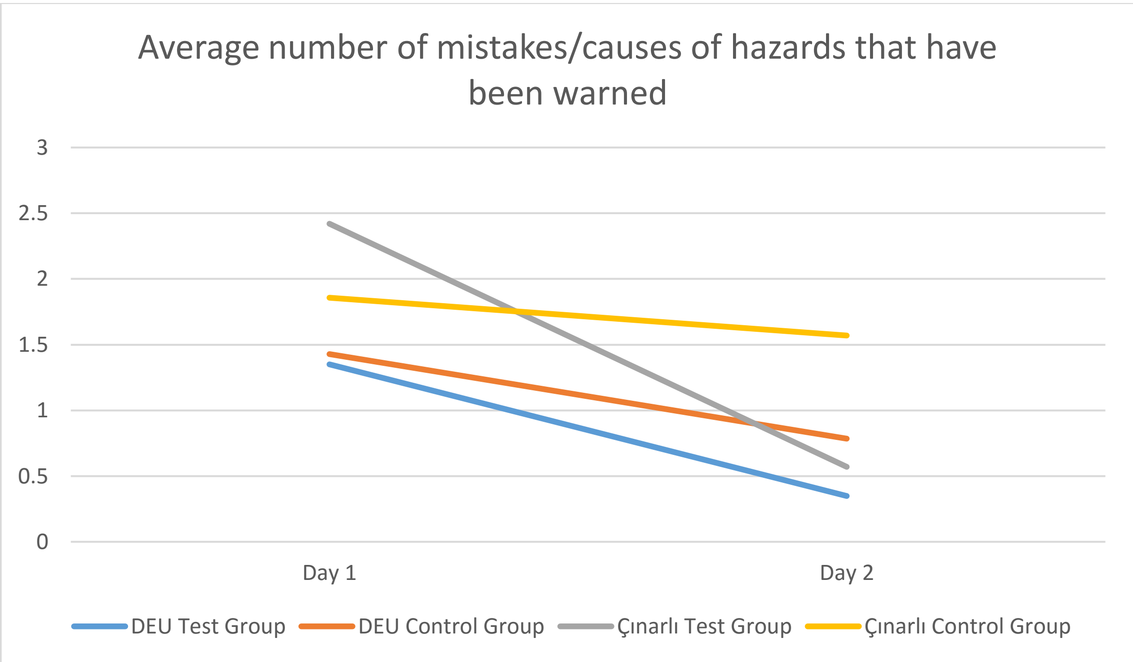

Figure 4.4. Average number of mistakes/causes of hazards that have been warned

On this previous graphic, it can be seen that in both cases, average numbers of mistakes have been decreased both in test and control groups. The most drastic change however, is seen in the test group of Çınarlı students. In both cases, test groups made fewer mistakes than the control groups. Averages have been used to eliminate the difference in the number of students in cases. Both cases have equally divided control and test groups.

4.3. Findings and Results of the Observations at the Workplace

Due to the recent regulations in Turkish education system, vocational schools need to fulfil the requirements of occupational health and safety standards from 2016-2017 fall semester on, meaning the time research was made was the last semester without the regulations. However, the machines in Çınarlı Vocational High School are not fit for the OHS standards and most of them are not reconfigurable in order to make them safer. Since there is a small budget given to the school and it being not enough even for repairing the broken down machines, the actions that will be done to fit the regulations for next semester are unknown even by the teachers.

Small work accidents are really common at this school, every day of the research, there were at least one student who had an accident, mainly cutting themselves with sharp objects by accident. When asked to the students and teachers what was the most life threatening accident of the year, they all showed one of the students, who came back to the school after the accident that happened 3 months ago. His wrist cut open with a tool bit while he was working on his assignment at school and was rushed to the hospital, his teacher explains. He still has the mark of the accident. However, students being prepared for small accidents make them ready for professional life. When an accident occurs at workshop, they mostly take care of the student by themselves, without informing their teacher, although they are obliged to do so. During the time of the case study, there was one accident that students failed to create safety immediately and it was when a hot metal chip flew into Hakan’ s (student’s name) eye. Other student who was near him failed to stop the machine, which may have caused a bigger accident.

4.3.1. Safety Hazards Caused by Surroundings

Unused electrical cables were not completely removed, they were taped. Although they may have no electricity in them or any source connected to them, they cause the risk of electrocution since the students work around them all day and their safety in not guaranteed.

