THE COMPLEX EVALUATION OF THE IMPACT OF COVID-19 PANDEMIC AT UNIVERSITIES: A SOFT COMPUTING APPROACH

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ABSTRACT

The COVID-19 pandemic impacted the educational process since the teaching process has been forced to go online in many countries. This enforced change revealed the weaknesses and strengths of the national educational systems and particular institutions. This article aims to analyse the impact of COVID-19 at selected European universities and assess the satisfaction of students, teachers, IT staff and management. This study is unique for its systematicity and complexity – it aggregates the opinions of all interested groups of stakeholders, distinguishes several time periods (before, during and after the pandemic), and allows the respondents to express hesitance in their evaluation. The evaluation model uses fuzzy sets to capture the uncertainty and to aggregate the opinions of different stakeholder groups. The empirical results show that most of the satisfaction development is the same or similar for all institutions examined. Then, the pandemic strongly influenced the satisfaction of all stakeholder groups at the universities examined. This impact was mostly negative, however, several lessons learnt have been revealed. Therefore, it was shown that it is highly beneficial to include these aspects to obtain a reliable picture of overall satisfaction.

Highlights

- *A complex model is established that covers all important stakeholder groups at various time stages with respect to the COVID-19 pandemic.*
- *The possibility of expressing hesitance in answers is considered.*
- *The forced switch to the online environment caused a substantial decrease in satisfaction for most stakeholder groups at all involved in terms of almost all factors.*
- *At all involved universities, overall satisfaction improved at the end of the pandemic, however, the final level differs with the countries.*

INTRODUCTION

The COVID-19 pandemic and the related measures applied by national governments have forced many schools all around the world to switch to online teaching mode instead of the regular on-site regime (Marinoni et al., 2020; UNESCO, 2020). For many of them, it was an absolutely first experience with distant learning, which came unexpectedly. For many universities, it cannot be considered a full-featured online teaching but a crisis teaching.

Diverse stakeholders groups were affected differently and usually had different expectations, satisfactions and complaints. These valuable, often hardy to exactly explain, experience should be collected, processed, and explained. Various surveys have been conducted among universities worldwide from different aspects: from general aspects (see, e.g., Duraku and Hoxha, 2021); from psychological aspects (see, e.g., Akour et al., 2020; Sitko-Dominik, 2021; Kim et al., 2021), motivation (Altbach and de Wit, 2020), technical aspects (Van der Graaf et al., 2021). More details are in Section 2. Many studies do not focus on a particular consequence of distance learning, but rather an evaluation of its quality and satisfaction of the stakeholders. The conclusions of these studies often differ substantially. But to our best knowledge, not a single survey has considered the hesitance of respondents caused by various factors. Collecting, processing and interpreting results in this environment is a demanding task. In addition, various stakeholder groups differ in the number of people and the relevant questions. In this environment, questionnaires should be tailored to each group. To solve this task, we adopted concepts from fuzzy sets and fuzzy logic in general (e.g., Galindo, 2008; Kacprzyk and Zadrozny, 2009), the theory of aggregation functions (summarized in, e.g., Grabisch et al., 2009; Grabisch, 2003), and the method for flexible data collection (including hesitance) and evaluation of answers proposed in Zapletal et al. (2023).

This article explores the experience and satisfaction with distance learning during the COVID-19 pandemic compared to before and after the pandemic situation (or at least when restrictions were relaxed) at selected European universities. The idea was to ask influenced stakeholder groups at universities about their opinions on the past development of working in an online regime, as well as its current state. This will help to reach three following aims:

- Describe the situation from the perspective of diverse interested groups (students, teachers, management, students' affairs departments, IT staff) at universities. Knowledge of differences between the institutions (cultural, social, technical) and between attitudes of different groups can be the source for further improvement and harmonisation of the systems.
- Understand the developments in the time from the beginning of the pandemic, during the pandemic, and after releasing restrictions. Knowledge of the adaptation of different stakeholders groups in four countries can be compared with the other works and a source for various sociological research.
- Explore the impact of hesitance on answers, i.e., whether respondents have clear opinion, or rather use this option to declare their hesitance. The recorded hesitance can also be a source for further research related to areas of a higher hesitance and the development of hesitance in time.

