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Pedagogical Diplomacy

Noise Monitoring in the School Metal Workshop

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Abstract

The study deals with the issue of noise in the school facility, in the school metal workshop, its measurement and evaluation of the results. The purpose of the carried-out study was to monitor and assess the conditions in which the students learn and work there and point out the shortcomings concerning noise's impact on human health. At the same time, the study aimed to optimise the workplace or workshop by legal regulations. Based on the monitoring results, several critical places were found where the limits were exceeded. A 3D noise propagation model modelled according to the measured results was created, allowing us to understand noise propagation better. Finally, the conducted study resulted in suggestions for improving the working conditions in the monitored school facility and for increased safety and health protection of students at work.

Keywords: Noise, Measurement, Metalworking workshop, Software visualisation, Noise load

1 Introduction

In daily life, we face different kinds of, like speech, music, and natural sounds. However, noise, defined as unwanted sounds, adversely affects human health. The World Health Organization defines human health as not just for lack of health but also physical, mental, and social well-being and happiness (Demirkale, 2016). Noise is an unpleasant, commonly loud sound to which workers in manufacturing and other industries worldwide are exposed daily. However, it can also be found in schools (Sajin et al., 2019, pp. 80 – 97), (Xie et al., 2011, pp. 551 – 555), (Vilcekova et al., 2017, p. 120, 29 – 40), traffic (Wang et al., 2017), bars, orchestras, and personal music players (Argalasova et al., 2016, pp. 535 – 541). For workers exposed to noise,

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it is important to follow the noise levels at their workplace regularly to evaluate the level of risk for hearing losses and damages and, accordingly, take measures for managing or preventing risks. Noise in the working environment and particular workplaces presents several risks for employers, either by direct effects such as hearing loss and possible deafness by the time of retirement or by extra-aural effects from long-term noise exposure, resulting in psychical problems, harmful effects on the autonomous nerve system, cardiovascular system or the organism in general (Vujica et al., 2020). Globally, about 16% of disabling hearing loss in adults is due to occupational-related noise (Mohamed, 2017).

Noise in the working environment of the school's metalworking workshop can disturb students and hurt their concentration; also, it can be a potential risk threatening their health. The main goal of the presented case study was to process the objectification of noise in the school's metalworking workshop and to compare the achieved results with legislative limit values. Based on comparing the measured values with the limit values determined by the Slovakian legislation, noise reduction solutions were proposed to achieve an effective acoustic design and ensure the control of noise hazards when working on machinery.

2 Description of the Monitored Space and the Noise Monitoring Method

2.1 Characteristics of the Monitored Area

The object for which a case study was carried out to objectify noise in its environment was a school metalworking workshop located in the Nitra region. The secondary vocational-technical school focuses on mechanical engineering and mainly on producing, assembling, and repairing devices and machines, including machinery repair. In the practical part of the curriculum, students spend most of their time in the metalworking workshop, which is the subject of a case study. In the monitored workshop, various practical activities related to mechanical and manual work, including the operation of machinery, are carried out. The graphic diagram of the room's floor plan was processed using AUTOCAD software, with precisely defined dimensions of the workshop space.

The school's metalworking workshop has the following dimensions: length 6.31 m x width 4.49 m x height 2.98 m^2. The workshop contains one double-wing door marked D1, and one single-wing door marked D2, which are marked on the project view of the workshop Fig. 1. Dimensions of single-wing door (D2): 0.89 x 2 m and double-wing door (D1): width 2 x (0.89 x 2 m). The workshop is equipped with natural ventilation through six window openings. The dimensions of the window (O1) are: width 0.71 m and height 1.94 m, and the dimensions of the window (O2) are: width 1.94 m and height 1.94 m. The layout shop and the metalworking machines are shown in Figure 1-5. The layout of the machines is shown in the project representation of the metalworking workshop in Fig. 6.

