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Effective measures to decrease air contaminants through risk and control visualization – A study of the effective use of QR codes to facilitate safety training

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ABSTRACT

Woodworking industries still consists of wood dust problems. Young workers are especially vulnerable to safety risks. To reduce risks, it is important to change attitudes and increase knowledge about safety. Safety training have shown to establish positive attitudes towards safety among employees. The aim of current study is to analyze the effect of QR codes that link to Picture Mix EXposure (PIMEX) videos by analyzing attitudes to this safety training method and safety in student responses. Safety training videos were used in upper secondary school handicraft programs to demonstrate wood dust risks and methods to decrease exposure to wood dust. A preliminary study was conducted to investigate improvement of safety training in two schools in preparation for the main study that investigated a safety training method in three schools. In the preliminary study the PIMEX method was first used in which students were filmed while wood dust exposure was measured and subsequently displayed on a computer screen in real time. Before and after the filming, teachers, students, and researchers together analyzed wood dust risks and effective measures to reduce exposure to them. For the main study, QR codes linked to PIMEX videos were attached at wood processing machines. Subsequent interviews showed that this safety training method enables students in an early stage of their life to learn about risks and safety measures to control wood dust exposure. The new combination of methods can create awareness, change attitudes and motivation among students to work more frequently to reduce wood dust.

1. Introduction

Young workers are often vulnerable to safety risks and injuries (AFA Insurance, 2013; Laberge et al., 2014). Within the wood and furniture industries, high safety risks are often associated with a lack of knowledge. In order to best protect themselves in the woodworking industry it is essential that workers is informed of these risks associated with their jobs, and that they learn effective control strategies to decrease air contaminants (Rosén et al., 2005). Scarce knowledge and lack of interest, as well as time constraints and a lack of financial resources, are often the reasons for inadequate work environment improvements (Bornberger-Dankvardt et al., 2005). It is necessary to increase knowledge as well as to change attitudes about safety for reduced proportion of injuries in the woodworking industry. For instance, good knowledge of working methods and working techniques as well as better attitudes that does not allow injury or poor work environment as part of the profession (Antonsson et al., 2008).

According to a comparative study between 25 member countries of the European Union, the most common exposures to wood dust occur within the furniture and construction industry (Kauppinen et al., 2006). Woodworking industry workers often work in poorly ventilated spaces. Kauppinen et al. reported that about 1.2 million workers were exposed to more than 2 mg/m^3 quantified as mean value for eight hour exposure at work, and 560,000 workers were exposed to over 5 mg/m,^{3} and the legal maximum allowed exposure in Sweden is 2 mg/m^3 (Swedish Work Environment Authority, 2011). In Sweden, at least 58,000 workers are exposed to wood dust, which may cause cancer, dermal symptoms, and respiratory diseases (Kauppinen et al., 2006). Further, knowledge of work environment risks needs generally to be monitored and disseminated to create awareness among employees (Statens Offentliga Utredningar, 2012).

To disseminate and increase knowledge and to better understand the risks and methods of controlling air contaminants, the present study applies safety training with QR-codes linked

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PIMEX-videos to a handicraft program that specializes in wood-working at an upper secondary school.

Safety training can address a variety of safety issues, such as ergonomics, risk communication, fire safety, ladders and stairways, confined spaces, asbestos, lead, hand tools and power tools, lifesaving equipment, personal protective equipment and electrical safety (Brunette, 2005). Previous studies have evaluated safety training on first aid (Lingard, 2002) and empowerment (Lippin et al., 2000); both these forms of safety training have been shown to be effective in improving safety behavior among workers as well as increasing their awareness of risks at work (Lippin et al., 2000; Lingard, 2002). Additionally, it has been found important to provide safety training for upper secondary schools (Davis and Pollack, 1995; Schulte et al., 2005; Pisaniello, 2013), as these schools prepares students for future work situations (Pisaniello, 2013). However, it has been found that high schools are not always set up to provide the necessary safety training.

In a survey at 103 high schools, 16% of the teachers and school-to-work advisors responded that they had not received any formal safety training, and 36% indicated that they had limited opportunities to teach safety training because of their other work demands (Pisaniello, 2013). According to Brunette (2005), another challenge with regard to safety training for future studies to investigate is that workers are often culturally and ethnically diverse, which makes it more difficult to create educational material that is suitable for everyone (Brunette, 2005).

