

Article

Spread of SARS-CoV-2 Infections in Educational Settings by Level of Education, Taking into Account the Predominant Virus Variant

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Abstract: The COVID-19 pandemic has negatively affected educational settings (ES) in Slovenia. To effectively limit the emergence and spread of SARS-CoV-2 infections in ES, it is important to identify the pathways of introduction and transmission of infection. This study aims to analyse the spread of infections in ES according to the level of education, taking into account the predominant variant of the virus in Slovenia in order to advise on public health action. We calculated the incidence rate of infection by age group, according to the level of the ES. Additionally, we analysed data on the reported outbreak criteria in ES. In Slovenia, SARS-CoV-2 infections in children and adolescents (1–18 years) accounted for 16.8% of all confirmed infections. The incidence and leading outbreak criteria differed according to the level of the ES and predominant SARS-CoV-2 variant. The occurrence of cases in ≥ 3 different “bubbles” was the most common outbreak criteria (59%). A high number of employee-imported outbreaks was observed in pre-school settings (44%). As countries move away from widespread nonpharmaceutical interventions, the focus should be on vaccination promotion among teaching staff in pre-school settings and systemic solutions, such as self-testing and ventilation, to enable safe educational environments.

Keywords: COVID-19; surveillance; outbreaks; educational settings; children



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1. Introduction

In Slovenia, after the declaration of the COVID-19 epidemic at the beginning of March 2020, educational settings (ES) were closed and distance education introduced. Children and adolescents started returning to ES gradually in May 2020, where they finished the school year. The 2020/21 school year also started in ES, but only remained there until mid-October, when ES gradually closed. At the end of January 2021, ES began to gradually reopen, and classes were held according to different models [1,2] during the ongoing pandemic (Table 1). During the course of the pandemic, preventive and hygienic measures were recommended (e.g., formation of permanent groups, ventilation), and over time the use of protective masks became mandatory for teaching staff and adolescents in secondary school, and then became mandatory for children in primary school, but not for pre-school children. The measure of employee testing and self-testing also became mandatory for children in primary schools.

Several studies have reported low transmission of SARS-CoV-2 infections in ES in Australia [3], Ireland [4], Germany [5], North Carolina, USA [6], Italy [7], Canada [8] and Norway [9]. In Veneto, Italy, during the period January–June 2021, 69% of ES-related infections produced no secondary cases, 24% produced one or two cases, and 7% produced more than two cases [10]. However, individual studies have also reported major outbreaks of COVID-19 in ES in Israel [11], Utah, USA [12], Poland [13] and California, USA [14]. In such analyses, it is important to consider the predominant SARS-CoV-2 variant during the study period, as SARS-CoV-2 variants have different levels of infectivity, with the Omicron variant (B.1.1.529) having the highest infectivity [15].

Table 1. Openness of educational settings in Slovenia during the COVID-19 pandemic (March 2020–January 2022).

Year	Level of Education	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2020	Pre-school setting												
	Primary school												
	Secondary school												
2021	Pre-school setting												
	Primary school												
	Secondary school												
2022	Pre-school setting												
	Primary school												
	Secondary school												

Legend: green—open educational settings, orange—partially open educational settings (individual levels/alternately/regional), red—closed educational settings, grey—summer holidays, white—nonobservation period.

The closure of ES has a detrimental effect on the physical and mental health of children and adolescents, as well as on their educational performance and development of social skills [16,17]. The European Centre for Disease Prevention and Control (ECDC) has identified school closures during the pandemic as a measure of last resort to prevent the spread of SARS-CoV-2 infections, but also noted the importance of monitoring the occurrence of infections in ES [18]. In Slovenia, a monitoring system with an algorithm for responding to infections in ES, and collaboration between ES and the National Institute of Public Health (NIJZ) have been set up to monitor outbreaks of SARS-CoV-2 infections in ES; a similar monitoring system is being used in England [19].

Delivering classes during the spread of SARS-CoV-2 infections requires an awareness that outbreaks of SARS-CoV-2 infections in ES will occur. Knowledge of the prevailing modes of introduction and spread is essential for effective containment of infections in ES, allowing targeted implementation and adaptation of measures. For this purpose, we have prepared an analysis of the spread of SARS-CoV-2 infections in ES according to the level of education, taking into account the predominant SARS-CoV-2 virus variant in Slovenia.

