This is an open access article under the
Creative Commons Attribution 4.0 International License

JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

MICROBIOLOGICAL AWARENESS AMONG UPPER-SECONDARY SCHOOL STUDENTS IN THE CONTEXT OF COVID-19 VACCINATION

Beniamin Abramczyk,
Szymon Ławicki,
Weronika Pyter,
Agata Bluszcz,
Ignacy Piszczek,
Jonatan Audycki,
Julia Pawłowska

Abstract. *There is evidence that education levels have an impact on people's attitudes toward vaccination. The recent COVID-19 pandemic has highlighted the need to maximize vaccinations - one of the most efficient ways to prevent the spread of infectious diseases. Young individuals play a major role in disease transmission due to their intense social life and frequent asymptomatic infections. In this study, a survey of upper secondary school students in Poland was conducted to assess their microbiological awareness depending on subjects that they studied on the extended level and COVID-19 vaccination willingness. Participants learning biology and chemistry on the extended level had significantly higher microbiological awareness. Clear proof of microbiological awareness's influence on vaccination willingness was not found. Although studying biology did not significantly influence students' willingness to be vaccinated, their place of residence did. Students from bigger cities were more willing to get vaccinated. These results show that while science education raises microbiological awareness among upper secondary school students, place of residence, likely through social pressure, is a more important factor influencing vaccination willingness. It is suggested that more effort should be put into educating society as a whole and encouraging vaccination particularly.*

Keywords: *attitudes towards vaccinations, infectious diseases, microbiological education, SARS-CoV-2, upper secondary school students*

Beniamin Abramczyk, Szymon Ławicki, Weronika Pyter, Agata Bluszcz, Ignacy Piszczek, Jonatan Audycki, Julia Pawłowska
University of Warsaw, Poland

Introduction

Vaccination is one of the most efficient and cost-effective procedures for preventing hospitalization and death from diseases, including COVID-19. Vaccines also play a major role in preventing the transmission of the disease and a modest one in the case of COVID-19 (Kraaijeveld, 2022). Although children and adolescents are less liable to the severe cause of this disease and less likely to die as a result of it (Viner et al., 2021), researchers emphasize the high value of vaccinating young people as they can transmit the infection to people at high risk - the elderly or chronically ill. Especially if one considers that young people lead a more intense social life and thus come into contact with more people - including potential carriers of the disease (Zimet et al., 2020).

The 2009 experience of the influenza epidemic (H1N1 virus) shows that societies are reluctant to vaccination - rates of vaccination-friendly attitudes in individual countries ranged from 17% to 67% (Al-Mistarehi et al., 2021). The more recent pandemic of COVID-19 seems to have demonstrated a similar tendency when the general public's cold reception of the developed vaccines challenged public health. Interestingly, data on attitudes toward vaccination among adults indicate that a higher level of education correlates with a more favorable attitude toward vaccination (Al-Mistarehi et al., 2021; Afifi et al., 2021; Lin et al., 2020), which is also true in Poland as demonstrated by Gołębiowska et al. (2023), and Raciborski et al. (2021). Moreover, the stream of studies also influences the decision whether to get vaccinated or not. For example, Šorgo et al. (2022) demonstrated that Slovenian medical students are more inclined to get vaccinated against COVID-19 than their peers who study different fields, including health care related subjects.

Nevertheless, education is not the only factor that impacts vaccination willingness in adults. Other factors such as place of residence (Raciborski et al., 2021; Gołębiowska et al., 2023), lifestyle (Fazel et al., 2021), and being a medical practitioner (Wang et al., 2020) have also been proven to influence

https://doi.org/10.33225/jbse/23.22.749

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

the attitude towards vaccinating. It has been found that medical students favor vaccination more than their peers who attend non-medical degree courses. According to an analysis carried out by Khubchandani et al. (2022) in 39 countries, COVID-19 vaccinations are strongly rejected by an average of 18.9% of medical students and as many as 22% of non-medical students.

To date, few studies have examined a big population of adolescents in the context of their vaccination willingness. In Austria, the impact of the type of school was studied - it was shown that students of general upper secondary schools are much more favorable to vaccination than those participating in vocational education (53% of applicants and an indicator of 4/5 points vs. 28% of applicants and an indicator of 3.16 / 5 points - where 5 is "I definitely want to get vaccinated" and 1 is "I definitely don't want to get vaccinated" (Humer et al., 2021)). Other questionnaires conducted among adolescents from different countries indicate that slightly more than half of the respondents declare the willingness to be vaccinated, for example:

- in the USA, age 12-17: 64% (26.1% vaccinated, 38.2% willing to get vaccinated) (Scherer et al., 2021);
- Canada, age 16-21: 65.4% (Afifi et al., 2021).
- Austria, upper secondary schools 53% (Al-Mistarehi et al., 2021);

Research from Great Britain shows that the older the students, the more they favor vaccination, and fewer are hesitant. On the other hand, the percentage of opponents is relatively constant (Fazel et al., 2021).

When examining education as a factor influencing vaccination willingness, one should also consider significant changes in the Polish education system, which happened several times in the last 20 years. The extensive structural reform of 1999 increased the autonomy of the schools and teachers, introduced standardized testing, but most importantly, cut the primary school from 8 to 6 years and established lower secondary schools (called gymnasiums) that children were obliged to attend before upper secondary school (Jakubowski, 2020; Wiśniewski & Zahorska, 2020). The reform led to a significant improvement in Polish students' PISA performance. The average Polish student's results have improved by over 30 points in reading since 2000 and by about 25 points in mathematics since 2003. Poland experienced the most considerable improvement from 2000 to 2018 among the OECD countries (Jakubowski, 2020). Despite that, in 2017, another major structural reform that canceled lower secondary schools was introduced. The reform was rapidly implemented without much thought, preparation, or consultation with the teachers in the name of 'the good old days' (Wiśniewski & Zahorska, 2020). It is important to note that the most recent PISA results are from 2018 and therefore are a product of children educated in a system introduced by the 1999 reform.

Vaccination willingness was also studied in the light of one other factor than education level among school children. The influence of the socioeconomic situation (including migration history) and gender was established on the students' approach and their guardians' (Humer et al., 2021; Scherer et al., 2021).

Research Problem

It is expected that education has a major influence on attitudes toward vaccination. However, there are no studies on schoolchildren that would directly link the scope of their biological knowledge with the willingness to vaccinate against COVID-19. The relationship, or lack thereof, is especially interesting since most conventional schools mainly focus on transferring and examining general theoretical knowledge.

Furthermore, the influence of other factors (place of residence, lifestyle, and close acquaintance with a medical practitioner) on willingness to vaccinate against COVID-19 was never studied in upper secondary school students in Poland. Even though in the research performed by Gołębiowska et al. (2023) some representatives of this group were probably present, they constituted less than 2.5% of the studied population and their answers were not analyzed separately.

Research Aim

The aim of the present research was to determine whether class profile, place of residence, lifestyle, and close acquaintance with a medical professional influence microbiological awareness and the decision to get vaccinated against COVID-19 among high school students. A question of whether the level of microbiological awareness impacts one's willingness to be vaccinated against COVID-19 was also addressed. In this case, microbiological awareness was understood as basic and strictly pragmatic microbiology knowledge that a Polish high school attendee should possess according to the official curriculum. The study was conducted in Poland, and, in this

https://doi.org/10.33225/jbse/23.22.749

context, it is important to note that in the Polish education system, high school students can learn each subject on two levels - basic and extended. The basic level is more pragmatic and obligatory for all students, while the extended is optional and is meant to prepare students for an extended level exam considering a particular subject (The Ministry of National Education, 2018). Consequently, it was presumed that learning a subject in an extended scope could affect microbiological awareness.

Research Methodology

General Background

A survey strategy was implemented for this research with the use of an online questionnaire (Table S1). The questionnaire aimed to gather information about microbiological awareness of students and their vaccination willingness. The answers were collected between November 2021 and April 2022 from students attending upper secondary schools across Poland.

Participants

The questionnaire was shared on social media. However, only several students submitted their answers. It was decided to recruit participants by emailing information about the possible study enrollment to the principal's office. The authors' Python script was used to send the emails to all high schools located in 6 voivodeships (Masovian, Greater Poland, Warmian-Masurian, Silesian, and Podlaskie) listed in the Polish Registry of Schools and Educational Facilities (https://rspo.gov.pl/). Unfortunately, only some headmasters agreed and expressed the will for their students to participate. All of the schools who agreed were enrolled in the study.