The current study was based on, and undertaken to contribute to, these findings on safety training. For the study, a safety training method was designed to be easily accessible, simple to use, consistent, inexpensive, and time effective. Another purpose of the study was to increase student motivation to participate in safety training. Additionally, a new combination of methods was implemented for safety training, as far as the author is aware a new combination of methods was implemented which uses QR codes (two dimensional barcodes scanned by mobile phones and linked to web pages) (Huang et al., 2012), and the PIMEX (Rosén et al., 2005). The training videos addressed the risks of contaminant exposure in work situations as well as effective measures to minimize them. The focus of current study was on methods to control wood dust by demonstrating how these exposure risks arise and how they can be prevented. Control measures can be understood to be "all possible means to control health hazards" (Lumens, 1997, p. 1).

The preventive approach was chosen as such an approach can effectively decrease health risks among individuals, including air contaminant risks. It would benefit a company's productivity, and reduce costs to have healthy employees. Employees who are on long-term sick leave are placed in a vulnerable position. Their psychological health, individual well-being and physiological state can decrease (The Nordic Council of Ministers, 2004).

Measures to reduce air contaminant exposure are often unsuccessful because workers are not involved. However, the PIMEX method can inspire commitment and motivation among employees to reduce air contaminants as well as increase knowledge and awareness of exposure prevention. An interactive process can be established, one with the help of workers, managers, scientists, and the recorded material, to create opportunities to develop measures to reduce exposure and to analyze the risks of them, including those based on the worker's knowledge. The PIMEX videos can be used for such safety training, and future research on the method may be directed towards adding more technical resources to the approach and to integrate it with mobile phones and self-training applications (Rosén et al., 2005). The PIMEX method was therefore chosen for the experiment and method in present study together with the following described tool QR codes.

QR codes can be useful in stimulating the development of individual knowledge (Chen et al., 2011; Yao, 2011; Huang et al., 2012; Price, 2013). QR codes could, for instance, be a practical method to show online videos (Walsh, 2010; Lynch et al., 2012), and these videos might also be used with mobile phones for the purpose of increasing knowledge (Lynch et al., 2012). Indeed, it has been shown that digital information combined with physical objects is a future trend in education (Huang et al., 2012). This may offer opportunities for QR codes to be used as a tool in a method or experiments within the woodworking industry, as well as in more specific vocational programs for upper secondary school students for the distribution and dissemination of knowledge with regard to the reduction of wood dust.

The current study focuses on preventive safety training using QR codes linked to PIMEX videos as a method to train students at woodworking vocational programs in upper secondary schools. The safety training goal is to avoid wood dust in work situations, and the goal of using the QR codes linked to PIMEX videos is to make the knowledge necessary to do so more accessible and easier to absorb, and to inspire and motivate workers to learn more about the relevant control measures. It has, for instance, been shown that many workers simply accept that they are exposed to air contaminants as part of their job. They believe that the control of air contaminant exposure is not needed (Rosen et al., 2005).

Additionally, future research should be adapted to make safety training more attractive, more readily available, and more effective (Goldenhar et al., 2001). The main objective is, therefore, to identify if QR codes linked to PIMEX videos can train students about safety in terms of control measures to reduce air contaminants and risks, as well as help improve their attitudes towards safety.

The next section of the paper provides a short review of the current literature and theories about safety training and attitudes, followed by a presentation of the methodological approach taken in this project. Then the empirical findings will be presented. Finally, conclusions and discussions of the main findings are presented, and the implications for future research are reflected upon.

2. Theoretical frame of references

2.1. Safety training to decrease air contaminants

Participation in safety training on the subject of air contaminants has been shown to increase the likelihood that workers will change their worksite conditions. Should workers participate in this safety training, there is also a much greater chance that safety and health improvements will be made. Studies have shown, for example, by evidence that respiratory protections were used to a greater extent after the safety training (Becker and Morawetz, 2004).

This study was designed to encourage student participation; for example, as part of the training, students wore encapsulated suits to simulate chemical spills. In addition, the curriculum was mostly a mix of hands-on activities and classroom programs (Becker and Morawetz, 2004). Furthermore, it has been shown that even though the trainer often plays a supervisory role, the worker's experience and knowledge is an important resource with regard to safety training (Hilyer et al., 1999; Becker and Morawetz, 2004; Brunette, 2005) as well as an interactive and experimental approach (Goldenhar et al., 2001). Participation in safety training, from top management down to the workers on the floor, is important for health and safety in the work environment, which helps to create an integrated culture of safety in production, and creates a more positive attitude regarding workplace safety (Seppala, 1995).