2. Materials and Methods

In this study, the study population consisted of children and adolescents (aged 1–18 years). In order to interpret the data by level of education, the age groups of children and adolescents were adjusted to the age structure of each level of education (Table 2). The levels of education do not include post-secondary or university education.

Table 2. Presentation of age groups of children and adolescents by level of education in the Republic of Slovenia.

Level of Education	Age Group	Population by Age Group on 01.07.2021 [20]	Proportion of Population [21]
Pre-school setting *	1–5 years	100,652	4.78%
Primary school	6–14 years	198,454	9.42%
Secondary school	15–18 years	75,787	3.60%

* In the 2021/22 school year, 85,957 children were included in pre-school setting, which represents 85.4% of all children aged from 1 to 5.

The observation period in the study represents the time after the establishment of the outbreak monitoring system in ES during which the delivery of classes in the premises of ES took place during the COVID-19 pandemic, from 26 January 2021 to 24 June 2021 and from 1 September 2021 to 18 January 2022. The periods of dominance of the individual SARS-CoV-2 virus variants in Slovenia were taken into account in the study. The period of dominance of a virus variant was defined by reaching 50% prevalence of that variant in the population. A more detailed time definition of the period is shown in Table 3.

Table 3. Periods of classes in educational premises and the prevalence of each SARS-CoV-2 variant in Slovenia.

Time Period	Delivery of Classes in Educational Settings	Predominant SARS-CoV-2 Variant ** [22]
26 January 2021–28 March 2021	YES	Wuhan variant (B.1.258.17)
29 March 2021–24 June 2021	YES	Alpha variant (B.1.1.7)
25 June 2021–4 July 2021	NO	Alpha variant (B.1.1.7)
5 July 2021–31 August 2021	NO	Delta variant (B.1.617.2)
1 September 2021–2 January 2022	YES	Delta variant (B.1.617.2)
03 January 2022–18 January 2022	YES	Omicron variant (B.1.1.529)

** The period of dominance of a virus variant was defined by reaching 50% prevalence of that variant in the population.

2.1. Confirmed Cases of SARS-CoV-2 Infections among Children, Adolescents and the General Population in Slovenia

Data on confirmed cases of SARS-CoV-2 infection in Slovenia were obtained from the official register of communicable diseases, maintained by the NIJZ, based on age at the time of official confirmation of infection.

We performed a descriptive analysis of data from the epidemiological monitoring system for SARS-CoV-2 infections in Slovenia. We calculated incidence rates of SARS-CoV-2 infections by age groups of children, adolescents, the rest of the population and the general population of Slovenia. Data on the population by defined age groups were obtained from the Statistical Office of the Republic of Slovenia Si-STAT database, as of 1 July 2021 [20]. In this part of the analysis, we have extended the data analysis to the period from the occurrence of the first case of infection in Slovenia, 4 March 2020, until 18 January 2022, with a focus on the periods of delivery of classes in ES.

2.2. COVID-19 Outbreaks in Educational Settings

We performed a descriptive data analysis on the fulfilled criteria that triggered SARS-CoV-2 infection outbreaks in ES. Data on the fulfilled criteria for SARS-CoV-2 outbreaks in ES were obtained from the system for monitoring outbreaks in ES, which is used by the managers of ES for reporting in accordance with the instructions of the Ministry of Education, Science and Sport and NIJZ algorithm. The monitoring system is comprehensive in terms of legal obligations and addresses all ES in Slovenia. Reporting was carried out in accordance with the NIJZ guidelines [23]. ES reported a worsening epidemiological situation to the epidemiological department when at least one of the following criteria was met: (c1) $\geq 15\%$ of children/adolescents from the “bubble” had a confirmed infection within a 14-day period; (c2) $\geq 10\%$ of the ES teaching staff had a confirmed infection within a 14-day period; or (c3) confirmed cases occurred in ≥ 3 different “bubbles”. In the event that several criteria were simultaneously met at the time of the outbreak, all criteria met were considered in the analysis. In total, 12% of pre-school settings (48/412), 41% of primary schools (184/454) and 28% of secondary schools (43/155) reported to the ES outbreaks monitoring system.