Hazard of materials to fall on students in the workshop is present. The cause for this is the lack of storing space for all materials. Although there are lockers for the tools and materials, some tools and materials are oversized for the lockers or they are too frequently or too rarely used. Rarely used and oversized materials are stored at top of lockers and these lockers are located near the machines where students work, meaning they work under the risk of burying under these materials in case of an earthquake or even a little vibration caused by a student bumping into the locker, closing the locker door too fast etc.

Another problem with the workshop is, since it has old machines, some of the machines do not contain the excess machine oil and leaks it. Grease and machine oil on the floor may result in the students or teachers falling down with stepping and sliding on it.

4.3.2. Safety Hazards Caused by Machinery

Most of the machines are faulty in the workshop, therefore only the one that cause extreme risk are mentioned in this chapter. Not having new technology of safety or lacking some safety gear will not be considered.

There are machines in the workshop that are placed out of order because of the lack of maintenance. Some of them have the sign as a warning, as “do not operate” “faulty machinery” or “out of order”. There are machines that students and teachers operate on although the machines are not working properly, safely or they lack parts that are vital in terms of safety. For example, some of the lathes lack the emergency stop button, although they are still in use and even the machine that the system was connected to, had missing parts. There also are some machines that the students mostly know that they are faulty or just got out of the order until they are fixed, therefore do not have sign that notifies the user about the disability to work on these machines. These machines are also connected to the electric system, which make them extremely dangerous since an unsuspecting student may not notice a missing part or a hazard on the machine and may try to operate it.

Figure 4.5. Faulty machine without a warning

4.3.3. Safety Hazards Caused by Students and Teachers

As mentioned earlier, in the test setting observations, students and teachers do make too many hazardous actions. Since the students who are either in the test or control group are mentioned in the previous chapters; teachers' and other students' behaviours will be mentioned in this chapter.

Teachers admit that they do not use the safety gear they need to use, especially safety goggles, even while operating the grinder which has a warning sign clarifying that it should not be operated without safety goggles. They do so while they are helping students make their tasks. This action contradicts with the method they use to teach students about OHS. Their method is to use their experiences about causes of accidents, however even when they admit to have such accidents with the lack of using protective gear, they still set a bad example to the students. This shows that they do not act according to the simple method they use.

Figure 4.6. Teacher working without safety goggles in front of the students and under the warning sign

Safety goggles is a way of covering eyes while working on a lathe and another option which does not provide a full safety from metal chips but safer than operating without any safeguards are using lathe safety guard and shield. Although, most students did not use the shield to cover them from metal chips and burns on their skin happened, one student even had a metal chip in his eye because of the lack of safety measures. Their excuse for not using the shield was that they cannot see the work piece while operating if they cover it. The students' claim is not completely irrational since these shields have not been cleaned for a long time and it is indeed not easy to see through them.

Emergency switches were covered or lacked the proper fittings, cases or even the whole emergency switch was missing in some machines. This disables the students and teachers to stop the machine quickly in an event of an accident. While the lack of emergency switches is a matter of faulty machinery, covering the switches is the fault of the students.

A problem only encountered with Dokuz Eylül University students is their lack of workshop discipline and not exactly knowing the rules. This resulted in leaving the tools where they do not belong and others searching for them or leaving the lockers open.

4.3.4. Storage and Tool Set Accessibility

Storage is not a main problem in the workshop, there are tool lockers with their contents written on them. There are also smaller lockers, named for the classes, enabling the teachers to control the tools and know who has which tool since the tools are also a financial burden to the school that cannot be afforded. Tool bits are shared between students and even teachers and they are whetted, no new bits are bought. This will be explained in another section.

The only problem with the storage units is the students not caring about the contents. However, this cannot be considered as a problem only in this particular school. This becomes a problem only when they cannot find what they are looking for or they sometimes think that the workshop lack a gear that is actually there, for example, safety goggles.

Tool set accessibility is a problem in this workshop, for both the safety and time management. Even when the test was on progress, students left the lathe to find tool bits, chuck wrench, metal pieces to compress the tool bit better and callipers. These are the main tools needed for machining in a lathe, only different tool bits may be in other machines or lockers. Every lathe has to have its own chuck wrench on the tool stand next to it so that the material machined can be tightened up properly of loosened in order to adjust the length of the pressured and machined zones.