Training has always been essential to achieving improved health and safety (Velle and Stephenson, 1995), and can even be interpreted as the most important element of the three E's in safety: education, engineering, and enforcement. Both enforce-

ment and engineering are dependent on a good education, and effective implementation is largely influenced by the understanding and appreciation of the reasons for workplace safety. Workers in a safe work environment can derive satisfaction from the fact that it is truly safe, rather than thinking of safety as a matter of them merely tolerating the rules. This kind of culture is also created by effective safety training. All organizations and their safety and health programs have a responsibility to include continuous safety evaluations in every work task and to create safety measures, which may, in some cases, be designated by laws (Velle and Stephenson, 1995).

Studies have demonstrated that there is a need for preventive strategies to avoid injury to individuals in the work environment (Laberge et al., 2014). It is necessary to identify self-regulatory strategies that prevent rule transgressions, in order to create more effective learning methods (Laberge et al., 2014). Preventive safety training programs have further been proven to be essential by being included already in the vocational and professional education. Indeed, individuals do not immediately adopt more effective safety practices when they initially completes the safety training. The safety way of thinking begins its slow process before the first working day and is influenced by family, friends, and other sources, such as the community (Seppala, 1995). Further, safety training programs should be flexible; training program needs to be tailored to each specific site (Cole et al., 1996). Using the literature about safety training for inspiration, the current study focused on safety training that involved typical work situations in vocational programs within the carpentry industry and furniture sector.

Within the wood and furniture sector, safety training plays an essential role in improving safety and reducing accidents (Stuart, 2013). It has been shown that students who have experience with woodworking machines require an adjustment period through practical labs. In contrast, students who do not have experience with machines can be intimidated by practical laboratory work but are nonetheless able to expand their knowledge through e-learning tools (Stuart, 2013). In a study conducted within the construction industry, it was shown that a majority of the contractors who were included in the study used a safety training method that included both external and internal trainers. The methods used were typically discussions, lectures, printed materials, videos, and demonstrations. It was shown that mentors, meaning workers who have more experience, can be paired with less experienced workers to benefit from their experience, which could be beneficial for the safety training of the workers (Goldenhar et al., 2001).

To summarize, the various experiments and the method in present study is based on above presented studies. Previous studies have shown that young workers often get injured at work, and even though training in safety is common, it can often be ineffective (Laberge et al., 2014). It has also been found that there is little written about the nature and quality of safety training available for workers and how the type of training can be related to improved safety at work (Goldenhar et al., 2001). The literature shows that safety training is an important aspect of mitigating safety risks, including the risks inherent to air contaminants (Becker and Morawetz, 2004) and the furniture sector (Stuart, 2013). For effective implementation, it has been proven important that workers understand the reasons for safety (Velle and Stephenson, 1995); additionally, effective safety training should include teaching workers the technical skills necessary to perform duties in a safe and healthy manner (Goldenhar et al., 2001). Indeed, Swedish regulations dictate that individuals in organizations, including students, are entitled to know the various risks in the workplace (The Swedish Work Environment Authority, 2011). These workers or students may also be an important source of information as their knowledge and experience can be valuable for conducting

safety training (see Hilyer et al., 1999; Becker and Morawetz, 2004; Brunette, 2005).

2.2. Attitudes and safety

Previous literature found that employee attitudes towards safety may affect their risk behavior (Rundmo, 2000) and safety behavior (Rundmo and Hale, 2003; Henning et al., 2009). Furthermore, organizational factors and commitment to safety, in addition to attitudes towards safety, may affect risk behavior (Rundmo, 2000) and employee behavior for a safe workplace (Henning et al., 2009). Previous literature also considered the relationship between attitudes towards safety and safety climate and determined that employee attitudes are an important factor in determining the safety climate (Williamson et al., 1997; Isla Diaz and Diaz Cabrera, 1997) and the culture in the workplace. In turn, the perception of a safety climate may also influence attitudes among employees towards safety, and affect how employees interact and perform work tasks, which can have a direct impact on accidents (Neal and Griffin, 2004).