3. Results

3.1. Confirmed SARS-CoV-2 Infection Cases in Children, Adolescents and the General Population in Slovenia

From the confirmation of the first COVID-19 case in Slovenia until 18 January 2022, a total of 559,469 COVID-19 cases were confirmed. Of these, 9911 were confirmed in the 1–5 age group, 57,983 in the 6–14 age group and 26,077 in the 15–18 age group. The incidence rate of COVID-19 cases per 100,000 population by age group of children, adolescents and the rest of the population according to the predominant SARS-CoV-2 variant and openness of ES in Slovenia is shown in Table 4. Figure 1 shows the monthly incidence rate per 100,000 population by age group for children, adolescents and the general population of

Slovenia. The figure shows the observed periods of the predominant SARS-CoV-2 virus variant during the open period of ES.

Table 4. Incidence rate of confirmed COVID-19 cases per 100,000 population by age group according to the period of predominance of variant SARS-CoV-2 and the openness of educational settings in Slovenia.

	Time Period	1–5 Years	6–14 Years	15–18 Years	Others
Period before the establishment of an outbreak monitoring system in educational settings	4 March 2020–25 January 2021	7481	12,910	41,683	88,613
Wuhan variant	26 January 2021–28 March 2021	8067	18,261	27,287	26,940
Alpha variant	29 March 2021–24 June 2021	6786	21,587	33,832	21,154
Summer school holidays	25 June 2021–31 August 2021	1470	3447	19,383	4881
Delta variant	1 September 2021–2 January 2022	51,097	155,704	143,851	88,121
Omicron variant	3 January 2022–18 January 2022	23,566	80,265	78,048	39,037