Fig. 1: Lathe type C8C universal


Fig. 2: Bench drill type FA-13


Fig. 3: Grinder TM2BR

Fig. 4: Vertical milling machine type FUS-22


Fig. 5: Stand drill type FO-20

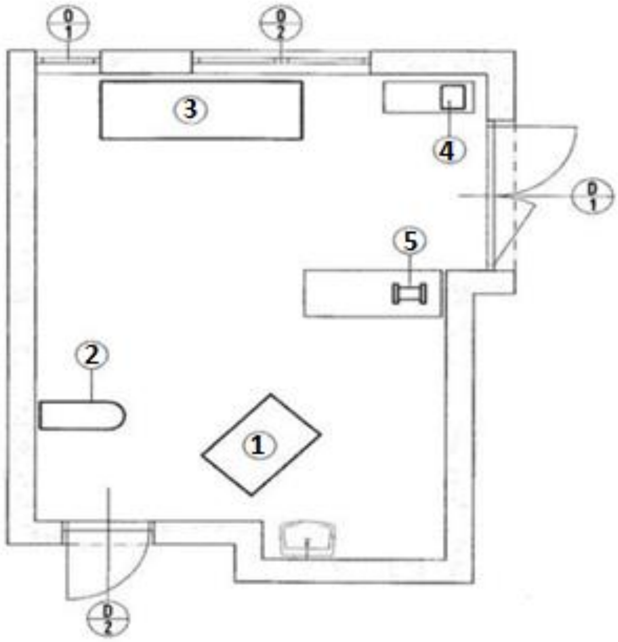

Fig. 6: Project representation of the layout of the machines (VAS et al., 2005). 1 Vertical milling machine type FUS-22; 2 stand drill type FO-203; 3 lathe type C8C universal; 4 bench drill type FA-13; 5 grinder type designation TM2BR

Using the ultrasonic laser distance measurer MEASURE LASER, we determined the measurement points for noise measurements depending on the location of the metalworking machines. Determination of the measurement points depends on the machine and the student who performs the work on the metalworking machine. The height of the measuring points was 1.5 m to 1.6 m above the floor surface at the zone near the students' hearing organs. The measurement locations are marked in Fig. 7 and indicate the student's position when operating the machine.

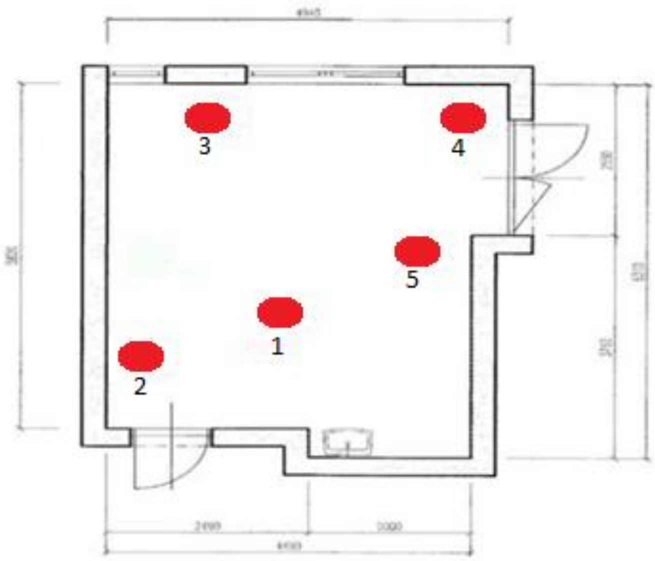

Fig. 7: Places of performed measurements

In the first step, we created a floor plan of the monitored space with the exact dimensions of the walls. Using the SKETCH UP software, a 3D model of the monitored space was modelled according to the entered input values, which are shown in Fig. 8.

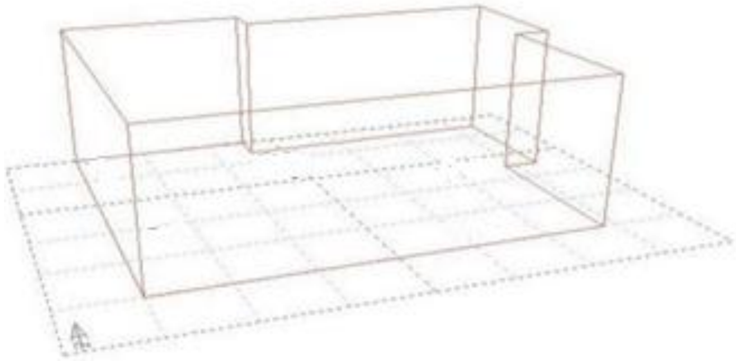

Fig. 8: 3D model of the monitored space

The room model was flipped into the ECOTECT ANALYSIS software, which allowed observing the propagation and reflections of noise in the given space, shown in the following Fig. 10, 12, 14, 16,18.

2.2 Measurement of Monitored Quantities

The TESTO 816-1 device was used for noise measurement. The basic parameters of the device are listed in Table 1. The dimensions of the monitored space for more accurate results were measured using an ultrasonic laser distance meter MEASURE LASER.
Table 2 shows the basic technical parameters.