However, attitudes towards safety have also led to various safety interventions (Williamson et al., 1997). In a study that measured the attitudes towards safety on an organizational and national level, individual responsibility, staff skepticism, effectiveness of arrangements for safety, safeness of work environment, and personal immunity were found to be essential factors to survey attitudes (Cox and Cox, 2007). Changes in attitudes towards safety in the workplace have also been related to individual factors, such as fatalism, prevention regulatory focus, agreeableness, and conscientiousness. Aside from conscientiousness, these factors were shown to be valuable in predicting attitudes towards safety (Henning et al., 2009).

Another study indicated that younger people tend to have better attitudes towards safety (Isla Diaz and Diaz Cabrera, 1997). One possible reason for this is that there is a greater degree of adaptation among younger individuals as well as an increased level of faithfulness towards risks (Isla Diaz and Diaz Cabrera, 1997). Attitudes can be understood as evaluative (Arnold, 2005), the way individuals feel about something (Arnold, 2005; Miles and Huberman, 2013). A positive ("ideal") safety attitude includes factors that promote increased safety in the workplace, including positive safety behavior and a decreased number of accidents. In contrast, a negative attitude ("not ideal") produces the opposite in work situations (Rundmo and Hale, 2003). As such, the current study will focus on young people and their attitudes with regard to the following described safety training method and experiments.

3. Method

3.1. Methodological process and educational development

The study was conducted over the period of 1.5 years. The research process included several steps (see Table 1). Upper secondary schools in Sweden were contacted to take part in the study, which examined measures to decrease exposure and assessed the risk of air contaminants together with three researchers. Overall, a total of five Swedish upper secondary school programs directed towards the carpentry industry and furniture sector participated in the study. Two schools were involved in the creation of the training material, which was included in the test study to test and evaluate the QR codes before the safety training material was used in the main study. These first two schools were involved in the process of measuring air contaminants and making videos. In order to identify air contaminant risks and control measures

Table 1
General research and development process and improvements made to QR codes linked to PIMEX videos following the test study.

Research and development process	Improvements made to QR codes linked to PIMEX videos (after test study)
Identify air contaminant risks and control measures at two schools	Use of colored paper
Create PIMEX videos Create QR codes	Increased size of QR codes Inclusion of informational text next to the QR codes
Test study of the QR codes and PIMEX videos at two schools Test study evaluation (after 2–3 weeks)	Inclusion of an informational poster regarding the safety training
Main study: QR codes attached in classrooms at three schools Main study evaluation (after 2–3 weeks)	

to decrease exposure, the PIMEX method, a video exposure monitoring (VEM) system, was used in accordance with Rosén et al. (2005). The PIMEX method involved video filming and measuring air contaminants. Real-time recording was performed with a video camera that was synchronized with the PIMEX2008 software (JBR consulting) to measure air contaminants. Exposure variability and video footage were then analyzed on a computer screen. Air contaminant samples were transported by using a tube from the breathing zone to the instrument, and a measurement signal was sent by telemetry to a receiver. The instruments used were Mini-RAM personal monitor model PDM-3 and TSI DustTrak II. The sample measurements were taken on 0.4 s sampling intervals. Exposure was displayed and analyzed for every work situation. The student, the teacher, and the researcher analyzed and discussed control measures, typical work situations, and risks both before and after the PIMEX measurements were taken. There were 8–12 students in each class, of which 1–3 actively participated in the group discussions and in the development of training material (based on risks and control measures).

From the sampled material of air contaminant risks and control measures for decreased exposure, educational materials were created by editing the PIMEX videos into shorter safety training video sequences. The video sequences included information on the task and how it was to be carried out to avoid air contaminant exposure. The PIMEX2008 software and Camtasia software (Tech Smith Corporation) was used to create the video sequences. The videos were posted on the Internet, and QR codes were created and linked to these videos. The mobile phones were used to scan a QR code, and it was linked to a website where the PIMEX videos were shown. These QR codes were placed near the most commonly used machines in upper secondary schools. According to teachers and students, these machines were considered to be the most commonly used (see Fig. 1).

After the QR codes and PIMEX videos were created, the test study was conducted with the purpose of developing the safety training material for the main study. Four upper secondary school students were interviewed to provide feedback for possible improvements of the safety training material before it was ready to be used in the main study.

After the test study, some improvements were made. The feedback received was used to make QR codes more visible and attractive (see Table 1). The QR codes, which were black and measured about 4 × 4 cm, were printed and laminated on green A4 paper. A short informational text on the QR codes that described the work task was also provided, and an informational poster was placed in the classroom at a central position chosen by the teacher. The

informational poster included information about the project, the QR codes, and PIMEX videos. Information about the website where each PIMEX video could be seen was also included in the poster.