Consequently, the questionnaire was filled by 1215 respondents from 6 abovementioned voivodeships: 3 schools from Masovian, 1 school from Greater Poland, 1 school from Warmian-Masurian, 2 schools from Silesian, and 2 schools from Podlaskie. These voivodeships create a nearly diagonal section through Poland. Therefore, the data were recognized to be fairly representative. However, low responsiveness of schools prevented the authors from obtaining more answers.

In further analysis, 1170 responses were considered. 45 responses were not taken into account due to (a) imperfection of the constructed questionnaire - problems with grading the answer "I don't know this rule" in question 7 - see Supplementary Table 1 (43 responses), (b) vulgar answers in open questions indicating that the participant did not take the questionnaire seriously (2 responses).

The considered respondents declared to study varied subjects on the extended level: 693 of them studied biology on the extended level, 605 - chemistry, 528 - foreign language, 394 - mathematics, 235 - Polish, 190 - history, 148 - social sciences ("wiedza o społeczeństwie"), 147 - geography, 124 - physics. 888 respondents declared to be vaccinated against COVID-19, 59 were not but planned to be in the future, 123 were not vaccinated and were hesitant to get the vaccination, 100 were not vaccinated and refused ever to be vaccinated against COVID-19.

Instrument and Procedures

An online questionnaire (Table S1) in Google Forms was designed. The questionnaire consisted of a contextual part and a cognitive part. In the contextual part, students were asked about their grade, place of residence, and if one or more of their family members have work experience in medicinal sciences (e.g., is/was a doctor, nurse, technician, etc.). Participants were also asked about extended subjects and preferred ways of spending free time. Based on this question, students were assigned to one of four groups: physically active, socially active, physically and socially active, or inactive.

The cognitive part focused on knowledge of microbiology. Respondents answered questions about basic microbiological knowledge, infectious disease prevention, and attitude towards vaccination against COVID-19. All questions in the cognitive part were constructed based on the Polish biology curriculum (Table S2), ensuring their validity. Questions and their aim are explained in Table S1.

Participants earned points for correct answers in the microbiological awareness part of the questionnaire. The maximum number of points in each question was equal to the number of correct answers in that question. In questions in which more than one answer was correct, points were subtracted for each incorrect answer, and the

https://doi.org/10.33225/jbse/23.22.749

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

minimum number of points participants could earn for those questions was zero. It was assumed that the number of earned points was proportional to the microbiological awareness of the participants.

The consent for students' participation in the study was sought with the school's headmaster. The principal was informed about the aims of the study in detail and was given an opportunity to examine the questionnaire. Afterwards, the questionnaire was sent by the headmaster electronically to the students. Participation in the survey was voluntary. The questionnaire contained information about the aims of the study so the students' consent to participate was informed. Participants could quit the study at any moment. No headmasters nor teachers had access to the results of the survey. The questionnaire did not collect personal data as understood in the General Data Protection Regulation (Regulation (EU) 2016/679) nor the information about the school to which a participant attended.

Reliability of the Instrument

The reliability of the cognitive part was assessed by calculating the ω coefficient, which was proved to be the most reliable (Zinbarg et al., 2005). Corrected item-total correlations (Cureton, 1966; v2.3.6; Revelle, 2023) and discrimination indexes (biserial point correlations) were also calculated for each question. To assess the difficulty of tasks, response frequency scores (defined as the mean score divided by the maximum possible score) were calculated (Brzezińska, 2020).

The calculated ω coefficients equaled: ω hierarchical = .44, ω total = .59, and ω hierarchical asymptotic = .75. It was decided that the asymptotic version of the ω hierarchical coefficient will be considered because it produces the least biased results of general factor reliability (Trizano-Hermosilla et al., 2021). Consequently, it was concluded that the reliability of the test was satisfactory.

The corrected item-total correlations exceeded .2 for all tasks, showing their acceptable consistency with the rest of the instrument (Collins et al., 2010). The discrimination index of five questions was higher than .4, indicating good discrimination. For three other tasks, the discrimination index was above .2, which was qualified as fairly discriminating (McGahee & Ball, 2009). Question 2 was recognized as a task of the lowest quality showing a discrimination index lower than .2 and a corrected item correlation of .206. However, this question referred to an important topic of human symbiotic microbiota. Consequently, it was decided not to remove it from the analysis.

Question 2 was also recognized as the easiest task, with a response frequency score of .979. On the contrary, Question 3 was considered the hardest. Results for all items analyzed are presented in Table 1.

Table 1
Results of the Quality Analysis for Each Question Asked In the Cognitive Part of the Questionnaire

Question	Corrected item total correlation	Discrimination index	Response frequency score
Question 1	.412	.515	.385
Question 2	.206	.187	.979
Question 3	.504	.733	.274
Question 4	.366	.565	.524
Question 5	.284	.505	.516
Question 6	.250	.241	.910
Question 7	.253	.266	.864
Question 8	.356	.443	.423
Question 9	.295	.367	.315

https://doi.org/10.33225/jbse/23.22.749

Data Analysis

Most of the respondents chose more than one extended subject. Consequently, to determine the influence of participants' chosen extended subject on microbiological awareness, groups of respondents that chose a particular extended subject and all participants that did not were compared. This analysis was conducted for the following extended subjects: social studies, foreign language, Polish language, mathematics, history, geography, physics, chemistry, and biology. Microbiological awareness of participants who were related to a medical worker and those who were not were compared. Respondents who answered "I don't know" in the questionnaire were grouped with those who answered "No." It was assumed that since the participants do not know if their relatives work in the medical field, it would not significantly affect them. For all groups of data Shapiro-Wilk's normality tests were conducted. In all cases, data could not be approximated by the normal distribution.

Consequently, the Kruskal-Wallis test was used. Effect sizes were measured by calculating the ε^2 coefficient for data showing statistically significant differences. Means (*M*) and standard deviations (*SD*) of obtained points within groups were calculated.

Microbiological awareness differences depending on the place of living were studied. Because of the low number of participants living in cities ranging from 50,000 to 150,000 citizens and 150,000 to 500,000 citizens, they were grouped into a single category of cities ranging from 50,000 to 500,000 citizens. Four groups of results were obtained: participants who lived in villages, towns smaller than 50,000 citizens, cities ranging from 50,000 to 500,000 citizens, and cities larger than 500,000 citizens. Microbiological awareness differences were examined depending on participants' vaccination and physical activity decisions. Based on the answers about their physical activity, participants were grouped into four categories:

a) Physically and socially active (spend time both on sports and activities with friends and family),
b) Physically active (spend time on sports, but not on activities with friends and family),
c) Socially active (spend time on activities with friends and family, but not on sports),
d) Not active (do not spend time on sports or activities with friends and family)

For this analysis, the Kruskal-Wallis test was used. If the differences between groups were statistically significant, post-hoc Dunn's test was performed. Means (*M*) and standard deviations (*SD*) of obtained points within groups were calculated.

It was studied if willingness to vaccinate depends on the place of living. Two groups were distinguished: participants living in villages and towns of less than 50,000 inhabitants and from cities of more than 50,000 citizens. It was also examined if willingness to vaccinate depends on physical activity (groups a, b, and c were merged) and close relationships with medical workers. Chi-squared tests were conducted, including described categories and participants' willingness to vaccinate. Theoretical distributions were calculated for the datasets in which differences were statistically significant. Effect sizes were measured by calculating the φ coefficient for data showing statistically significant differences.

Statistical analysis was conducted using the R software (R Core Team, 2013), dunn. test package (Dinno & Dinno, 2017), psych package (v2.3.6; Revelle, 2023), and rcompanion package (v2.4.30; Mangiafico, 2023) according to the procedures described. Statistical significance at $p < .05$ was assumed. ε^2 Values were interpreted as follows: $\varepsilon^2 > .14$ = strong effect, $.14 > \varepsilon^2 > .06$ = medium effect, $.06 > \varepsilon^2 > .01$ = weak effect, $\varepsilon^2 < .01$ = no effect (Khalilzadeh & Tasci, 2017). φ Coefficient values were interpreted as follows: $\varphi > .5$ = strong effect, $.5 > \varphi > .3$ = medium effect, $.3 > \varphi > .1$ = weak effect, $\varphi < .1$ = no effect (Cohen, 1977).