The analysis done in this paper is based on the survey performed at four European universities (Technical University of Ostrava, Czech Republic; Technical University of Košice, Slovakia; University of Economics Katowice, Poland; University of Santarem, Portugal) in 2021 within the project DANTE - Digital Area for Networking Teachers and Educators no. 2020-1-CZ01-KA226-HE-094368. The first three countries have similar higher education systems, are culturally and geographically close to each other, and were affected by the covid pandemic at the same time, and universities were pushed to the transition to online under similar conditions with little experience in distance education. Meanwhile, the Portuguese university exists in a different environment and has long experience in distance education as it provides educational activities in multiple countries on different continents.

The rest of this paper is organised as follows. First, the state-of-the-art analysis is introduced in Sec. 2. This analysis is focused on (a) mapping the satisfaction with blended learning at universities and (b) requirements relevant to collecting and processing uncertain answers and interpreting the results. This analysis gave space for adopting the methodology which is introduced in Sec. 3. Sec. 4 is devoted to the data collection. Namely, the questionnaire designed within the project and the survey realisation are presented there. The core section of this report is Sec. 5, since the results are introduced and thoroughly discussed there. The article ends with the concluding messages in Sec. 6.

STATE-OF-THE-ART ANALYSIS RELATED TO DISTANCE LEARNING AND SURVEYS

This section introduces existing studies and approaches of distance learning evaluation and requirements for covering hesitance of answers as well as the relevant concepts required for the survey among the participating universities.

Evaluation of blended and distance learning

A sudden switch to lockdown during the COVID-19 pandemic forced teachers and students into online teaching and learning. The UNESCO study (2020) claims that the nationwide closures affected more than 91% of the world student population. This unprecedent change brought many troubles as well as opportunities. It is natural that immediately after this enforced change occurred, a large wave of research was focused on distance learning and the recognised issues. Most of the studies performed are supported by surveys among students, teachers, or even parents; see Duraku and Hoxha (2021). The studies differ in the geo ical location where the survey was conducted and in the levels of education. It should be noted that the COVID-19 lockdown affected the people surveyed not only by closing schools, but also in other areas of their lives. Therefore, it should be taken into account that if the online regime is applied during the "regular" (meant non-pandemic) period, the evaluation of distance learning could be different. The lack of direct social contacts, the necessity to adopt new skills in a short time, and crucial changes in time management are the most frequently mentioned reasons in the literature. The study presented by Akour et al. (2020) confirmed the negative psychological impact of distance teaching during the COVID-19

pandemic (the study has been implemented in Jordan). Hoofman and Secord (2021) showed that the necessary rapid adaptation of both students and teachers was uneasy and had some negative impacts. They also confirmed the negative impact of the situation on students' mental health. The analysis was more focused on high schools, thus, many evaluation criteria are not applicable in our study. However, an interesting conclusion is that computational knowledge suffered more during lockdown than the knowledge of language, arts, etc. Duraku and Hoxha (2021) explored the possible negative impacts of the sudden change in the teaching regime on teachers' mental health. They showed that forced distance learning during the COVID-19 pandemic has a significant impact on the deterioration of mental health and even behavioural changes for children. Jakubowski and Sitko-Dominik (2021) focused purely on teachers' mental health during the pandemic in Poland because they felt under high pressure, especially during the first part of the lockdown. The study confirmed that the pandemic and related online teaching caused a blurring of the frontiers between teachers' professional and private lives. Kim et al. (2021) also explored the impact of closing and reopening schools on teachers' satisfaction and well-being. A group of 24 teachers from UK basic and secondary schools was surveyed and the results showed that the school governments should support teachers to feel autonomous, competent, and connected with colleagues.

Next, Goudeau et al. (2021) explored that distance learning during the lockdown will probably increase the social class gaps in society. Mishra et al. (2020) concluded that it is necessary to develop multimodal approaches to achieve course content objectives for a better learning outcome to deal with the complexity of online education and emphasised the role of high-quality technical equipment. It is worth highlighting that the study by Mishra et al. (2020) has been applied in India where the conditions are hardly comparable to those of Central and Western Europe. Despite that, many criteria for assessment in India are the same as in the European environment. Duraku and Hoxha (2021) showed the crucial role of good communication among teachers, students, and parents. Furthermore, the satisfaction of the students and teachers is highly dependent (one cannot expect a highly satisfied student if teachers feel frustrated and vice versa), thus they propose that teachers should feel involved and motivated for changes. Van der Graaf et al. (2021) emphasized the necessity of improving the technological support by both hardware and software to provide efficient distance learning. According to Shim and Lee (2020), students and academics argue that distance learning is "inferior" and not of the same quality as face-to-face lessons. Means and Neisler (2020) presented the study that showed that satisfaction and motivation decreased substantially during the pandemic (more than 50% of US students felt dissatisfaction after going online). Altbach and de Wit (2020) saw the main challenge of distance learning during the pandemic in keeping the motivation of students to work hard enough even without face-to-face contact.