4.3.5. Safeguards and Gear

Students lack the information about the importance of personal protective equipment. Teachers have this information, however they admit to fail at practicing it at all times. They also stated that they have had injuries from flying metal chips too while operating lathe. One of the teachers admitted that he was just “lucky” for not having a permanent damage done to his eyes.

When asked, students insisted that there were not enough safety goggles in the workshops. Material list on the locker in the workshop stated that there are 8 safety goggles present. The students did not know about their existence and they were looking new, not used. Safety goggles were given to the students and the reasons are explained why they should be wearing them while operating the machine.

Lathes that are bought more recently to the school have sensor triggered systems that disables the machine while safety equipment on the machine are not present or not in the armed position. These lathes also have two emergency stop buttons at both ends of the machine.

4.3.6. Warning Signs

There are various types of warning signs in the workshop. Some are the ones that were produced by the government, warning posters to show the importance of safety at work, mostly with a friendly voice. These signs are produced in order to use at workplaces, not schools, so they lack the information the students are able to get. And since they are for professionals, their target group consists of older people, the visuals used and the way of communication is not for high school age children who are aged 14 to 18. Although these government signs are helpful to show these students they need to take care of their own safety, the effectiveness of these signs are a matter of another research.

Material selection of the warning signs was neither out of ordinary nor causing danger. Moreover, they were fit for the environment since chemical exposure is not present in the workshop. Only some government produced posters were faded due to sun exposure, however these were not considered as a hazard, since they are not crucial warning signs.

Government provided signs can be seen everywhere in the workshop. However, these are not the recently designed posters and have been there for years. New posters include the occupational illnesses as well as occupational accidents and injuries, such as the diseases caused by chemical exposure in long term. Recent administrators in government about these issues are considering occupational illnesses too although the field’s professionals think these measures are not enough. These ideas and comments were gathered from the TIOSH conference in Istanbul in April 2016.

The most frequent warning sign in the workshop has been the one that says “standing beside the lathe is dangerous and forbidden” with it being on every lathe machine's other side. However, even with this warning, students were standing there watching their friends who are operating the lathe.

Figure 4.7. Most common warning sign in the workshop

Another warning is about covering your hands, eyes and feet off the rotating parts of the machine. This sign lacks the logic since the correct form should be covering or avoidance of the limbs from the rotating parts. Eyes could not get into the rotating parts by their nature, contrary, they should be watching the rotating parts in order to be alert about emergency situations. Therefore, it can be concluded that this sign needs to be corrected and not all signs in a facility is guaranteed to be right or thought carefully.

The last sign observed in this section is to warn students and teachers about not using the machinery they do not know. This sign can be seen in most factories and have varieties such as not doing a job you do not know or leave the job to the person who is capable and experienced.

4.4. Final Design of the System

According to the results of the literature review and case study, two main designs are considered; one with built-in and encased projection system (either a projector or LEDs) and one without projection system. Second system is considered to be more cost efficient and more applicable for schools in Turkey since the government supplies every school with projectors. However, this type of system would not be the right choice for factories or environments other than schools, while an external projection system will be needed and factories are highly polluted areas for non-encased projectors, without sufficient proofing from dust and chemicals. In Çınarlı, dust proofing has not been seen as a need, therefore a normal projector with an attached system is sufficient for this school. The different designs considered are explained in the continuing sections.

Raspberry Pi's do have cases produced officially or by other firms or people. However, since this system does contain more than only the mentioned single-board computer and does need to be suitable for the environment it will be used in, these cases will not be sufficient.

The system's design also includes the user scenario of the product. This system is intended to be used in vocational schools as mentioned before. This product, depending on the budget for such educational project, can be installed on all machines, even to machines other than lathe with the development of the software. Installing this system to all the machines in a workshop will enable the teachers to spend more time on teaching new methods to the students rather than controlling all off them and wasting time while walking between the machines. It will also prevent the accidents from happening sine the teacher in a workshop cannot be everywhere at the same time and the students mostly are alone while working. The system will warn them just as a teacher was near them and the student will both avoid the accident and will learn from their mistakes.