Research Results

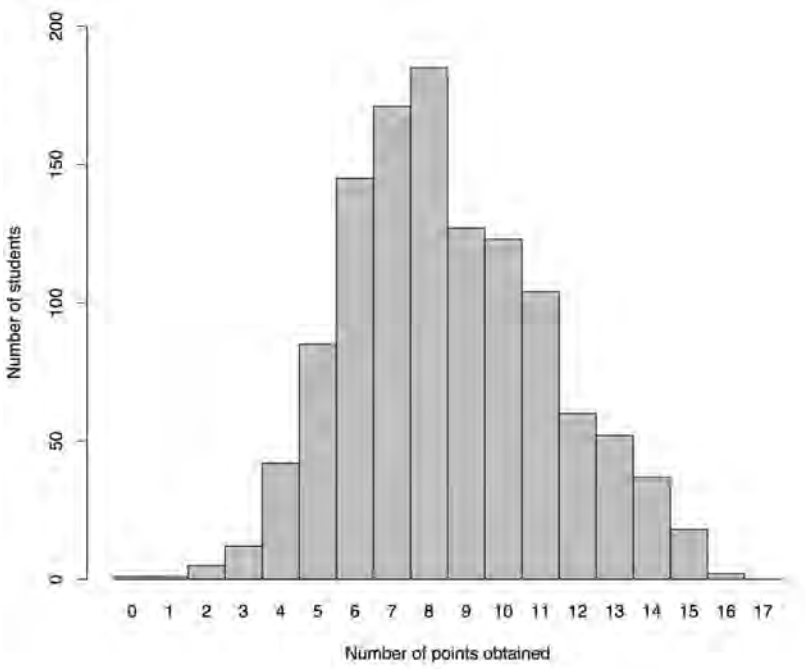
Microbiological Awareness

On average, the respondents scored 8.5 points (out of 17 points possible in the test) with a standard deviation of *SD* = 2.7. The maximum score obtained was 16. The minimum score obtained equaled 0. The frequency distribution of all scores is presented in Figure 1.

https://doi.org/10.33225/jbse/23.22.749

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Figure 1
Histogram of Number of Points Obtained In the Knowledge Test



Note. The height of a bar indicates the number of students who obtained a particular number of points in the cognitive part of the questionnaire.

Extended subjects that had a moderate positive influence on microbiological awareness were biology ($p < .001$, $\varepsilon^2 = .0837$) and chemistry ($p < .001$, $\varepsilon^2 = .0912$). It should be mentioned that only 11 people studying chemistry did not study biology at the extended level. Therefore, it was impossible to examine the influence of studying chemistry without the obvious influence of studying biology simultaneously. Mathematics, without excluding individuals studying biology on the extended level, seemed to also have a positive impact ($p = .003$). However, the ε^2 value of .0072 indicated no significant effect.

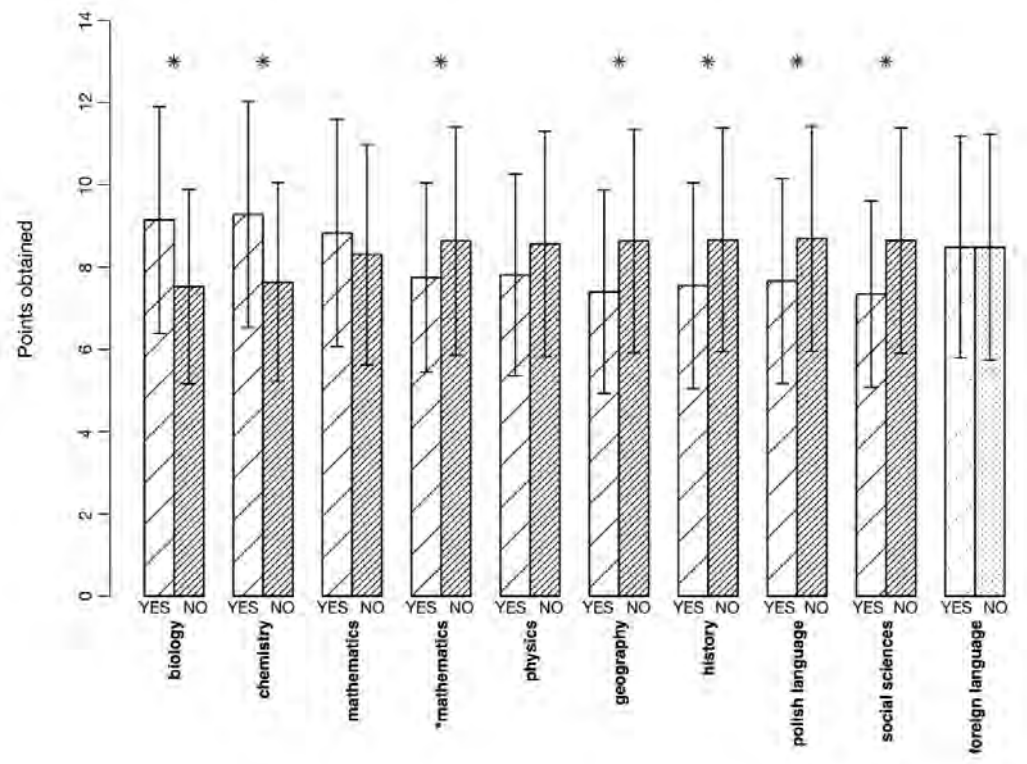
Extended subjects that had a weak negative influence on microbiological awareness were geography ($p < .001$, $\varepsilon^2 = .0239$), history ($p < .001$, $\varepsilon^2 = .0207$), Polish ($p < .001$, $\varepsilon^2 = .0234$), social studies ($p < .001$, $\varepsilon^2 = .0227$) and mathematics when individuals studying biology were excluded ($p < .001$, $\varepsilon^2 = .0148$). Studying physics also seemed to impact microbiological awareness negatively ($p = .006$); however, a low ε^2 (.0064) indicated no effect.

In the case of foreign languages, no significant differences were detected in the total sum of points scored on the test in the case of people who studied this subject and those who did not take it at an extended level ($p = .973$). All of the above results are presented in Figure 2. The exact average score values and standard deviations for each subject are presented in Table S3.

https://doi.org/10.33225/jbse/23.22.749

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Figure 2
The Influence of Studying Different Subjects at an Extended Level on the Microbiological Awareness of Upper-Secondary School Students



Note. The height of the bars indicates the mean number of points obtained in the test. Error bars indicate standard deviation in designated groups. that study the subject at an extended level (YES) compared to those that do not (NO) Statistically significant differences between the groups is marked with solid line patterns ($p < .05$). Statistically insignificant differences between the groups are marked with dotted line patterns. $\varepsilon^2 > .01$ for the designated data groups is marked with asterisks. "*mathematics" indicates students who study mathematics at an extended level but not biology.

Significant differences were detected in the number of points obtained by people with a medical professional among their relatives compared to those who do not have such a person ($p = .003$). Students with a medical relative performed slightly better - $M = 8.7$ ($SD = 2.8$) versus $M = 8.3$ ($SD = 2.6$). However, no effect of relative health professionals on microbiological awareness was observed ($\varepsilon^2 = .0073$).

Statistical significance was not achieved in the case of differences in the number of points obtained depending on the place of residence ($p = .11$, $\varepsilon^2 = .0051$).