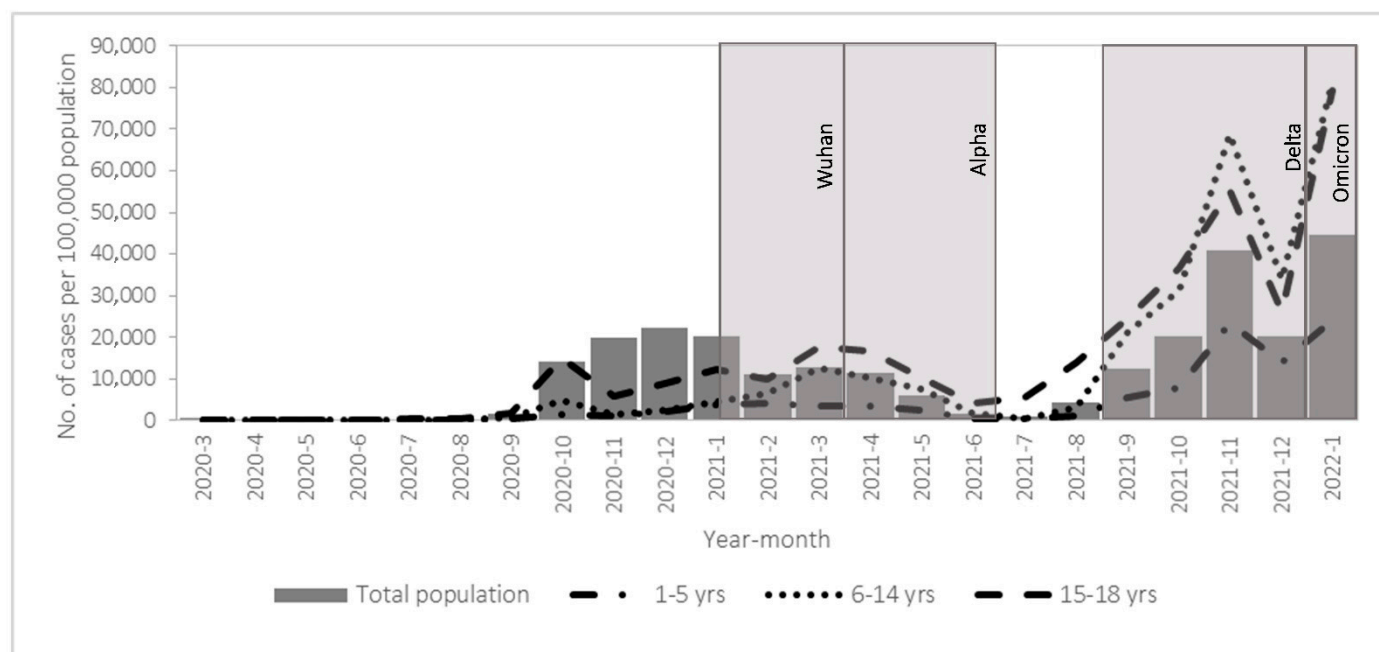


Figure 1. Monthly incidence rate of SARS-CoV-2 cases per 100,000 population by age group and total population in Slovenia, period 4 March 2020–18 January 2022. The periods of the predominant variant of the SARS-CoV-2 virus during the period of open ES are marked in the shaded fields.

3.2. COVID-19 Outbreaks in Educational Settings

During the observed period, 527 outbreaks were reported, of which 117 were in pre-school settings, 319 in primary schools and 91 in secondary schools. The most common cause for the outbreak was the criterion that ≥ 3 different “bubbles” had confirmed cases (59%), followed by $\geq 15\%$ of children/adolescents in the “bubble” had a confirmed infection within a 14-day period (25%) and $\geq 10\%$ of teaching staff in ES had a confirmed infection within a 14-day period (16%). The representation of each criterion at each level of ES according to the predominant SARS-CoV-2 variant in Slovenia is shown in Table 5 and Figure 2.

Table 5. Representation of the fulfilled COVID-19 outbreak criteria in educational settings in Slovenia in the period from 26 January 2021 to 18 January 2022, taking into account the periods of predominance of each SARS-CoV-2 variant in Slovenia.

	Pre-School Settings				Primary Schools				Secondary Schools			
	c1	c2	c3	Sum	c1	c2	c3	sum	c1	c2	c3	Sum
Wuhan variant	5	19	15	39	12	10	30	52	3	0	7	10
Alpha variant	2	13	7	22	15	6	35	56	7	0	12	19
Delta variant	9	28	24	61	67	3	121	191	14	2	39	55
Omicron variant	1	10	13	24	19	7	58	84	6	3	20	29

Legend: c1— $\geq 15\%$ of children/adolescents in bubble (fixed children's groups) had a confirmed infection; c2— $\geq 10\%$ of employees had a confirmed infection; c3—confirmed cases occurred in ≥ 3 bubbles.