Three schools were included in the main study, with 7–13 students in each class. The teacher asked every student if they wanted to participate in the interviews. There were five participants from one school, and six participants from the two additional schools. Before the QR codes were attached in the classroom, the teacher briefly introduced the process of how to use the QR codes to view the PIMEX videos. The students were able to use their mobile phone cameras to capture the QR codes and link to every specific PIMEX sequence that demonstrates air contaminant risks and control measures to decrease air contaminant exposure. Two to three weeks after the QR codes were attached to machines, the interviews were conducted, transcribed, analyzed, and coded as further described below.

3.2. Interviews and analysis of students' attitudes

After three weeks, the students' attitudes towards safety and the use of QR codes linked to PIMEX videos were evaluated with 17 telephone interviews. These semi-structured interviews were performed with an interview template and lasted between 12 and 22 min. The template had four themes: work environment (5 questions), QR codes in general and as linked to PIMEX videos as a safety training tool (10 questions), mobile phones as a safety training tool (6 questions), and work environment safety training in general (2 questions).

The interviews were analyzed through the coding of statements regarding students' attitudes towards the safety training. Drawing inspiration from the definition of values coding and descriptive coding provided by Miles and Huberman (2013), the interviews were transcribed and coded. Values coding is a way of identifying and coding attitudes, values, or beliefs, which draws from personal knowledge and experience. The transcription and coding was performed continuously following the interviews. Descriptive coding labels were used to summarize the essential topics in a paragraph (Miles and Huberman, 2013).

Different statements concerning woodworking students' attitudes about QR codes linked to PIMEX videos were coded into six themes. When more than one statement had been included that related to same topic, it was coded into a theme. The themes were: (1) positive attitudes, (2) motivation to improve work environment, (3) knowledge development, (4) negative attitudes, (5) possible improvements to the use of QR codes linked to PIMEX videos, (6) did not know what QR codes meant before the safety training, and (7) knowledge of what QR codes was perceived as prior to safety training. The coding process analyzed student attitudes according to these themes. For example if students indicate that they had learned something about the QR codes by stating, "I saw that you should avoid compressed air or else you get highly exposed to dust," the statement was segmented into the "knowledge development" theme. The evaluation of the statements consisted of an objective assessment of how the statements indicated that the safety training method could be used to control and, therefore, decrease air contaminants.

4. Results

A majority of the statements indicated positive attitudes about the linking of QR codes to PIMEX videos and about the mobile phone as a training device. Most of the respondents stated that they knew what QR codes were prior to the safety training, and that their knowledge about how to decrease air contaminants in the workplace developed following the safety training (see Table 2).

Fig. 1. Example of a QR code linking to a PIMEX video.

Table 2
Values and approach of the safety training method QR codes linked to PIMEX videos presented as themes in student responses.

Themes	Number of respondents that made statements	Minimum number of statements	Maximum number of statements	Sum of statements
Positive attitudes to QR codes	14	1	16	61
Negative attitudes to QR codes	6	1	4	13
Did not know what QR codes meant before the safety training	2	1	1	2
Knowledge of what QR codes was perceived as prior to safety training	15	1	1	15
Motivation to improve work environment	7	1	5	15
Knowledge development	15	1	9	54
Possible improvements to the use of QR codes linked to PIMEX videos	11	1	5	26

The left-most column, "Number of respondents that made statements," shows how many students had comments about the theme. For instance, 11 students made statements regarding how the QR codes linked to PIMEX videos could be further developed, and there were 26 statements in total by all respondents, with a minimum of one and a maximum of five statements in one interview in this theme.

4.1. Positive attitudes to QR codes linked to PIMEX videos

The positive attitudes reflected in the responses indicated that, in general, QR codes were a quick method to disseminate knowledge in the woodworking classroom. In general, there were more positive than negative statement about the linking of QR codes to PIMEX videos. For example, the majority of the positive statements indicated that QR codes linked to PIMEX videos were good, smart, or effective.

We thought it was pretty good and smart in class, we did not know before how the wood dust could be avoided ... and good so you do not get exposed to a lot of wood dust and such ... it affects how you hold the wood board when cutting the length and width (Student 2).