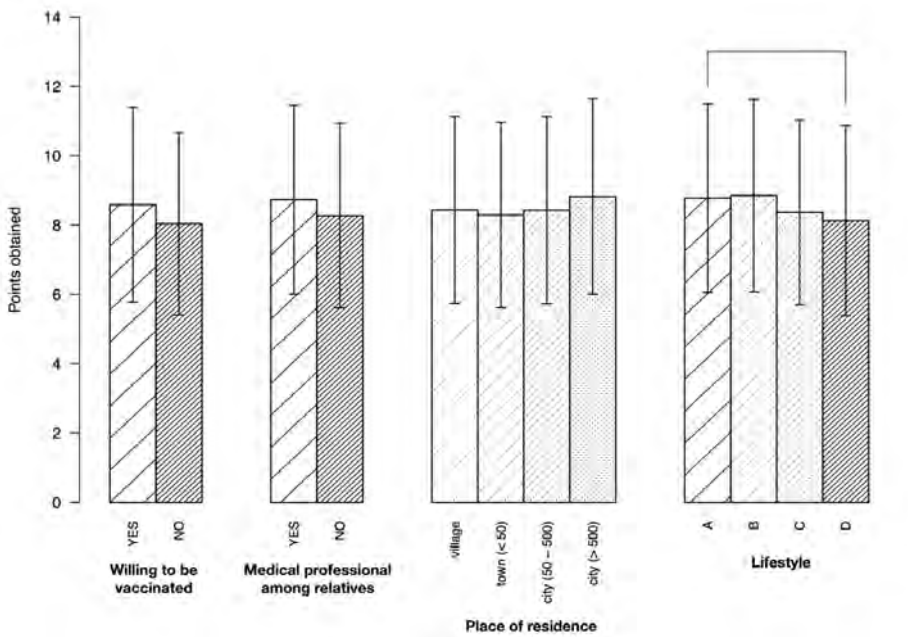
The number of points obtained differed significantly depending on the willingness to get vaccinated ($p = .012$). Students who were vaccinated or expressed the will to be obtained an average of 8.6 points ($SD = 2.8$). Those who were hesitant or strongly refused ever to be vaccinated against COVID-19 obtained an average of 8.0 points ($SD = 2.7$). However, no effect of willingness to get vaccinated on microbiological awareness was observed ($\varepsilon^2 = .0054$).

There were significant differences in the number of points obtained depending on the respondents' lifestyle ($p = .008$). After more detailed analysis, it turned out that the groups that showed significant differences were "physically and socially active" and "not active" ($p = .010$ - obtained from Dunn's test). On average, physically and socially active students obtained a higher score on the test ($M = 8.8$; $SD = 2.7$) than non-active students ($M = 8.1$; $SD = 2.7$). However, no effect of lifestyle on microbiological awareness was observed ($\varepsilon^2 = .0095$). For the remaining groups, no significant differences were found. All of the above results are presented in Figure 3.

https://doi.org/10.33225/jbse/23.22.749

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Figure 3
The Influence of Different Factors on the Microbiological Awareness of Upper-Secondary School Students



Note. The height of the bars indicates the average number of points obtained in the test. Error bars indicate standard deviation in designated groups. In the section "Willing to be vaccinated," students included in the group "YES" were vaccinated or planned to at the time of taking the questionnaire (low-density stripes). Students included in the group "NO" were hesitant or refused ever to be vaccinated against COVID-19 (high-density stripes). In the "Place of residence" section, the citizen number (thousands) of towns and cities where respondents lived is indicated. Rising citizen numbers of place of residence are indicated by increasing pattern density. In the section "Lifestyle," designated groups are "physically and socially active" (A), "physically active" (B), "socially active" (C), and "not active" (D). The decreasing activeness of designated groups is indicated by the rising density of the pattern. The statistical significance of differences between groups is marked with solid lines within the bars ($p < .05$). Dotted lines within the bars indicate no significant differences. In all groups of data, ε^2 was lower than .01.

Vaccination Willingness

Significantly more respondents from big cities (with a population of over 50 thousand residents) were willing to be vaccinated compared to respondents from smaller towns and villages (with a population of less than 50 thousand residents) ($p < .001$, $\varphi = .118$). Moreover, the difference in microbiological awareness in view of willingness to get vaccinated was slightly higher in cities (8.7 ($SD = 2.7$) vs. 8.0 ($SD = 2.6$)) than in small towns and villages (8.5 ($SD = 2.7$) vs. 8.1 ($SD = 2.7$)). However, these dissimilarities were statistically insignificant ($p = .128$ and $p = .06$, respectively).

No correlation was found between the willingness to get vaccinated and having a medical practitioner among relatives ($p = .060$), the lifestyle ($p = .214$), studying biology at the extended level ($p = .929$), nor any other subjects at the extended level.

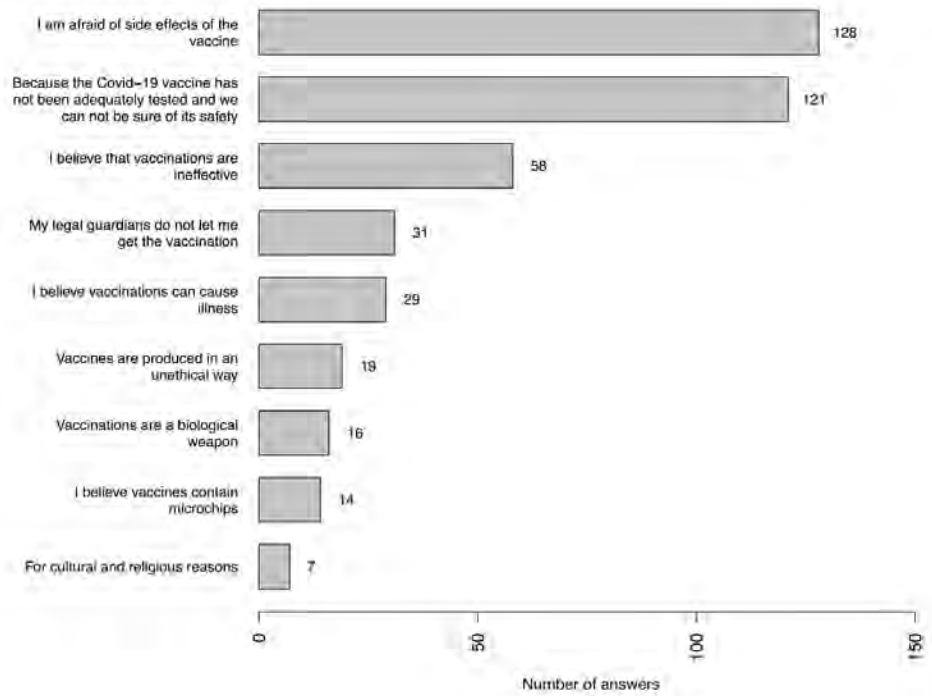
Reasoning

The most frequently designated reasons for being against or hesitant towards the vaccination were the fear of side effects, insufficient research on the COVID-19 vaccine before its wide-range use, and the belief in the lack of vaccines' efficacy in preventing diseases in general (Figure 4). The will to vaccinate oneself was motivated mainly by the expected protection against the severe course of COVID-19 for the respondent, the will to end the pandemic, and the protection of relatives and loved ones (Figure 5).

https://doi.org/10.33225/jbse/23.22.749

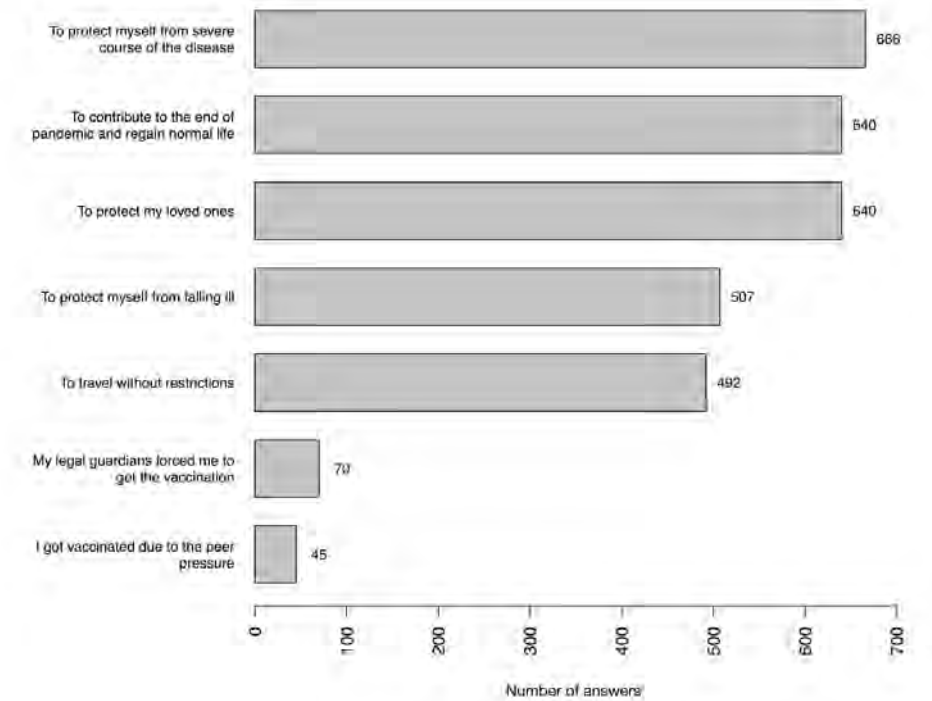
ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Figure 4
Reasons Why Respondents Do Not Want to Get Vaccinated against COVID-19



Note. The number of people who indicated each of the reasons is shown beside each bar.