Memory	31,000 measurements
Operating temperature	0 to +40°C
Weight	390g
Dimensions	272 x 83 x 42 mm
Battery type	4x AA battery
Measuring range	30 to 130 dB
Accuracy	± 1.4 dB
Resolution	0 Hz to 8 kHz

Table 1: Technical parameters of the TESTO 816-1 sound meter

Measured units	Meters/feet
Operating temperature	0 to +43°C
Max – min range	0.45 m to 17 m
Dimensions	150 x 70 x 30 mm
Battery type	9V alkaline battery
Operating frequency	40kHz
Accuracy	±0.5%
Resolution	two decimal places, e.g., 1.11 m

Table 2: Technical parameters of the ultrasonic laser distance meter MEASURE LASER

Sound intensity level

From a physical point of view, the decibel is a dimensionless scale that expresses the ratio of two values. Noise intensity **I** and sound intensity level **L** are expressed on a logarithmic scale by the relation:

$$L_1 = 10 \log (I/I_0) \quad (1)$$

I_0= hearing threshold intensity (10 – 12 W.m^{-2}).

The formula for calculating sound pressure (dB)

$$L_p = 20 \log (p/p_0) \quad (2)$$

p = acoustic pressure of the measured sound (Pa)
p_0= sound pressure corresponding to hearing pressure = 2.10^{-5} Pa
L_p= 0 dB = hearing threshold
L_p = 140 dB = pain threshold.

As the noise measurement was carried out on the machines and facilities in the case study design, the individual machines were first started up individually and then simultaneously in order to record the synergistic effect of the overall noise level. The measurement was carried out so that the noise spread to the zone of the following machine was recorded, the zone where the student or teacher performs work. This state represents a situation that can, with high probability, occur during practical teaching.

The measurement was carried out in the time from 9:00 a.m. to 3:00 p.m. Five students worked in the metalworking workshop, working individually on machinery (milling machine, stand drill, lathe, bench drill, two-disc grinder).

3 Results of individual measurements and their discussion

The first measured data was the noise in the metalworking workshop without the machinery turned on. This value was 33.9 dB. Subsequently, measurements were carried out for individual machines in designated locations. At the same time, modelling identified zones of noise propagation in the space, that is, places where students and teachers may be exposed to excessive noise from running equipment during work.

3.1 Noise measurement at the milling machine

The measurement was carried out at the maximum speed of the cutter, 1800 revolutions per minute (Instructions for the device vertical cutter FUS-22). The average value for the cutter (point 1) was 80.21 dB (Table 3). Suppose a student was to work in a work environment for 8 hours with a milling cutter. In that case, it is more than likely that the value of 80 dB will be exceeded, which we include in the IV group of work, which includes noisy machines and tools or activities performed in a noisy environment. Based on the above, we can conclude that this device does not meet the conditions of noise in the working environment. It is recommended that the necessary safety precautions must be taken on this device.

Measurement point	Noise measurement number (dB)							Average
	1	2	3	4	5	6	7	
Point 1	**79.8**	**79.9**	**80.1**	**80.2**	**80.5**	**80.3**	**80.7**	**80.21**
Point 2	71.8	71.8	78.1	78.8	79.1	79.5	79.7	**76.97**
Point 3	77.5	77.7	77.4	77.4	77.7	77.5	77.6	**77.54**
Point 4	77.3	77.4	77.6	76.9	77.0	77.2	77.1	**77.21**
Point 5	77.1	77.1	78.5	76.0	76.9	77.6	77.3	**77.21**

Table 3: Noise measurement at milling machines in the surrounding control points at the machines

Figure 9 shows measurements in individual locations with the cutter turned on.

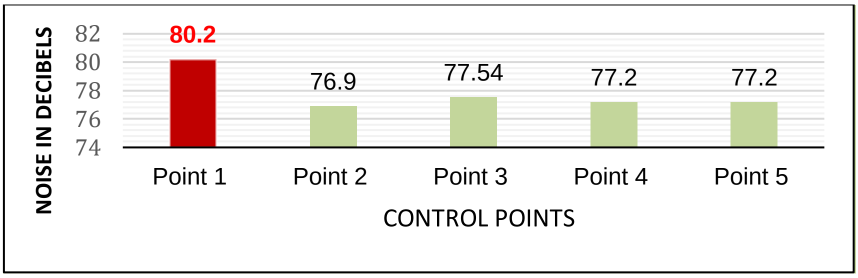

Fig. 9: Noise values measured at control points – point 1 when the cutter is running

The visualisation of sound propagation and its reflection in the Ecotect Analysis program is shown in Fig. 10. The 3D model of the room shows possible noise propagation at the height of 1.5 – 1.6 m from the mill.