In case of a low budget, system will be installed in one, or a few lathes; the students in that workshop will work on that lathe by turns. Since every student will get their turn to work with the system, the educational aim of this system will be accomplished. As mentioned before, with additions to the software, this system can work on any machinery, so this system can be demounted from the lathe when all students have trained with it and can be mounted on another machinery such as milling machine or bench drills. With only one system, all students can get the OHS training in all machinery in a workshop.

With another simple addition to the system, a counter, students' mistakes can be counted and their grade can be differed with figures given by the system.

This system can also be used in factories or workshops. With this system, OHS inspection can be made easily. The red dot can be switched off.

Final scenario for using this system is home/hobbyist use of it. With this system, non-professional users can also learn about OHS in lathe or other machinery on their own. Additional information such as how to operate or how to adjust for a material can also be shown on the work surface for educational purposes.

4.4.1. System with Built-in Projection

This system's measurements are determined with the measurements of the projection device which is the biggest device in terms of size. In case of the use of LEDs, these measurements are smaller. LED embedded system will be given as an alternative but the method used to control the light is not finalized.

The projection used in the prototype has enough light power and the recent projectors with same light source are mostly in similar sizes. Only smaller projectors with the same light levels are high in price, therefore not considered for such system. Since the projector is the biggest part in this system, it is more like the computer and camera are embedded to the projection device.

4.4.2. System Without Built-in Projection

This system is much smaller in size than the first alternative. However, this system does need an external projection device.

Advantages of this type of system are as following;

- Cost efficient
- Able to be used with all projectors
- Modifiable (since the projection device technology is developing and these systems are getting smaller and cheaper)
- Smaller in size

- Can be dust-proofed without the ventilation problems that would have been caused with the embedded projector
- Can be distributed to schools easily because of the size and the lack of lenses in the projector that need care while shipping.

In order to design this type of system, the maximum measurements are considered as the measurements of the single-board computer which is Raspberry Pi 3. However, since the Raspberry Pi does not have VGA or DVI outputs, HDMI input projectors or converters are needed, either HDMI to VGA or HDMI to DVI. Raspberry Pi also needs a power supply. These two cables are the minimum cables needed to operate the system. Since the power supply is micro USB, it can be provided without problem and in case of a defect, cable can be changed without waiting for supply. And this power supply enables the system to work with any USB power supply such as PCs, Macs or even portable power banks. With this ability, the system does not need to be close to a wall socket.

The system can be controlled with a wireless keyboard and mouse set with Bluetooth adapter. In order to provide the memory, a micro SD card is used. Micro SD card is also where the operating system is installed since these computers do not have internal memory in order to be affordable, durable and small. These hardware are installed in the system at the beginning and with a cover, can be ejected manually in order to change a faulty part or to install other programs to the computer.

Single-board computers do need a monitor in order to operate just as the PCs (personal computers). In this system the monitor output is the projection device. Audio output is also available, therefore it is possible to add audial signals to the systems if needed.

Earlier Raspberry Pi models does not have internal Wi-Fi antennas therefore Raspberry Pi 3 is selected in order to supply the need of a central control of the systems in a school. It also enables the systems to be updated without the need of ejecting the micro SD card.

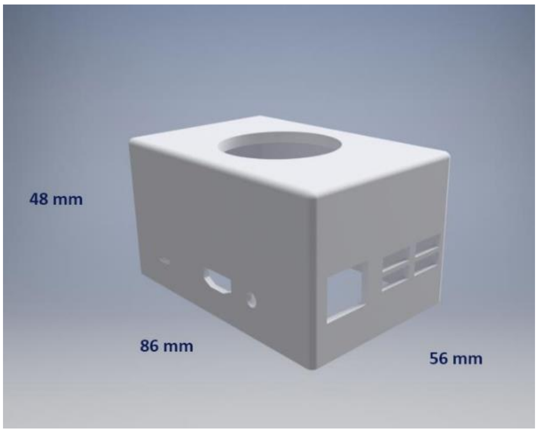

Figure 4.8. Opaque case design for the system

As an aesthetical preference, two models of the system without the built in projectors are suggested with final forms. One of the options have an opaque case and the other has a transparent one, both having the same dimensions. All features other than the case material are the same. The transparent option is suggested in order to catch the students' attention and make them more interested in new technology, which is not what they work with in the school. An example of transparent electrical/mechanical system is given below.