Figure 5
Reasons Why Respondents Want or Have Already Got Vaccinated against COVID-19



Note. The number of people who indicated each of the reasons is shown beside each bar.

https://doi.org/10.33225/jbse/23.22.749

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Discussion

Among reasons against vaccination against SARS-CoV-2 that the respondents of the questionnaire indicated, the most common were:

- the vaccine has been available on the market for too short a time
- insufficient information about the vaccine;
- potential post-vaccination reactions and unwanted, long-term side effects (Figure 4, Figure 5).

In other studies, conducted so far (Al-Mistarehi et al., 2021; Scherer et al., 2021), the same reasons were indicated by 40-70% of respondents who were undecided or unwilling to get vaccinated.

The present results also confirmed the hypothesis that the school class profile influences microbiological awareness, where the most influential subjects were biology and chemistry (Figure 2). Surprisingly, even though it was possible to confirm that deepened knowledge of biology increases microbiological awareness, no clear proof was found that microbiological awareness increases the willingness to vaccinate. No relationship was observed between learning biology and the willingness to vaccinate either. This is, however, consistent with psychology studies implying that a higher level of education or intelligence may not always lead to challenging one's preexisting beliefs, but it may instead be used to support them (Driscoll, 2019; Hornsey, 2016; Lewandowsky & Oberauer, 2016; Sobkowicz & Sobkowicz, 2021).

Moreover, the obtained results may suggest that the presence of a medical practitioner among relatives influences microbiological awareness (Figure 3); however, the ε^2 was very low (see Results). To understand the anti-vaccination group's activity, Sobkowicz and Sobkowicz (2021) developed an Agent-Based Model that included four agent entities: doctors, patients, initiators, and messages in the infosphere. All agents were given an opinion about vaccination ranging from -2 (strongly against vaccines) to +2 (strongly supporting vaccines). The model assumed that patients might visit a doctor or get access to official information about vaccines and adjust their opinion according to the algorithm described in the publication. However, the doctors' opinion was prepared in a special way as it may have varied from +1 to +2 since some medical practitioners, for many reasons, may not want to get engaged in discussions about vaccines with their patients. As shown by the model, radicalizing anti-vaccination messages increases the number of unvaccinated patients. The trend may be reversed if the doctor's impact is greater than the messaging and if the number of anti-vaccination activists is low. Consequently, it may be that medical practitioners' influence has some potential to indirectly shift public opinion in favor of vaccinations by increasing microbiological awareness. However, the study conducted here does not provide clear evidence to support this conclusion.

In addition, it was impossible to confirm the phenomenon observed in the study conducted by Fazel et al. (2021). Researchers from Oxford have observed that people who are hesitant towards or against vaccinations are more likely to lead an unhealthy life (little exercise, smoking) and spend a lot of time on social media. It is imaginable that this relationship is absent among high school students in Poland. Nevertheless, data collected by Fazel et al. (2021) are more detailed and assess participants' lifestyles more accurately. Consequently, the lack of relationship was probably caused by the imperfection of the present study.

Lastly, the difference in the level of microbiological awareness between the vaccinated and unvaccinated living in cities was slightly bigger than the difference between the same groups living in smaller towns or villages in view of vaccination willingness. However, there was no direct difference in microbiological awareness between urban and rural students.

Therefore, it is plausible that in towns and villages, the social pressure not to vaccinate is more dominant than in cities, and when the pressure gets mitigated, microbiological awareness becomes more important. It is also worth mentioning that people living in rural areas are more likely to conform due to the lack of anonymity. Bourke et al. (2004) mentioned that although urban and rural citizens have approximately the same number of strong ties among their respective communities, rural residents usually have a significantly lower number of weak ties. This can result in a lack of anonymity among rural citizens compared to urban citizens.

It is also important to note that the introductory 1999 structural reform aimed to improve the quality of education in the rural areas of Poland (Wiśniewski & Zahorska, 2020). It succeeded in reducing the differences between urban and rural areas (Jakubowski, 2020), which is also proved by this study, considering that all questions were constructed based on Polish curriculum requirements (Table S2) and no differences in microbiological awareness between urban and rural areas were observed in high school students.

As a consequence of the 1999 reform, lower secondary schools prioritized hiring experts in fields such as

https://doi.org/10.33225/jbse/23.22.749

physics, biology, and chemistry as teachers and financing equipment for laboratory classes (Wiśniewski & Zahorska, 2020). After the 2017 reform, numerous lower secondary schools were not closed down but became a formal part of local primary schools. Thus, younger children could continue classes in the same primary school they used to attend, and adolescents had lessons in a former lower secondary school building. Therefore, the lack of significant difference in microbiological awareness between rural and urban areas could result from the equipment and expert teachers that stayed in schools even after the 2017 reform. It may be speculated that the differences in health education that were present before the 1999 reform may result in the present social pressure not to vaccinate, which older inhabitants in rural areas could create. Consequently, high school students living in towns and villages are less willing to vaccinate, which was proved by the present study (see Results).

Given all of the obtained results, it may be presumed that microbiological awareness is not the most influential factor, and other components like filter bubble, social pressure, guardian consent, and cultural background may be more crucial in deciding whether or not to vaccinate. For example, it was suggested by Kahan et al. (2017) that it is a scientific curiosity rather than IQ or level of education that may lead to contradicting one's viewpoint. Considering the present results, it could be speculated that the level of biological knowledge can indirectly affect the willingness to vaccinate but is not the most important factor in the decision process.

It is important to note that by the time the study was conducted, barely half of children and adolescents in Poland (0-17 years old) and 57% of the general public had been vaccinated (Information Service of Republic of Poland, 2023; Statistics Poland, 2022), which is similar to the percentage of people declaring their willingness to be vaccinated. It can be concluded from this that most people with a favorable attitude toward vaccinations have already been vaccinated. Therefore, to increase vaccination coverage in the population, reaching those not in favor of vaccination is necessary. The present research shows that it is important to dispel all doubts about vaccinations and post-vaccination reactions among young people (Figure 4).

It could also be beneficial to rerun the study with a bigger group of students and a questionnaire that measures scientific curiosity, especially considering that there was no clear evidence for a difference in microbiological awareness between the vaccinated and the unvaccinated. Another option worth considering is rerunning the study to obtain more data on the social aspects of unwillingness to vaccinate and microbiological awareness in society as a whole rather than in high school students.

Last but not least, adding more questions should be considered to measure microbiological awareness more accurately before rerunning such a study. This would considerably diminish the issue with low ω hierarchical and ω total coefficients compared to ω asymptotic, which were obtained in the quality analysis of the knowledge test. In several cases, some researchers would also regard the corrected item-total correlations as unsatisfactory (Ladhari, 2010). Reevaluation of tasks is advised if a similar study is to be conducted.

Conclusions and Implications

The study confirms that the class profile influences microbiological awareness in a significant way, where the most influential subjects were biology and chemistry. Nevertheless, learning those subjects in an extended scope did not increase the willingness to vaccinate. It also remained unresolved whether microbiological awareness affects vaccination willingness. Data collected did not provide clear proof that factors such as lifestyle or a medical practitioner among relatives influence the level of microbiological awareness. The abovementioned factors did not change the desire to get vaccinated either.

It was determined that students' place of residence is an important factor in considering vaccination willingness. High school students living in small towns and villages in Poland were less willing to be vaccinated. It may be due to the higher social pressure of distrusting and opposing vaccinations, which might be more prevalent in rural areas than in big cities. Consequently, higher conformity of people living in rural areas could have a negative effect on vaccination willingness among high school students from towns and villages. Therefore, more effort should be put into health education and vaccination encouragement of society as a whole.