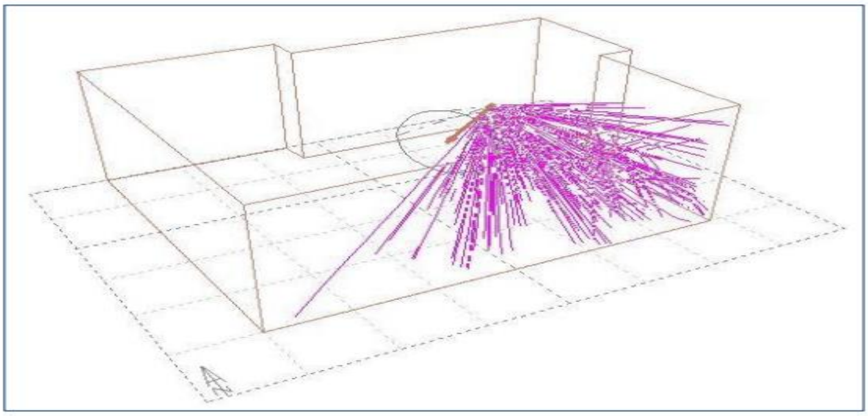

Fig. 10: 3D visualization of the noise propagation direction for the cutter

Sound reflections are reflected in a specific part of the room where the standing drill is placed. The employee or the student who will operate the standing drill was in a space where the noise was reflected and spread. Appropriate measures must be implemented so that the noise exposure of the equipment operator is maximally reduced by organisational measures or by assigning effective personal protective work equipment.

3.2 Noise Measurement at a Stand Drill

The measurement was carried out at a maximum of 2000 revolutions per minute of the device (Instructions for the grinder TM 2 BR B150). The results of the noise measurement for the standing drill (point 2) are shown in Table 4. The average noise value when working on the standing drill was 73,14 dB. If the student worked in the work environment for 8 hours, it is more than likely that the equipment met the requirements of the standardised sound level for the IV group of work and activities in a noisy environment, the value of which is less than 80 dB.

Measurement point	Noise measurement number (dB)							AVERAGE
	1	2	3	4	5	6	7	
Point 1	68.5	68.2	68.3	68.2	67.9	68.1	67.4	**68.08**
Point 2	71.1	68.1	70.3	74.5	75.7	76.2	76.1	**73.14**
Point 3	65.3	64.7	67.4	62.8	67.0	66.5	66.2	**65.70**
Point 4	66.3	65.7	65.5	66.8	66.4	66.7	64.6	**66.00**
Point 5	65.1	63.9	63.3	66.7	64.5	65.1	66.2	**64.97**

Table 4: Measurement of the noise of the standing drill and in the surrounding control points at the machines

Figure 11 shows the measurements in individual stations with the standing drill turned on.

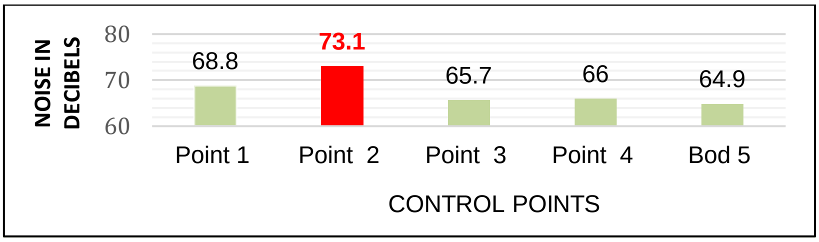

Fig. 11: Noise values measured at control points – point 2 at the standing drill

During the operation of the standing drill, it is possible to see sound reflections in different directions. Since the standing drill was stored against two walls, sound reflections bounced off in two directions. One towards the student who operates the stand drill, but also towards the student who operates the milling machine (Figure 12).