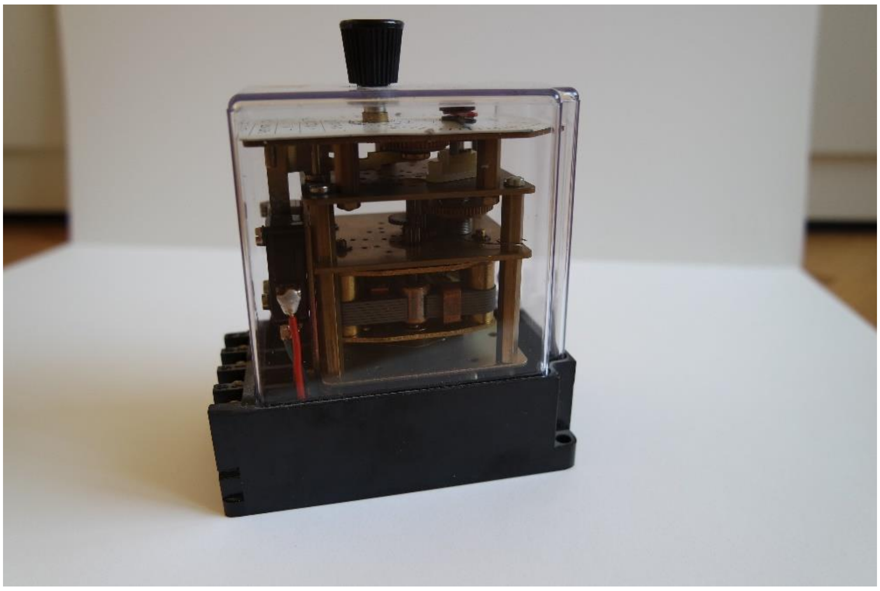

Figure 4.9. An example for transparent design of mechanical objects

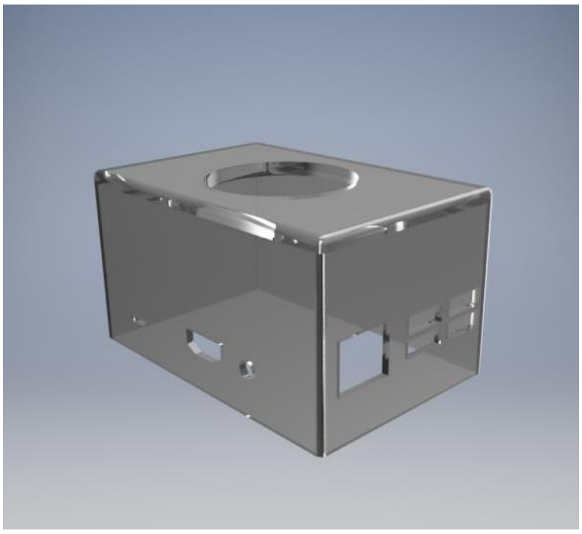

Figure 4.10. Suggested transparent design for the system case

CHAPTER 5

CONCLUSION

Conditions of the vocational high schools in Turkey in terms of OHS is found to be poor and insufficient. Both the OHS trainings and materials used in the school lack safety and the teachers are found to be not effective enough on the students. The causes of this is another research's matter.

The young students' attention is hard to catch since they did not choose to be in vocational high schools in the first place. However, new technology caught their interest with this system. Future systems of educations in vocational schools should depend on technology more.

The system designed to teach vocational education students and mechanical engineering students is found to be efficient and tought students about OHS and it enabled the students to understand the hazards caused by specific parts of the machine. This is understood by the students avoiding other hazardous actions that can be caused by the same part of the machine. With the use of the system average of the mistakes done by students dropped dramatically. The biggest decrease was in Çınarlı Vocational High School Students with from nearly 2.5 mistakes to 0.5. In both cases, high school students and mechanical engineering students, test groups have had more decrease in the number of mistakes per person than the control groups. This confirms that this system is more effective than the warnings coming from the teacher and was the most effective in high schoolers, who are with their teachers all year.

Augmented Reality is found to be effective for an education system and spatial augmented reality is found to be cheap and applicable in vocational high schools since these schools lack budget and cannot afford expensive systems or cannot afford to change all their machinery.

For further research, different information can be adapted to the system to test the legibility and visibility. This information or visual can be static or dynamic. These suggestions are given in the light of the success of red dot by visibility and understandability.

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