On the other hand, there are also studies that reveal the positive impact of distance learning during the pandemic. Almendingen et al. (2021) surveyed Norwegian university students. Their results showed that students got used to distance learning quite quickly (a significant improvement was apparent in a couple of months) because of the high-quality support from online teaching materials and frequent communication with teachers by software. However, students suffered from a lack of social contact during the lockdown. Khalil et al. (2020) performed a qualitative study among medical students in Saudi Arabia. This study came with interesting results that the online modality was well received by students and their performance improved during distance learning.

Some studies also looked into the future and asked questions like "what online tools should also be preserved for times after the pandemic". It would be too simplifying to claim that if students and teachers felt highly satisfied with distance learning during COVID-19, then this way of learning should also be used also in the future (and vice versa). UNESCO (2020) claims that despite all troubles caused by a sudden switch to the online environment, the situation in the last two years provided an unprecedented opportunity to increase the resilience of national education systems and transform them into equitable and inclusive systems. Rapanta et al. (2020) claim that online teaching is an essential part of the professional preparedness of universities anywhere in the world nowadays…

The enthusiasm for maintaining at least some elements of distance learning in the future is also shared with some studies built on surveys. Pokhrel and Chhetri (2021) conducted a survey among teachers and students at different levels of education in Bhutan. The authors found that both students and teachers should be focused on use of different online educational tools and after the normal classes resume, they should be encouraged to continue using them. In the study by Khalil et al. (2020), medical university students in Saudi Arabia would mostly prefer online learning also for the future despite they confessed that they had to deal with several challenges during the lockdown period like technical troubles, troubles during exams, etc.

The studies mentioned above helped us to choose the set of evaluation criteria for our complex model (distinguishing didactical, technical, and social factors seems to be reasonable). The factors must be adapted to the fact that our survey has been done in universities in Western and central Europe. We considered different groups of stakeholders. Teachers and students are straightforward, considering our aim, but we want to make our model more complex. We also asked the other members of staff at universities: IT staff (they play a crucial role during the online regime, like technical support), members of the study affairs department, and university management. Duraku and Hoxha (2021) claim that communication among all these stakeholder groups is even more vital during the distance mode than in the face-to-face mode.

Satisfaction with a school in general is a qualitative measure highly influenced by emotions and hesitance in expressing them. Therefore, it is highly reasonable to allow interviewees to reveal their feelings as accurately as possible by including the uncertainty in answers (classical linguistic evaluation scales such as the Likert scale covering only answers from absolutely yes to absolutely no are not sufficient; see Zapletal et al. (2023)). To the authors' best knowledge, no such study has been published so far (at least for the COVID-19 period).

Another contribution of the study should lie in the aggregation of partial satisfaction of individuals through all considered criteria and for all members of each stakeholder group together. The complexity of the proposed model should help to understand the distance learning process in a more systemic way than in past studies.

The needs and requirements for flexibility in the survey and evaluation of answers

Valuable information can be obtained by collecting and analysing opinions from diverse stakeholder or respondent groups, which usually have different backgrounds and are variously affected by the topics under survey (Albert and Tullis, 2013).

The following requirements should be considered:

- Stakeholder groups naturally have different levels of expertise and skills, as well as they differ in preferences and goals (teachers, students, technical staff, etc.). Therefore, questionnaires should be tailored to each group to improve their cooperation in surveys (Snijkers et al., 2013; Torres van Grinsven, 2015). In addition, the hesitation when providing categorical answers should also be supported.

- Different sizes of these groups. It causes differences in the number of questionnaires filled in by each group, the different number of questions and their granularity and, therefore, the need for a robust and flexible aggregation (Rakovská and Hudec 2019; Švaňa et al., 2021).