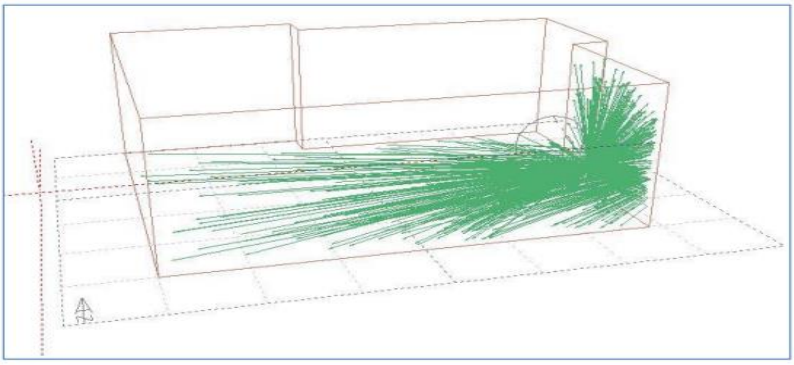

Fig. 12: 3D visualisation of the direction of noise propagation for a stand drill

3.3 Noise measurement at the lathe

The measurement was made at the maximum 1800 revolutions per minute (Bakič, n.d.) of the lathe (point 3) and at the other four control points. The average value at the lathe was 76.01 dB. The results of the noise measurement are shown in Table 5. During an 8-hour work on the lathe, it is highly likely that the equipment meets the requirements of the standardised sound level A of the IV group of work and activity in a noisy environment, the value of which is less than 80 dB.

Measurement point		Noise measurement number (dB)							AVERAGE
		1	2	3	4	5	6	7	
Point 1		72.6	73.4	73.2	75.1	74.5	75.2	75.0	**74.14**
Point 2		74.0	74.8	73.0	72.9	73.1	73.3	72.8	**73.41**
Point 3		75.4	76.4	76.0	76.1	75.3	75.7	77.2	**76.01**
Point 4		73.6	72.6	72.4	73.1	72.6	73.0	73.1	**72.91**
Point 5		73.8	73.9	72.8	74.5	72.9	73.8	73.7	**73.60**

Table 5: Noise measurement at the lathe and in the surrounding control points for other machines

Figure 13 shows the result of measurements in individual locations with the lathe turned on.

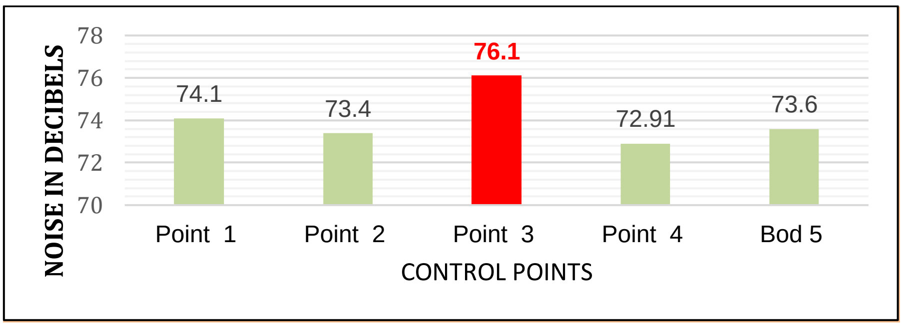

Fig.13: Noise values measured at control points – point 3 when the lathe is running

In the case of a lathe, whose 3D model shows sound propagation at a height of 1.5-1.6 m, the sound spreads to the entire environment of the space (Figure 14). When the lathe is started, the sound waves will hit all the machinery, with a high probability also the teachers and students in the workshop who are working on the machinery. Some of the sound waves are reflected from the front wall and return to the middle of the room, but as the model shows, the noise is reflected in the centre of the room and from the side walls, it is piled up to the centre of the room.

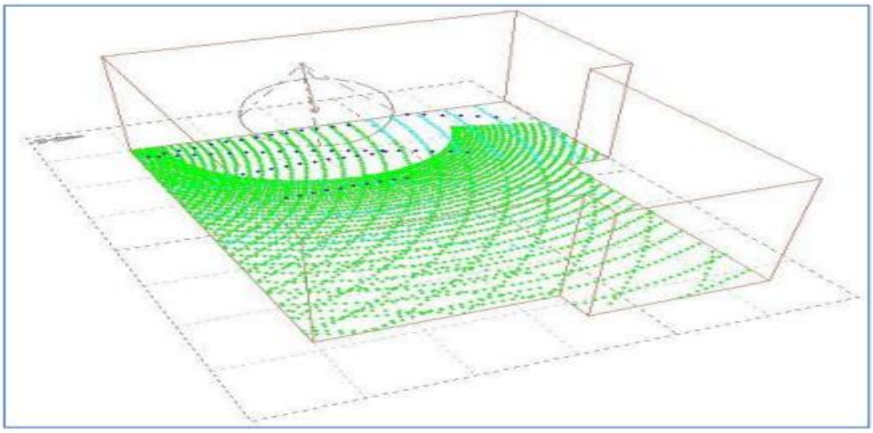

Fig. 14: 3D visualisation of the direction of noise propagation for a lathe

3.4 Noise Measurement with a Bench drill

The measurement took place at a maximum of 1800 revolutions per minute (Instructions for the device table drill FO-20) of the drill, where the average value at point 4 (for the table drill) was 70.20 dB. The results of the noise measurement are presented in Table 6. Based on the above, we can conclude that this device does not exceed the limit values for noise in the working environment. This means that even with an 8-hour exposure while working with a table drill, the normalised sound level A of group IV work and activity in a noisy environment would not be exceeded since the value is less than 80 dB.