The reasons for vaccination unwillingness among Polish high school students were unraveled. It is advised that biology teachers use these results to address the uncertainties of students considering not only COVID-19 but also other illnesses. This could contribute to maximizing vaccinations in the Polish population.

It is suggested that a study with a bigger group and a methodology to measure scientific curiosity rather than microbiological knowledge might be necessary to determine the effect of education on vaccination willingness. Analyzing factors such as online infosphere would help resolve the relationship between the lifestyle or relative

https://doi.org/10.33225/jbse/23.22.749

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

medical practitioner and the desire to get vaccinated. Larger scale research would also be useful to unravel whether the obtained, slight impact of lifestyle and relative medical practitioner on microbiological awareness is truly significant or just a result of the size of the study.

This preliminary but informative study shows how complex research on the willingness to vaccinate really is. Any future studies should focus on measuring a person's education or knowledge and factors like scientific curiosity, social pressure, and online community.

Acknowledgments

The authors would like to sincerely thank Marcin Chrzanowski PhD for inspiring us to perform this kind of study.

The authors would also like to thank the headteachers of all schools, who allowed the study to be performed, and all students who took part in the study.

The authors appreciate all the insightful comments made by Alicja Okrasińska and the Reviewers, which helped them improve the article.

The authors would also like to show their gratitude to Maja Koperska for the linguistic correction of the article.

The authors would like to thank Remigiusz Cynkier for the ever-lasting support.

Declaration of Interest

The authors declare no competing interest.

References

Afifi, T. O., Salmon, S., Taillieu, T., Stewart-Tufescu, A., Fortier, J., & Driedger, S. M. (2021). Older adolescents and young adults' willingness to receive the COVID-19 vaccine: Implications for informing public health strategies. *Vaccine*, *39*(26), 3473–3479. https://doi.org/10.1016/j.vaccine.2021.05.026

Al-Mistarehi, A. H., Kheirallah, K. A., Yassin, A., Alomari, S., Aledrisi, M. K., Bani Ata, E. M., Hammad, N. H., Khanfar, A. N., Ibnian, A. M., & Khassawneh, B. Y. (2021). Determinants of the willingness of the general population to get vaccinated against COVID-19 in a developing country. *Clinical and Experimental Vaccine Research*, *10*(2), 171–182. https://doi.org/10.7774/cevr.2021.10.2.171

Bourke, L., Sheridan, C., Russell, U., Jones, G., DeWitt, D., & Liaw, S. T. (2004). Developing a conceptual understanding of rural health practice. *The Australian Journal of Rural Health*, *12*(5), 181–186. https://doi.org/10.1111/j.1440-1854.2004.00601.x

Brzezińska, J. (2020). *Modele odpowiedzi na pozycje testowe (IRT) w badaniach ekonomiczno-społecznych* [Item response theory (IRT) models in economic and social research]. University of Economics in Katowice.

Cohen, J. (1977). *Statistical power analysis for the behavioral sciences: Revised Edition*. Academic Press.

Collins, G. S., Mughal, S., Barnett, A. H., Fitzgerald, J., & Lloyd, C. E. (2010). Modification and validation of the revised diabetes knowledge scale. *Diabetic Medicine*, *28*(3), 306-310. https://doi.org/10.1111/j.1464-5491.2010.03190.x

Cureton, E.E. (1966). Corrected item-test correlations. *Psychometrika*, *31*, 93–96. https://doi.org/10.1007/BF02289461

Dinno, A., & Dinno, M. A. (2017). Package 'dunn. test'. *CRAN Repos*, *10*, 1-7.

Driscoll, D. (2019). Assessing sociodemographic predictors of climate change concern, 1994–2016. *Social Science Quarterly*, *100*(5), 1699–1708. https://doi.org/10.1111/ssqu.12683

European Parliament and the Council. (2016). Regulation of the European Parliament and of the Council (EU) 2016/679 of April 27th, 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation) (Text with EEA relevance) OJ L 119, 4.5.2016, p. 1–88. https://eur-lex.europa.eu/eli/reg/2016/679/oj

Fazel, M., Puntis, S., White, S. R., Townsend, A., Mansfield, K. L., Viner, R., Herring, J., Pollard, A. J., & Freeman, D. (2021). Willingness of children and adolescents to have a COVID-19 vaccination: Results of a large whole schools survey in England. *eClinicalMedicine*, *40*, Article 101144. https://doi.org/10.1016/j.eclinm.2021.101144

Gołębiowska, J., Zimny-Zając, A., Dróżdż, M., Makuch, S., Dudek, K., Mazur, G., & Agrawal, S. (2023). Evaluation of the approach towards vaccination against COVID-19 among the Polish population-in relation to sociodemographic factors and physical and mental health. *Vaccines*, *11*(3), Article 700. https://doi.org/10.3390/vaccines11030700

Hornsey, M. J., Harris, E. A., Bain, P. G., & Fielding, K. S. (2016). Meta-analyses of the determinants and outcomes of belief in climate change. *Nature Climate Change*, *6*, 622-626. https://doi.org/10.1038/nclimate2943

Humer, E., Jesser, A., Plener, P. L., Probst, T., & Pieh, C. (2021). Education level and COVID-19 vaccination willingness in adolescents. *European Child & Adolescent Psychiatry*, *32*(3), 537–539. https://doi.org/10.1007/s00787-021-01878-4

Jakubowski, M. (2020). Poland: Polish education reforms and evidence from international assessments. In N. Crato (Ed.), *Improving a country's education* (pp. 137-158). Springer, https://doi.org/10.1007/978-3-030-59031-4_7

Kahan, D. M., Landrum, A. R., Carpenter, K., Helft, L. & Jamieson, K. H. (2017). Science curiosity and political information processing. *Advances in Political Psychology*, *38*(1), 179–199. https://doi.org/10.1111/pops.12396

https://doi.org/10.33225/jbse/23.22.749

Khalilzadeh, J., & Tasci, A. D. A. (2017). Large sample size, significance level, and the effect size: Solutions to perils of using big data for academic research. *Tourism Management*, *62*, 89–96. https://doi.org/10.1016/j.tourman.2017.03.026

Khubchandani, J., Biswas, N., Mustapha, T., Talbert, S., & Dharamsi, S. (2022). COVID-19 vaccination refusal among college students: Global trends and action priorities. *Brain, Behavior, and Immunity*, *99*, 218–222. https://doi.org/10.1016/j.bbi.2021.10.006

Kraaijeveld, S.R. (2022). The ethical significance of post-vaccination COVID-19 transmission dynamics. *Bioethical Inquiry*, *20*, 21–29. https://doi.org/10.1007/s11673-022-10223-6

Ladhari, R. (2010). Developing e-service quality scales: A literature review. *Journal of Retailing and Consumer Services*, *17*(6), 464–477. https://doi.org/10.1016/j.jretconser.2010.06.003

Lewandowsky, S., & Oberauer, K. (2016). Motivated rejection of science. *Current Directions in Psychological Science*, *25*(4), 217–222. https://doi.org/10.1177/0963721416654436

Lin, C., Tu, P., & Beitsch, L. M. (2020). Confidence and receptivity for COVID-19 vaccines: A rapid systematic review. *Vaccines*, *9*(1), Article 16. https://doi.org/10.3390/vaccines9010016

Mangiafico, S. (2023). Package 'rcompanion: Functions to support extension education program evaluation' (version 2.4.30). Rutgers Cooperative Extension, New Brunswick, New Jersey. https://CRAN.R-project.org/package=rcompanion

McGahee, T. W., & Ball, J. (2009). How to read and really use an item analysis. *Nurse Educator*, *34*(4), 166–171. https://doi.org/10.1097/nne.0b013e3181aaba94

R Core Team (2023). _R: A Language and Environment for Statistical Computing_. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Raciborski, F., Samel-Kowalik, P., Gujski, M., Pinkas, J., Arcimowicz, M., & Jankowski, M. (2021). Factors associated with a lack of willingness to vaccinate against COVID-19 in Poland: A 2021 nationwide cross-sectional survey. *Vaccines*, *9*(9), Article 1000. https://doi.org/10.3390/vaccines9091000