- The evaluation should be performed at the individual level, as well as at the level of the respondents' groups and among the groups considering the relevancies of subsets of the groups related to the particular evaluation (Zapletal et al., 2023).

In our opinion, a survey which does not consider these requirements could be considered simplified. Anyway, this work considers the conducted survey in a complex way to cover the hesitance and aggregation of answers influenced by the hesitance. When hesitance should not be collected, the adopted model does not change. It only uses precise (crisp) values instead of fuzzy numbers and elastic quantifiers.

To achieve this, we adopted the fuzzy logic theory and the theory of aggregation functions. The next section explains the preliminaries of these theories and the method initially proposed in Zapletal et al. (2023).

METHODOLOGY AND METHODS

Since the proposed methodology is based upon the uncertainty expressed by hesitance and vague data, preliminaries of the fuzzy sets are introduced in this section.

A fuzzy set A (a subset of universe X) is expressed by the membership function $\mu_A(x)$, which assigns the membership degree α, $\alpha \in [0, 1]$, to each $x \in X$ (Zadeh, 1965). The set of x for which the assigned membership degree is equal to 1 is called the core of the fuzzy set (core(A)). The set of x for which the assigned membership degree is positive is called the support of the fuzzy set (supp(A)); see, e.g., Klir and Juan (1995).

Two examples are fuzzy concept, in our case, positive opinion and fuzzy number, in our case, the answer m with hesitation are shown in Figure 1, where the dashed line stands for the precise answer m and the crisp opinion *positive*. Triangular fuzzy numbers are more suitable to express hesitance around a particular answer. The modal point is only in this value, while the level of hesitance is reflected in the skewness of the support. In case of trapezoidal fuzzy set, an interval express answer and, therefore, the hesitance is maximal in its vicinity.
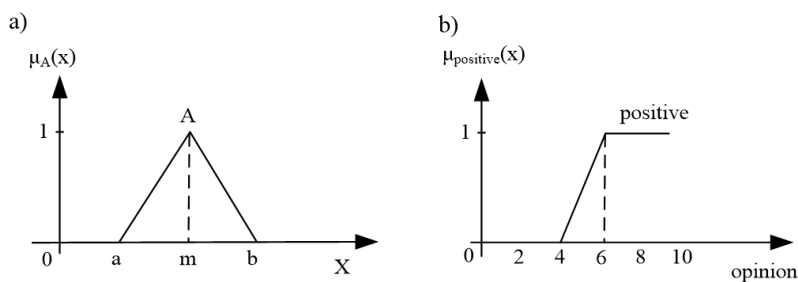
a)

b)

Figure 1: Fuzzy sets: a) triangular fuzzy number *A*(*a*, *m*, *b*) and fuzzy concept *positive opinion* (Zapletal et al., 2023)

In this work, the answers covering hesitance should be aggregated. The extension principle of fuzzy numbers (Ramík and Vlach, 2012; Zadeh, 1996) formalises the summarisation of fuzzy sets and multiplication by a parameter. When piecewise liner membership functions are used, then the extension principle is straightforwardly simplified. Thus, the sum of two fuzzy numbers $A(a_A, m_A, b_A)$ and $B(a_B, m_B, b_B)$ is expressed as

$$A \oplus B = \left(a_A + a_B, m_A + m_B, b_A + b_B \right), \quad (1)$$

while multiplication by parameter is calculated as

$$p \bullet A = \left(p \bullet a_A, p \bullet m_A, p \bullet b_A \right). \quad (2)$$

Note that the parameter p is any non-negative real number (including 0, as multiplication with 0 leads to the singleton 0). Thus, the arithmetic mean of three fuzzy numbers A, B, C is computed as

$$M = \left(p \cdot (a_A + a_B + a_C), p \cdot (m_A + m_B + m_C), p \cdot (b_A + b_B + b_C) \right), \quad (3)$$

where $p = 1/3$.