Measurement point	Noise measurement number (dB)							AVERAGE
	1	2	3	4	5	6	7	
Point 1	61.3	63.6	63.5	65.4	65.8	67.9	65.4	**64.70**
Point 2	60.2	62.8	92.8	62.7	63.3	66.2	64.8	**67.54**
Point 3	61.8	60.0	61.9	65.0	62.8	67.1	64.1	**63.24**
Point 4	69.5	68.4	69.1	70.0	70.2	73.9	70.3	**70.20**
Point 5	63.7	63.2	63.6	63.4	63.9	67.0	64.2	**64.14**

Table 6: Measuring the noise of the bench drill and in the surrounding control points for other machines

Figure 15 shows the result of measurements in individual locations with the table drill turned on.

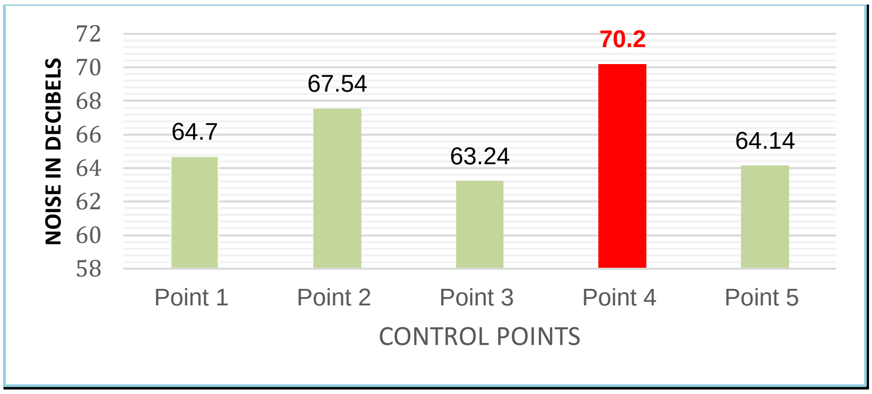

Fig. 15: Noise values measured at control points – point 4 with the table drill running

The 3D model shows the sound reflections for the bench drill (Figure 16). The location of the equipment and the propagation of noise confirm that the operator of the surrounding equipment is significantly exposed to the noise of the bench drill. The lathe and stand drill employees will be the most exposed; those who operate the milling machine and table drill will be less exposed to excessive noise.

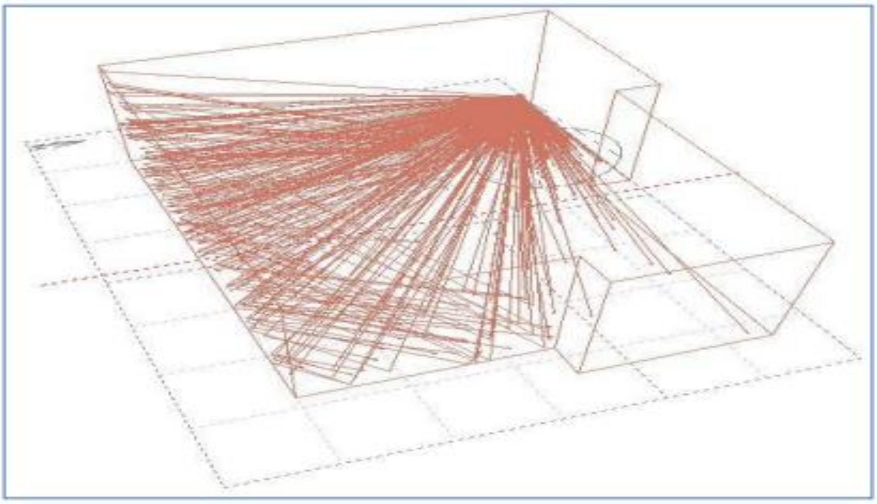

Fig. 16: 3D visualisation of the direction of noise propagation for a bench drill

3.5 Noise Measurement at a Double-disc grinder

The measurement was carried out at a maximum speed of 2840 revolutions per minute of a two-disc grinder (Instructions for the device sander TM 2BR B150). The average measured noise value at point 5 (double-disc sander) was 81,62. The measurement results are shown in Table 7. We can conclude that this device would not meet the conditions for noise; it is highly probable that if the employee, i.e., the student, worked on this equipment for 8 hours, the values of the normalised sound level A of the IV group of work and activities in a noisy environment would have been exceeded, as the value of 80 dB was exceeded. This equipment also requires increased protection of employees, and it is necessary to prioritise the protection of the health of employees from exposure to excessive noise.