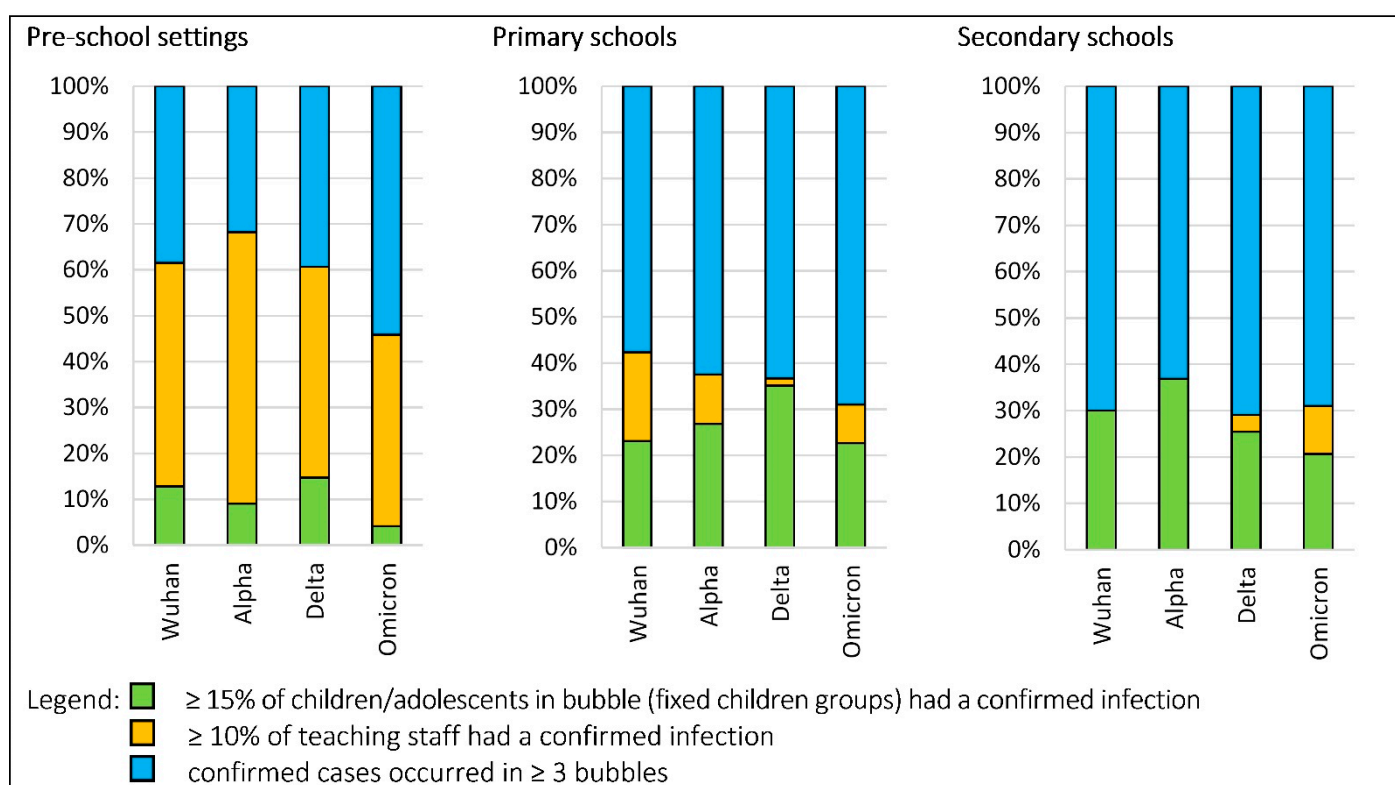


Figure 2. Representation of the fulfilled COVID-19 outbreak criteria in educational settings in Slovenia in the period from 26 January 2021 to 18 January 2022, taking into account the periods of prevalence of each SARS-CoV-2 variant in Slovenia.

4. Discussion

In Slovenia, in the period from the first COVID-19 case on 4 March 2020 to 18 January 2022, 16.8% of SARS-CoV-2 infection cases were confirmed in the age group of children and adolescents (1–18 years). During the first wave and through the summer of 2020, the number of infections among children and adolescents was low, then the number of infections started to rise at the start of the school year, until the closure of society and the consequent closure of schools at the end of October 2020. Until the gradual reopening of schools in the spring of 2021, the infection rates of children and adolescents at each level of education did not exceed those of the general population. After the gradual reopening of schools in the spring of 2021, the number of infections among children and adolescents

first increased slightly and then started to decrease until the start of school in September 2021. During this period, the infection rate among children aged 6–15 years was similar to the infection rate in the general population, while the infection rate in the 15–18 age group exceeded the infection rate in the general population, especially in the months of summer 2021. The large number of COVID-19 outbreaks on graduation trips attended by adolescents aged 17 and 18 years may also have contributed to the increase in infections [23]. In autumn 2021, after the start of the new school year and when the Delta variant was predominant, the number of cases among children and adolescents started to rapidly increase. The infection rates in the 6–14 and 15–18 age groups were consistently higher than in the general population. In October 2021, the infection rate in the 6–14 age group exceeded the infection rate in the 15–18 age group for the first time, and this continued until the end of our observation period in January 2022. In the beginning of 2022, when the Omicron variant prevailed, the number of confirmed cases among children and adolescents increased, but the infection rates for the 6–14 and 15–18 age groups remained higher than the infection rates in the general population. Over the entire observation period, the infection rate in the 1–5 age group was the lowest among all three groups of children and adolescents, and lower than the infection rate in the general population.