Revelle, W. (2023). *Package 'psych: Procedures for psychological, psychometric, and personality research' (version 2.3.6)*. Northwestern University, Evanston, Illinois. https://CRAN.R-project.org/package=psych

Scherer, A. M., Gedlinske, A. M., Parker, A. M., Gidengil, C. A., Askelson, N. M., Petersen, C. A., Woodworth, K. R., & Lindley, M. C. (2021). Acceptability of adolescent COVID-19 vaccination among adolescents and parents of adolescents — United States, April 15–23, 2021. *Morbidity and Mortality Weekly Report*, *70*(28), 997–1003. http://dx.doi.org/10.15585/mmwr.mm7028e1

Information Service of Republic of Poland. (n.d.). *Report of vaccinations against COVID-19.* [Serwis Rzeczypospolitej Polskiej. (n.d.). *Raport szczepień przeciwko COVID-19*.] Retrieved March 10, 2023, from https://www.gov.pl/web/szczepimysie/raport-szczepien-przeciwko-covid-19

Sobkowicz, P., & Sobkowicz, A. (2021). Agent based model of anti-vaccination movements: Simulations and comparison with empirical data. *Vaccines*, *9*(8), Article 809. https://doi.org/10.3390/vaccines9080809

Statistics Poland. (2022, February) *Structure of the population*. https://stat.gov.pl/en/topics/population/population/structure-of-the-population,7,1.html

Šorgo, A., Crnkovič, N., Cesar, K., Selak, Š., Vrdelja, M., & Gabrovec, B. (2022). The influence of anxiety and fear of COVID-19 on vaccination hesitancy among postsecondary students. *Scientific Reports 12*, Article 20564. https://doi.org/10.1038/s41598-022-25221-2

The Ministry of National Education. (2018). The Order of Ministry of National Education of January 30th 2018 [Rozporządzenie Ministra Edukacji Narodowej z dnia 30 stycznia 2018 r. w sprawie podstawy programowej kształcenia ogólnego dla liceum ogólnokształcącego, technikum oraz branżowej szkoły II stopnia]. https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20180000467

Trizano-Hermosilla, I., Gálvez-Nieto, J. L., Alvarado, J. M., Saiz, J. L., & Salvo-Garrido, S. (2021). Reliability estimation in multidimensional scales: Comparing the bias of six estimators in measures with a bifactor structure. *Frontiers in Psychology 12*, Article 508287. https://doi.org/10.3389/fpsyg.2021.508287

Viner, R. M., Mytton, O. T., Bonell, C., Melendez-Torres, G. J., Ward, J., Hudson, L., Waddington, C., Thomas, J., Russell, S., van der Klis, F., Koirala, A., Ladhani, S., Panovska-Griffiths, J., Davies, N. G., Booy, R., & Eggo, R. M. (2021). Susceptibility to SARS-CoV-2 infection among children and adolescents compared with adults: A systematic review and meta-analysis. *JAMA Pediatrics*, *175*(2), 143–156. https://doi.org/10.1001/jamapediatrics.2020.4573

Wang, K., Wong, E. L. Y., Ho, K. F., Cheung, A. W. L., Chan, E. Y. Y., Yeoh, E. K., & Wong, S. Y. S. (2020). Intention of nurses to accept coronavirus disease 2019 vaccination and change of intention to accept seasonal influenza vaccination during the coronavirus disease 2019 pandemic: A cross-sectional survey. *Vaccine*, *38*(45), 7049–7056. https://doi.org/10.1016/j.vaccine.2020.09.021

Wiśniewski, J., Zahorska, M. (2020). Reforming education in Poland. In: F.M. Reimers (Ed.), *Audacious Education Purposes* (pp. 181-208). Springer, Cham. https://doi.org/10.1007/978-3-030-41882-3_7

Zimet, G. D., Silverman, R. D., & Fortenberry, J. D. (2020). Coronavirus disease 2019 and vaccination of children and adolescents: Prospects and challenges. *The Journal of Pediatrics*, *231*, 254–258. https://doi.org/10.1016/j.jpeds.2020.11.002

Zinbarg, R.E., Revelle, W., Yovel, I., Li, W. (2005). Cronbach's α, Revelle's β, and Mcdonald's ω H: Their relations with each other and two alternative conceptualizations of reliability. *Psychometrika, 70*, 123–133. https://doi.org/10.1007/s11336-003-0974-7

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Appendices

Supplementary Table 1 (Table S1) - Table containing questions asked in an online questionnaire with the specified aim for each question.

Supplementary Table 2 (Table S2) - Table containing learning objectives and curriculum requirements on which questions were based.

Supplementary Table 3 (Table S3) - Table containing the exact average score values and standard deviations of scores obtained in the test for students attending each subject studied on the extended level and those not attending it.

Table S1

Questions Asked in an Online Survey with the Specified Aim for Each Question

No.	Question from the survey	Aim of the question
Following questions aim to test students' knowledge and microbiological awareness.		
1.	In treatment of which diseases antibiotics are used? a. Bacterial diseases b. Viral diseases c. Fungal diseases d. I don't know	The question tests if participants possess knowledge about antibiotics usage in healthcare.
2.	"All bacteria are harmful" - do you agree with this statement? a. Yes b. No c. I don't know	The question tests if participants possess knowledge about symbiotic bacteria.
3.	Finish the sentence (you can choose more than one answer): "Antibiotics are effective in the treatment of…" a. Flu b. Quinsy c. Mononucleosis d. Common cold e. Lyme disease f. Gonorrhoea g. Tetanus h. Mumps i. Chickenpox j. COVID-19 k. I don't know	The question tests if participants possess knowledge about antibiotics usage in disease treatment and pathogenesis of highlighted diseases.
4.	Which microorganisms listed below can cause pneumonia? a. Bacteria b. Viruses c. Fungi d. I don't know	The question tests if participants know which microorganisms can cause pneumonia.
5.	Which of the agents listed below are efficient in daily hand sanitation? You can choose more than one answer. a. Alcohol 20%-40% (e.g., vodka, ardent spirits) b. Alcohol 60%-70% c. Pure alcohol 96% (spirits) d. Water with soap e. Cold water f. Ready-to-use sanitizers from pharmacy	The question tests participants' knowledge about sanitizing agents.

https://doi.org/10.33225/jbse/23.22.749

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

No.	Question from the survey	Aim of the question
6.	Franek returned home from school. In the kitchen he found a piece of cake, partially covered in green residue. He cut off the green part and ate the rest of the cake. In your opinion, was it safe for his health? a. Yes b. No c. Different answer (submitted by participant)	The question tests participants' basic knowledge about fungi, fungal toxins and healthy eating.
7.	Does the "five seconds rule" work? a. Yes b. No c. I don't know this rule	The question tests participants' elementary knowledge about hygiene basics, healthy eating and health-promoting practices. "Five seconds rule" concerns food that fell on the floor and the common assumption that it is safe to eat if it was picked up before five seconds passed.
8.	What are cyanobacteria? a. Small plants b. Water fungi c. Bacteria d. Protists e. I don't know	The question tests participants' knowledge about cyanobacteria. NOTE: although the English name "cyanobacteria" explains what kind of organisms they are, in Polish there is no such connotation (Polish word for cyanobacteria is "sinice").
9.	Why is swimming in cyanobacteria-blooming water dangerous? a. Cyanobacteria are pathogenic and can cause e.g., infections of urinary tract b. Cyanobacteria produce dangerous toxins c. Contact with cyanobacteria can cause skin burns and rashes d. This activity is not dangerous e. I don't know	The question tests participants' knowledge about cyanobacteria, bacterial toxins and algal blooms.
The following questions aim to find participants' reasons and motivations to vaccinate against COVID-19 and reasons for not wanting to do so.		
10.	Are you vaccinated against COVID-19? a. Yes b. No, but I want to c. No and I still don't know if I want to d. No, I don't want to	The question aims to determine participants' willingness to vaccinate against COVID-19.
11.	If you answered you do not want to vaccinate against COVID-19 in the previous question, answer why. a. I'm afraid of side effects of vaccination b. I consider vaccinations ineffective c. Because of cultural or religious reasons d. Vaccines are produced unethically e. I think vaccines contain microchips or other devices f. I think vaccines can cause diseases g. Vaccine against COVID-19 wasn't subjected to enough number of trials and tests h. We cannot be sure if it's safe i. Vaccinations are a form of biological weapon j. My parents/caregivers did not allow me to vaccinate k. Other answer	The question aims to determine reasons why participants are not vaccinated.

https://doi.org/10.33225/jbse/23.22.749

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

No.	Question from the survey	Aim of the question
12.	If you answered you are vaccinated or you are, willing to vaccinate against COVID-19, why a. I want to be protected against COVID-19 b. I want to be protected from severe consequences of COVID-19 c. I want to protect my relatives d. I want to protect people who cannot be vaccinated against COVID-19 or suffer from immunodeficiency e. I want to contribute towards ending of pandemic f. Because of social pressure g. My parents/caregivers told me to vaccinate h. I want to travel without restrictions i. Other answer	The question aims to determine reasons why participants are vaccinated.