This safety training method was described as effective because it was easy to simply read the QR codes with a mobile phone. Additionally, students specifically discussed improvements after they watched the videos, and one student stated that it would be beneficial to make use of QR codes in other educational subjects at school. The safety training was further described as an important control measure because workers will be reminded about exposure to wood dust. Another student described that the use of QR codes linked to PIMEX videos is important because these videos can increase awareness. Several students commented on the fact that they were given different work situations with exposure visualized in videos, and that they found it useful in the development of methods for controlling air contaminants. Two categories received more frequent positive responses than others. These categories were increased knowledge from the safety training as well as motivation and inspiration to improve the work environment. The latter is further described below.

4.1.1. Motivation and inspiration to improve the work environment

Some students' attitudes indicated that they had been motivated by how the safety training can inspire changes in safety behavior. This means that the respondents indicated that they saw the risks, and that these risks inspired them to develop an interest in gaining a greater understanding of air contaminants and how to control exposure to them.

Yes, when you saw how much dust you were exposed to, you became interested and wanted to check out more. .. just to see it for yourself, and how much you are exposed to in just a few seconds, then it gets interesting, and then you want to see how it affects you, how fast it goes, and you want to see more and more ... it was an eye-opener ... you have got to think about how to work, it affects you in the future (Student 7).

The evidence of air contaminant exposure in different work situations and the fact that individuals are subjected to exposure clarified the risks to students, who expressed this as the inspiration for changes in work behavior regarding safety. It was also mentioned that the training knowledge was both easy to access and interesting to learn.

4.1.2. Knowledge development from QR codes linked to PIMEX videos

A majority of the respondents had general positive attitudes that also included examples of how the safety training could work
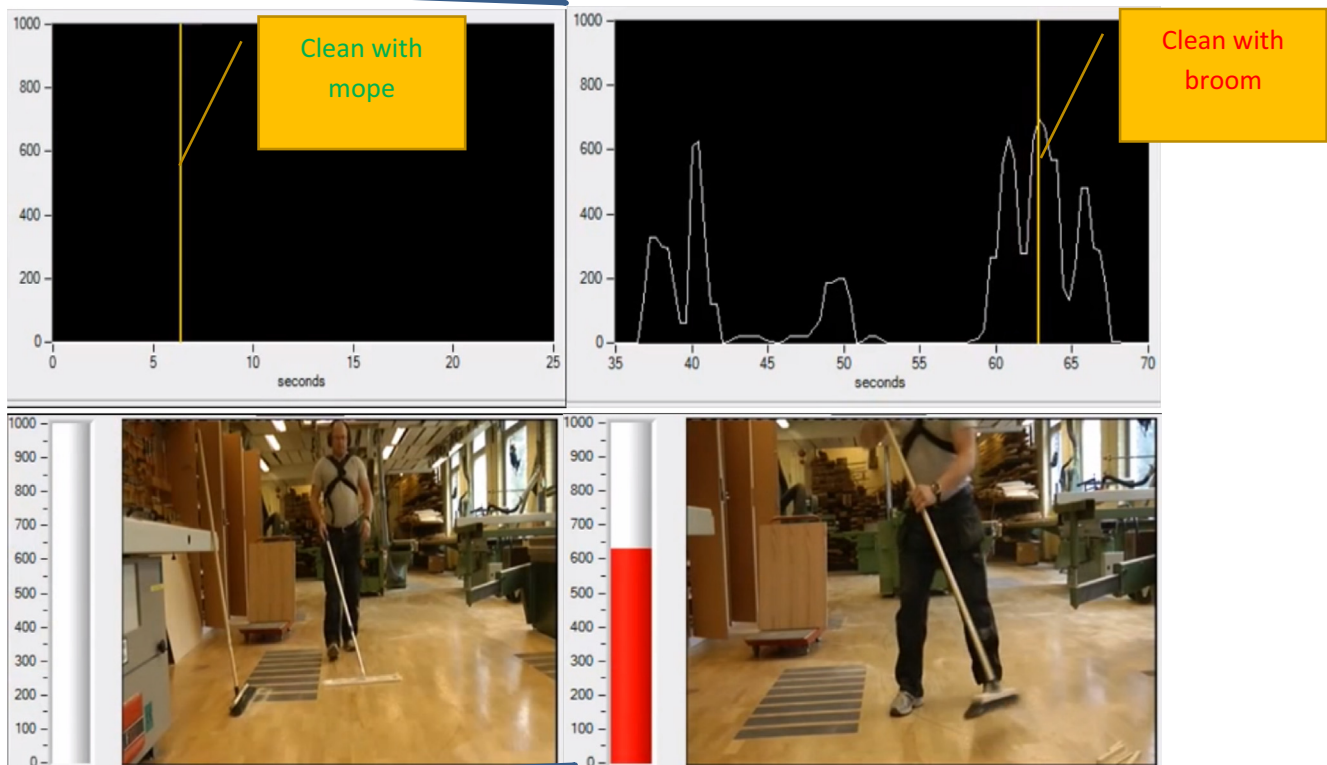
to reduce the exposure to air contaminants. In these responses, it was stated that the safety training was a positive, communicative, and informational tool for knowledge development about safety in the future. The respondents also described the information from the videos as very clear in terms of improving the work environment. Another common statement was that the safety training were described as positive by students' friends, and that it was a useful method of communicating information.