Measurement point	Noise measurement number (dB)							AVERAGE
	1	2	3	4	5	6	7	
Point 1	80.2	77.6	77.8	76.2	73.9	78.1	78.3	**77.44**
Point 2	79.0	74.7	74.2	77.5	75.0	77.3	78.2	**76.55**
Point 3	78.3	73.1	72.0	72.4	71.1	79.6	73.9	**74.34**
Point 4	80.9	76.7	74.0	73.8	75.3	79.8	73.9	**76.34**
Point 5	83.5	81.1	79.9	80.3	80.5	83.6	82.5	**81.62**

Table 7: Measurement of the noise of the double-disc grinder in the surrounding control points

Figure 17 shows the measured noise levels at individual stations when the two-disc grinder is switched on.

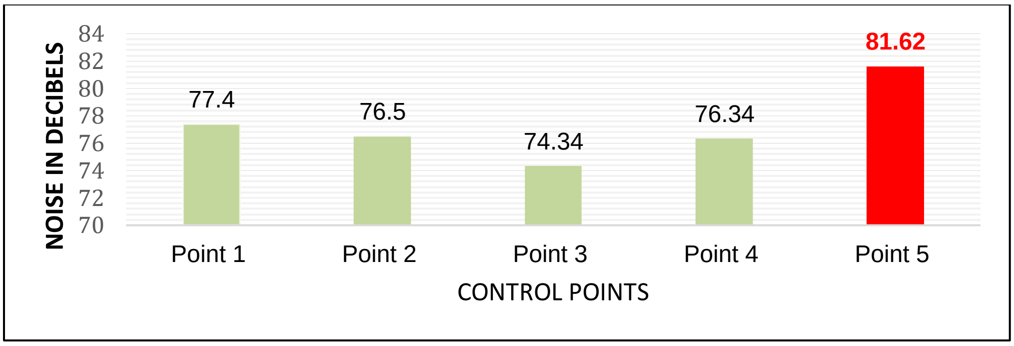

Fig. 17: Noise values measured at control points – point 5 with the double disc grinder running

The 3D model shows the noise reflections of the grinder (Figure 18). The highest noise exposure will be for the operator of the milling machine and the stand drill. Less reflected sound waves spread into the space near the lathe and table drill stations.

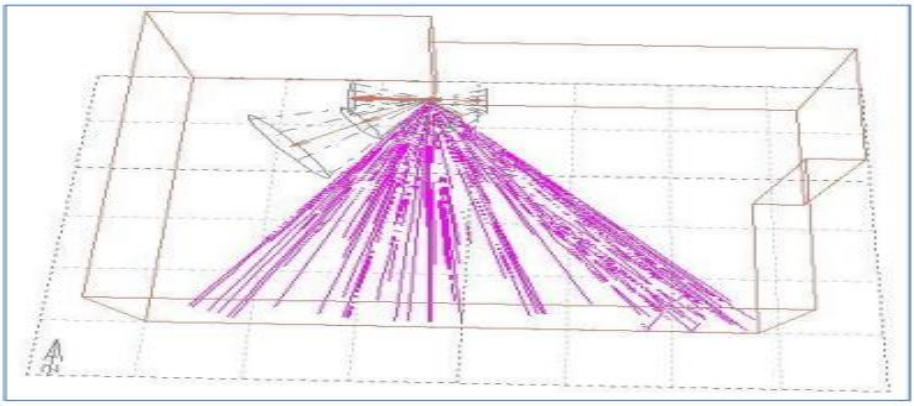

Fig. 18: 3D visualization of the direction of noise propagation for a two-disc grinder

3.6 Measuring the Synergistic Effect of Machine Noise

The measurement was made with all machines running simultaneously. The smallest average value of 81.1 was in point 4 (with a table drill), and the highest average value recorded was 83,2 in point 5 (with a double-disc grinder). The results of measuring the synergistic effect of the machines in the workshop are shown in Table 6. We can conclude that during an 8-hour exposure of students in the workshop with all five devices running at the same time, the values of the normalised level and sound of the IV group of works and activities in a noisy environment would be exceeded because the limit value of 80 dB was exceeded.