Table S2
Learning Objectives and Curriculum Requirements on Which Questions in the Online Questionnaire Were Based

Subject	Learning objectives	Curriculum requirements
Natural science	I. Knowledge. 4. Acquiring knowledge about systems of the human body (skeletal, respiratory, digestive, blood circulation, reproductive, nervous). II. Skills and practical usage of knowledge. 5. Application of rules concerning self-healthcare, including disease prevention.	IV. Me and my body. Student: 1. Lists systems of the human body: skeletal, respiratory, digestive, blood circulation, reproductive, nervous and explains their basic functions; 6. Explains basic rules of self-body care and care about the surrounding environment. V. Me and my surroundings. Student: 2. Explains ways pathogens infect the human body, explains ways of disease prevention.
Biology in primary school	V. Knowledge of factors of human health. Student: 1. Analyzes the connection between their actions and maintaining health and recognizes situations demanding consultation with physicians.	II. Diversity of life. 2. Viruses - non-cellular forms of matter. Student: 2) explains ways of spreading and prevention of viral diseases (flu, chickenpox, rubella, mumps, measles, AIDS) 3. Bacteria - unicellular organisms. Student: 1) lists bacterial habitats; 4) explains ways of spreading and prevention of bacterial diseases (tuberculosis, Lyme disease, tetanus, salmonellosis); 5) explains importance of bacteria in natural environment and human body 4. Protists - organisms of diverse cellular structure. Student: 4) explains ways of spreading and prevention of diseases caused by protists (toxoplasmosis, malaria). 6. Fungi - heterotrophic organisms. Student: 5) explains the role of fungi in the natural environment and human life. III. Human body 6. Immune system. Student: 3) compares the mechanism of action of vaccines and antivenom; lists medical indications of their use and justifies the necessity of mandatory vaccinations. 12. Reproduction and development. Student: 6) explains ways of prevention of sexually transmitted diseases.

https://doi.org/10.33225/jbse/23.22.749

Biology in upper secondary school	Extended programmes: V. Deepening the knowledge of human health factors. Student: 1. plans health-promoting activities; 2. understands the importance of preventive screening and recognizes situations demanding consultation with physicians; 5. acknowledges the importance of research in disease prevention. Primary programmes: II. Deepening the knowledge of human health factors. Student: 1. plans health-promoting activities; 2. understands the importance of preventive screening and recognizes situations demanding consultation with physicians; 4. acknowledges the importance of research in disease prevention.	Curriculum for high school, extended programmes: VI. Bacteria and archaeans. Student: 5. explains the importance of bacteria in the natural environment and human body, including pathogenic bacteria and bacterial diseases (tuberculosis, tetanus, Lyme disease, salmonellosis, syphilis, gonorrhea). VII. Fungi. Student: 5. explains ways of infection and prevention of diseases caused by fungi (skin mycosis, reproductive organs mycosis, lung mycosis) VIII. Protists. Student: 5. explains ways of spreading and prevention of diseases caused by protists (malaria, toxoplasmosis, lambliosis, amoebiasis, trichomoniasis) XII. Viruses, virions, prions. Student: 6. explains ways of infection and prevention of viral diseases (rabies, AIDS, poliomyelitis, HPV-related diseases, flu, measles, chickenpox, rubella, mumps, viral hepatitis, some types of cancer).

Table S3

Exact Mean Score Values (M) and Standard Deviations (SD) of Scores Obtained in the Test for Students Attending Each Subject Studied on Extended Level and Those Not Attending It

Subject	Participants studying the subject on extended level		Participants not studying the subject on extended level	
	M	*SD*	*M*	*SD*
Biology	9.1	2.8	7.5	2.4
Chemistry	9.3	2.7	7.6	2.4
Mathematics (extended biology included)	8.8	2.8	8.3	2.7
Physics	7.8	2.5	8.6	2.7
Geography	7.4	2.5	8.6	2.7
History	7.5	2.5	8.7	2.7
Polish	7.7	2.5	8.7	2.7
Social studies	7.3	2.3	8.6	2.7
Foreign language	8.5	2.7	8.5	2.7
Mathematics (extended biology excluded)	7.7	2.3	8.6	2.8

https://doi.org/10.33225/jbse/23.22.749

MICROBIOLOGICAL AWARENESS AMONG UPPER-SECONDARY SCHOOL STUDENTS IN THE CONTEXT OF COVID-19 VACCINATION
(PP. 749-766)

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Received: *June 17, 2023* Revised: *August 28, 2023* Accepted: *October 02, 2023*

Cite as: Abramczyk, B. M., Lawicki, S., Pyter, W., Bluszcz, A., Piszczek, I., Audycki, J., & Pawłowska, J. (2023). Microbiological awareness among upper-secondary school students in the context of Covid-19 vaccination. *Journal of Baltic Science Education*, *22*(5), 749-766. https://doi.org/10.33225/jbse/23.22.749

Beniamin Mateusz Abramczyk
(Corresponding author)
Bachelor of Science, Biology of Microorganisms Students' Society, Faculty of Biology, University of Warsaw, Ilji Miecznikowa 1, 02-096 Warsaw, Poland.
E-mail: b.abramczyk2@student.uw.edu.pl
ORCID: https://orcid.org/0000-0003-1245-0984

Szymon Ławicki
Bachelor of Science, Biology of Microorganisms Students' Society, Faculty of Biology, University of Warsaw, Ilji Miecznikowa 1, 02-096 Warsaw, Poland.
E-mail: s.lawicki@student.uw.edu.pl
ORCID: https://orcid.org/0009-0008-6758-1483

Weronika Pyter
Bachelor of Science, Biology of Microorganisms Students' Society, Faculty of Biology, University of Warsaw, Ilji Miecznikowa 1, 02-096 Warsaw, Poland.
E-mail: w.pyter@student.uw.edu.pl

Agata Bluszcz
Bachelor of Science, Department of Environmental Microbiology and Biotechnology, Institute of Microbiology, Faculty of Biology, University of Warsaw, Ilji Miecznikowa 1, 02-096 Warsaw, Poland
E-mail: a.bluszcz@uw.edu.pl
ORCID: https://orcid.org/0009-0009-1814-2684

Ignacy Piszczek
Bachelor of Science, Department of Bacterial Genetics, Institute of Microbiology, Faculty of Biology, University of Warsaw, Ilji Miecznikowa 1, 02-096 Warsaw, Poland
E-mail: i.piszczek@student.uw.edu.pl
ORCID: https://orcid.org/0009-0006-7498-2715

Jonatan Audycki
Master of Science, Institute of Evolutionary Biology, Faculty of Biology, Biological and Chemical Research Centre, University of Warsaw, Żwirki i Wigury 101, 02-089 Warsaw, Poland.
E-mail: j.audycki@student.uw.edu.pl
ORCID: https://orcid.org/0009-0004-9507-3217

Julia Pawłowska
PhD, Institute of Evolutionary Biology, Faculty of Biology, Biological and Chemical Research Centre, University of Warsaw, Żwirki i Wigury 101, 02-089 Warsaw, Poland.
E-mail: julia.z.pawlowska@uw.edu.pl
Website: https://ibe.biol.uw.edu.pl/pracownicy/dr-julia-pawlowska
ORCID: https://orcid.org/0000-0003-4914-5182