The COVID-19 vaccination rate among children and adolescents in Slovenia is low. In the 6–14 age group, until the predominance of the Omicron variant, vaccination coverage under the basic scheme did not reach 10%. Among adolescents aged 15–18 years, vaccination coverage with all doses started to increase during the 2021 summer school holidays and reached 43% coverage during the Omicron variant period. Data on the vaccination prevalence among teaching staff in ES was not available [24]. Vaccination experts in Slovenia recommend basic vaccination for all children and adolescents aged 12 years and older. Primary vaccination for younger children aged 5–11 years is recommended for children with chronic diseases and children aged 5–11 years who are in contact with persons at higher risk of severe COVID-19 disease and cannot be effectively protected by vaccination. People aged 18 and older are recommended to receive one additional vaccination dosage [25].

When the SARS-CoV-2 infection is introduced into ES, it can spread between members of the same “bubble” or among employees (e.g., due to socializing in common areas). With higher local transmission, the infection can be simultaneously introduced by different persons, generating further infections. The results of our research showed that during the observed period at all levels of education, the most common cause of outbreaks in ES was the occurrence of infection in ≥ 3 different “bubbles” in the ES, which means the simultaneous introduction of infection into the ES by different persons. The least common cause of the outbreak in ES varied according to the level of education; in pre-school settings, it was the occurrence of infection in $\geq 15\%$ of “bubble” members, and in primary and secondary schools, it was the occurrence of infection in $\geq 10\%$ of teaching staff. The results show that the proportion varied according to the level of education and the predominant SARS-CoV-2 variant.

In pre-school settings, the prevalence of infection in $\geq 10\%$ of the teaching staff was the leading cause during the Wuhan, Alpha and Delta variants, and the prevalence of infection in ≥ 3 different “bubbles” in ES was the leading cause during the Omicron variant. Regardless of the predominant variant, the least common cause of the outbreak in the pre-school settings was the occurrence of infection in $\geq 15\%$ of the “bubble” members. The important role of teaching staff in the spread of SARS-CoV-2 infection in pre-school settings was also shown by a retrospective study of SARS-CoV-2 outbreaks in November and December 2020 in pre-school settings in Berlin (Germany), which concluded that the spread of SARS-CoV-2 in the pre-school environment occurred mainly through teaching staff, while children transmitted the infections mainly to the home environment [26]. A possible reason for the higher representation of the fulfilled criterion for the spread of infections among teaching staff in pre-school settings compared with the other ES is that there are more teaching staff in each department who, due to the nature of their work, have

more close contacts with children. It may also indicate that pre-school teaching staff have more contacts with other employees outside the department.

In primary schools, during the entire observed period, the most common cause of an outbreak in ES was the occurrence of infection in ≥ 3 different “bubbles”, with the highest proportion in the period of predominance of the Omicron variant and the lowest proportion in the period of predominance of the Wuhan variant. The least common cause of an outbreak in primary schools was infection in $\geq 10\%$ of teaching staff with the highest proportion in the Wuhan variant predominant period and the lowest proportion in the Delta variant predominant period.

In secondary schools, just as in primary schools, the most common cause of an outbreak in ES throughout the observation period was the occurrence of infection in ≥ 3 different “bubbles” in ES. The proportion of this cause ranged between 60% and 70%, regardless of the virus variant. The rarest cause of the outbreak in secondary schools was infection in $\geq 10\%$ of the teaching staff, which was not recorded during the period of predominance of the Wuhan and Delta variants. During the period of dominance of the Delta variant, the share of this cause was less than 4%, which almost tripled in the Omicron period. A seroprevalence survey among adolescents and teaching staff in English secondary schools (UK) in September and December 2020 also suggested a role for local transmission, finding that the incidence rate was not significantly different between adolescents and teaching staff, but was similar to the population incidence rate [27].

Similar to a Spanish study [28], our results show that when analysing outbreaks and transmissions and their causes, it is important to consider the predominant SARS-CoV-2 variant at each time period in the population, as variants of SARS-CoV-2 have different levels of infectivity [15]. This is also shown in a German study [29], which found that at the appearance of the Alpha variant (B.1.1.7), the susceptibility and infectiousness of children aged 1–6 years were significantly higher compared to the pre-Alpha period and may have been approaching those of adults.