I think it's a great way to get information out … it feels like a good tool to train students … for example, the video of which he stood and cleaned the machines, one might think more about brushing or vacuuming now. .. Yes, most students have been positive … I believe it could be a great asset, with the cell phone, for example, with QR codes in the future (Student 1).

Other comments were that QR codes were easy to read and aided in the development of knowledge regarding air contaminant exposure (see Fig. 2). The responses also indicated that they were beneficial as a pedagogical complement to tasks that were formulated by the teacher.

Further, more separate comments were spoken of about knowledge development related to safety training. One respondent thought that it was easier and more interesting to use QR codes compared to ordinary lectures when it came to develop knowledge. Another respondent felt that it was a good idea these days to use cell phones in the classroom. This was confirmed by another student who thought cell phones were a better technology than computers when it came to knowledge development. The use of cell phones as a safety training device may, however, encounter some challenges as further described below.

Fig. 2. Video examples related to student statements.

Table 3
Positive aspects related to the method of QR codes linked to PIMEX videos.

Safety technology use and pedagogy	Effectivity of safety training method	Knowledge, attitudes and awareness increase
Mobile use	No books are needed	Awareness of wood dust risks
QR-code use	Immediate and quick safety training directly related to work task	Awareness of how to use work tools to decrease wood dust exposure
Videos use visualizing wood dust exposure	Adapted for a young target group	How to practice work tasks to PIMEX decrease wood dust exposure
Clear and distinct tool to communicate safety information	Easy accessible safety training	Motivation or attitude change to work safely in order to reduce air contaminants
Creates conditions for future safety training methods		

4.2. Possible improvements to the use of QR Codes linked to PIMEX videos

Few respondents exhibited negative attitudes; consequently, there were more statements about possible improvement of QR codes linked to PIMEX videos. A majority of negative comments cited bad internet connections or the desire for better information about QR codes related to PIMEX videos.

When there is no internet access on the mobile, it will be difficult for you to get ahold of the safety training information after school ... We're having WIFI at school but it has though been a bit difficult for us students to get into the WIFI at school ... some can connect and others cannot (Student 1)

Other more rare negative comments were related to the classroom context. The respondents explained that students could tear down the QR codes or that they would use the cell phone for other non-learning activities.

Further, several respondents had constructive comments about how to improve the knowledge development process of QR codes linked to PIMEX videos. They mentioned that something inspiring could be written or visualized with pictures next to the QR codes. This could, according to the respondents, eventually create additional interest in or the motivation to use the QR codes and PIMEX videos. Additional information could also be provided next to the QR codes. For instance, text or a picture describing exposure to air contaminants or the importance of health could appear next to the QR codes. There was also the comment that someone who knows about the videos other than the teacher could inform others about how the QR codes and PIMEX videos worked, and that this would create additional interest.

5. Discussion and conclusions

This study has focused on safety training using QR codes linked to PIMEX videos for a woodworking program in upper secondary schools. The interview responses showed generally that QR codes linked to PIMEX videos can improve knowledge about the work environment. This is in agreement with prior research that has found that QR codes can stimulate knowledge (Chen et al., 2011; Yao, 2011; Huang et al., 2012; Lynch et al., 2012), and that the PIMEX method has positive training characteristics, for instance by spreading knowledge and risk communication (Rosén et al., 2005). The vocational student group was trained in practices showing risks and control measures to avoid air contaminants. Their attitudes were shown in interviews where 14 students out of 17 responded positively towards the safety training, and 15 felt that their knowledge increased. This indicates that by increasing students' awareness of risks and control measures, the method can be used to control wood dust in the work environment. In addition, attitudes to safety has been shown to be important to determine

because it affects risk behavior (Rundmo, 2000), and safety behavior (Rundmo and Hale, 2003; Henning et al., 2009).