Measurement point	Noise measurement number (dB)							AVERAGE
	1	2	3	4	5	6	7	
Point 1	81.3	81.7	82.3	82.1	82.7	82.6	82.4	**82.15**
Point 2	81.4	81.0	81.2	81.8	82.3	84.7	83.2	**82.22**
Point 3	80.9	81.1	80.9	81.0	81.5	83.9	82.7	**81.71**
Point 4	80.7	80.2	80.3	80.8	80.4	83.3	82.0	**81.10**
Point 5	83.0	81.7	82.5	84.5	81.9	85.1	83.8	**83.21**

Table 8: Noise measurement at control points when all operating machines are switched on

Figure 19 shows the measured noise levels at individual stations with all machines in the workshop turned on.

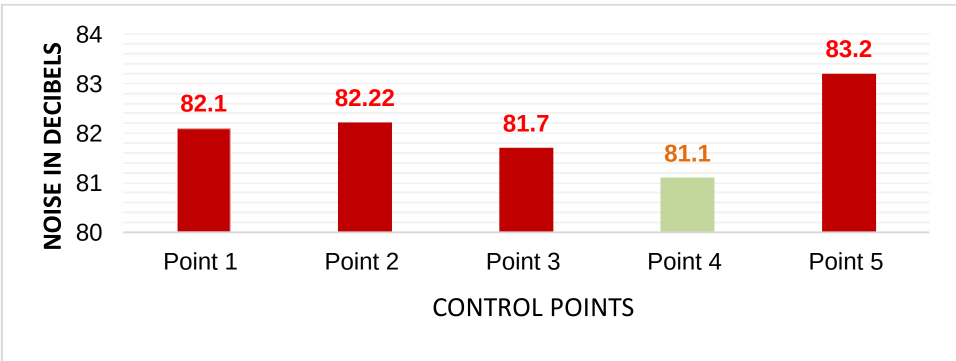

Fig. 19: Noise values measured at all control points with fully operating machines

4 Discussion

The measurements showed that the sound level is above 80 dB, which means exceeding the limit values for pupils and teachers in the workshop. Measures must be taken to reduce noise pollution. The measures would be of a technical and organisational nature.
Vas et al. (2005) claim that "noise level always depends on the technology". An existing option to reduce noise is the replacement of machinery with more modern ones, which are insulated

against excessive noise by their construction. However, new equipment does not always mean lower noise exposure; this does not apply to grinders.

From an economic point of view, these technical measures are financially demanding. There are more modern devices on the market, for example, Bernardo CRL lathe (price € 51,330), milling cutter RCT-FS4030-2200-4A (price €12,054), bench drill OTPTdrill B (price €13,141), stand drill OTPdrill B 28 HV (price €2,363), TPgrind GU 20 grinder (price €163). The replacement of equipment would amount to approximately €66,050.

Another possibility is to reduce the noise by regular checks and revisions of machinery, in case of heavy wear, the equipment would have to be discarded.

If it is impossible to reduce the equipment's noise, organisational measures follow. This can be achieved by reducing the number of students in the workshop, organising the schedule for working with machines, shortening the machine operation time, or soundproofing the workstations with noise barriers.

A suitable solution is to change the positions of the machines in the workshop because it was 3D modelling that brought exciting results that the noise level of the equipment also depends on the location.

The last but necessary option to reduce noise in the workshop is allocating personal protective work equipment. Earplugs are the most suitable and cheapest solution. A proven alternative for hearing protection is plugging from the American company 3M and type designation E-A-R, which can reduce noise by 36 dB.

5 Conclusion

The main goal of the implemented case study is to highlight and map the noise measurement and evaluation issues in the working environment for individual machines. AUTO DESK Ecotect Analysis software was used, which showed us the direction of noise propagation in 3D modelling.

We evaluated the measured results in the school's metalworking workshop, which is equipped with a lathe, a milling machine, a stand drill, a grinder, and a table drill, and proposed several solutions. The most problematic machine was the cutter, the grinder and the synergistic effect after running all the equipment simultaneously. In the discussion, solutions were proposed to reduce noise of a technical and organisational nature and assign effective personal protective equipment.

For pedagogical practice, we suggest using the Autodesk Ecotect Analysis software to map noise propagation in space and better understand the importance of the correct arrangement of machinery.

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