The primary importance of ES is the educational development of children and adolescents; furthermore, ES have a positive impact on their physical and mental health and psycho-social development. The extent of the overall positive impact that ES have on the development of children and adolescents was shown during the COVID-19 pandemic and the closure of ES. During this period, a decline in educational and social development, worsening of mental health problems, and negative changes in sleeping patterns, eating habits and screen use were observed [2,16,17,30]. From this perspective, it is necessary to examine the social acceptability of the measure to close ES in relation to its effectiveness in controlling the pandemic.

Data on the fulfilment of the criteria that triggered the infection outbreak in ES, which were analysed in this study, were reported in the monitoring system by the managers of individual ES. Perhaps better-quality data would have been collected if the department of epidemiology had reported to the system after an individual outbreak had been investigated. Nevertheless, we estimate that the data collected are of sufficient quality for analysis, as the ES have a detailed algorithm in place to identify the fulfilment of the criteria in the ES and report to the monitoring system. At the same time, teaching staff in ES were empowered to report through a videoconference presentation and had the possibility of online consultation in case of any questions. An important advantage of this study is the long time period covered, which includes the periods of predominance of the four SARS-CoV-2 variants in Slovenia. We have not found such results in previous studies, so our research will provide important insights for the design of targeted measures at different levels of education, including in the light of the emergence of new variants, that will allow undisturbed delivery of classes in ES, without closures and all the consequences for children’s health and development.

The need for targeted measures at different levels of education, indicated from the results of this study, should be incorporated into the COVID-19 management strategy. This strategy, linked with the characteristics of the Omicron variant, is relaxing strict nonphar-

maceutical interventions and replacing them with measures focusing on the protection of the most vulnerable populations and systemic solutions associated with the management of a broader spectre of respiratory diseases. In relation to the most vulnerable population groups, our results indicate the need to design measures with the focus on teaching staff in pre-school settings, among which promotion of vaccination against COVID-19 is significant. High vaccination prevalence among teaching staff in pre-school settings could have a significant impact on developing less severe disease symptoms and reduce absenteeism from work, both important to continue undisturbed education at ES during pandemics. Systemic solutions, from this study's results, could be self-testing of primary and secondary school children and adolescents. This would limit infections in a population group with many interactions outside of the ES, and who are responsible for the transmission into the ES. Another systemic solution on the ES infrastructure level is the ability to effectively ventilate closed spaces, as required by the characteristics of COVID-19 transmission [31]. Additionally, it is important to maintain sufficient capacities at national and international levels to monitor SARS-CoV-2 variants for the purpose of rapid adaptation of measures and strategies [32].

5. Conclusions

The first study of its kind to investigate the spread of infection in ES by level of education, taking into account the predominant SARS-CoV-2 variant, showed that the predominant causes and frequency of their occurrence vary according to the level of education, as well as the predominant SARS-CoV-2 variant. In designing further measures to limit the spread of SARS-CoV-2 infections in ES, it is necessary to be aware that the key actions are at the population level and not only in ES; since, as the results show, the most common cause of the spread of infection in ES is the simultaneous introduction of the virus by several persons from different “bubbles”. The results also showed that different virus variants affect the way the virus spreads at each level of the ES, as it is linked to the infectivity of the SARS-CoV-2 variant. This is particularly evident at the pre-school level, where interactions are closer. These findings should be taken into account in the event that new variants of SARS-CoV-2 emerge. This would mean further targeting of the recommendations at teaching staff general adherence to the recommendations and self-testing, thereby controlling infections in these population groups with many interactions also outside the ES. Measures recommended by our study are aligned with the strategy, which responds to the characteristics of the Omicron variant, as most countries are moving away from strict nonpharmaceutical interventions and replacing them with a focus on protection of the most vulnerable populations (e.g., vaccination) and systemic solutions enabling safe educational environments linked to the management of a broader spectrum of respiratory diseases (e.g., self-testing and ventilation improvements). This way, it is possible to avoid measures that have a negative impact on the process of education and socialisation in the educational system.

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Data Availability Statement: Data supporting the findings of this study are available from the corresponding author upon reasonable request.

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Conflicts of Interest: The authors declare no conflict of interest.

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