The study also demonstrated that the students can be self-motivated and sufficiently curious to test the QR codes and to find an alternative way of working to reduce air contaminants. However, more research is necessary to optimize this method and ensure efficiency both in industries and upper secondary schools (see Table 3).

These findings, that the safety training method of using QR codes to link to PIMEX videos led to knowledge development and elicited positive attitudes towards safety, is both supportive of, and contradictory towards, the earlier literature. Previous studies have shown that safety training videos can provide a positive effect on safety within organizations. The current studies revealed safety training interventions that involved dialogue, behavioral modeling, practice (Burke et al., 2006), and informational meetings within organizations about inter alia safety solutions to problems (Farina et al., 2014) to be efficient. The study by Burke et al. (2006) supports the idea that videos can be an effective safety training method, and that they can increase knowledge (Lynch et al., 2012). It remains unanswered, however, whether the method of using PIMEX videos that are linked via QR codes by the mobile phone or iPad is more effective than regular videos. The current study could also be developed further by, for example, including more participation or dialogue in the ongoing training. This may be an important area for future research. Safety training can have the advantage of being interactive (Goldenhar et al., 2001; Williams et al., 2010) and experimental (Goldenhar et al., 2001). More interactive methods could involve dividing workers into groups, to in current study analyze facts about how to control air contaminants and solve problems, which may include workers' own experiences (Williams et al., 2010).

The safety training method of using PIMEX videos linked by QR codes is to some extent experimental, but it could be more interactive in the safety training phase of the intervention process. One practical suggestion is, therefore, to incorporate some interactive and experimental practices by adding a task during safety training for the students, which would be followed by teacher feedback. A majority of the students also described the practical teaching and tutorial to be important. The task can, for instance, involve questions related to the videos showing risks and measures to avoid air contaminants in the workplace, which goes along with the idea that practice and feedback are essential for developing skills (Eraut, 2004).

Further, development of the safety training method was the third most commented upon theme, with 26 statements (see Table 2). These statements show an opportunity for further research using, for instance, more frequently obtained information for the target group regarding the safety training as in a similar study by Kaner et al. (1999). Students were given information both before the QR codes were attached to the machines as well as by an informational poster. However, it was stated by the students that it is important to avoid confusion with information, and that an

individual that worked at the university could provide context for the use of QR codes. Nevertheless, most students were satisfied with the information they had received from the videos. In general, to avoid misunderstandings, more informational posters could have possibly been placed in the classroom. More informational briefings by the teacher could also have been given regarding the PIMEX videos and QR codes. The importance of air contaminants could also be emphasized through pictures next to the QR codes, as a few students suggested.

Since the students were tested after three weeks, long-term knowledge retention cannot be determined. However, among the 14 students who had positive statements, clear examples indicated how they intended to work and had worked since their participation in the safety training. For instance, students stated that they now try to avoid the use of compressed air and use instead vacuum cleaners to prevent air contaminants when cleaning.

The present study confirms that QR codes can be a time- and cost-effective method, since the QR codes were easy and inexpensive to mail, implement, and use in the classroom, as the earlier literature also found (Price, 2013). Organizations with air contaminant risks could benefit from this. Additionally, upper secondary school woodworking students are an interesting target group for present intervention. They are the future employees of the woodworking industry and can bring their knowledge about preventing air contaminants into the industry. As such, safety training has been shown to be important for students to prepare them for future work situations. Some contributions of this study are highlighted below.

– First, the intervention method of using QR codes linked to PIMEX videos improves upper secondary school students' safety knowledge and motivates them to improve their work environments.
– Second, QR codes linked to PIMEX videos were previously an unobserved area of research within work environment studies.
– Third, it is difficult to motivate employers to actually implement measures to improve the work environment in Sweden (see Andersson et al., 2006), because of issues like lack of time or finances with QR codes, both time and economy can be saved. This makes industrial settings favorable for future studies implementing QR codes linked to PIMEX videos.
– Fourth, a method to prevent negative impacts to health among individuals working in air contaminant contexts was developed (see Rosén et al., 2005).
– Fifth, a website has been developed that can be used by various organizations, such as schools and industries. The video training material can be downloaded on the website www.du.se/pimexfilm.

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