The next required concept is the possibility measure that a fuzzy number A belongs to the fizzy concept FC. It is calculated as (Galindo, 2008)

$$\text{Pos}(A, FC) = \sup_x \min \left(\mu_A(x), \mu_{FC}(x) \right). \quad (4)$$

An example of three fuzzy numbers and their respective possibilities to belong to the fuzzy concept is depicted in Figure 2.
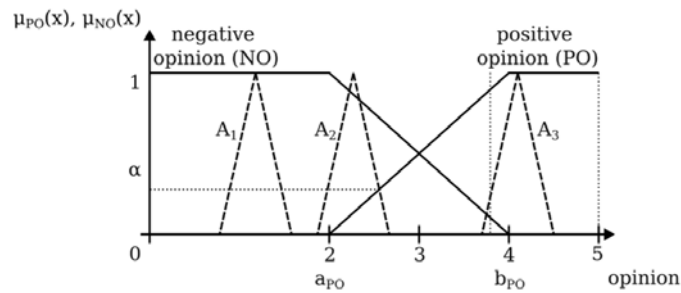
Figure 2: Definition of positive and negative opinion and example of a possibility measure for three fuzzy numbers: Pos(A_1, PO) = 0, Pos(A_2, PO) = α, Pos(A_3, PO) = 1

Next, we need a linguistic quantifier for *most of the calculations* to calculate the validity of the sentence: Most of *the respondents* have positive (neutral, negative) opinion. Quantifier *most of* is depicted in Figure 3.
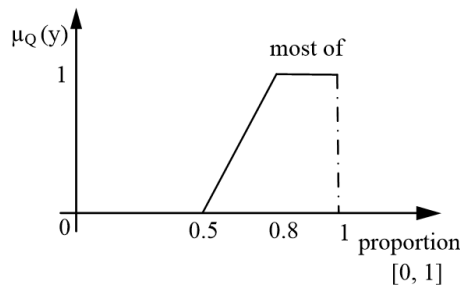

Figure 3: Linguistic relative quantifier *most of*. (Zapletal et al., 2023)

A formal structure of quantified sentence is *Q entities have P*, where *Q* is quantifier and *P* predicate. The validity of such a sentence is calculated as (Yager 1982, Kacprzyk and Zadrozny 2005)

$$v(Q_x(P_x)) = \mu_Q\left(\frac{1}{n}\sum_{i=1}^{n}\mu_P(x_i)\right), \qquad (5)$$

where *n* is the number of entities and $\mu_Q(x)$ $\mu_P(x)$ formalise the quantifier *Q* and the predicate *P*, respectively.

In the theory of aggregation functions, three main axioms, monotonicity, and two boundary conditions: $f(0, 0,…, 0) = 0$ and $f(1, 1,…, 1) = 1$ should be met (Grabisch et al., 2009). When not a single respondent answer belongs to the positive opinion, the validity of the summarised sentence is 0. On the contrary, when all the answers express a clear positive opinion, the validity is 1. When the number of positive answers increases, the result of aggregation either remains the same or increases. Therefore, all three axioms of the proposed method for evaluating opinions related to evaluating education are met.

Furthermore, this aggregation way mitigates the influence of careless answers (that is, respondents who provide neighbouring values instead of the desired ones are evaluated similarly (Rakovská and Hudec 2019)) and handles hesitance in responses. Moreover, this approach deals with the group sizes of the problem of the unbalanced respondents and their backgrounds. It causes a different number of questions in each respondent group, because questionnaires are tailored to these groups.

Using this approach, we can compare opinions of different stakeholders' groups regarding the education at the beginning of COVID-19, during the pandemic, and after the relaxation of the pandemic measures at one university and among the participating universities.

An overall opinion for a university considering all stakeholder groups can be calculated by various aggregation functions, because the result for each stakeholder group is in the unit interval. Aggregation by arithmetic mean is a possible solution but oversimplified because groups do not have the same relevance for different criteria. This can be covered by weights, but weight also weak points (see, e.g., Dujmovi, 2018). Aggregation among respondents' groups should consider the relevance of groups and subsets of groups. It could be managed by the fuzzy measure and the discrete Choquet integral. More details related to the theory of this robust approach are in, e.g., Grabisch et al., 2009.

The adopted methodology can be concluded in the following 3 steps:
- Expressing each individual opinion with hesitance using a triangular fuzzy number.
- All opinions provided by a single individual are aggregated for all questions.
- The possibility of belonging to the predefined quantities 'positive' and "negative" opinion is calculated (4).
- The aggregation of individual values is aggregated using linguistic quantifiers 'most of' (5).

INPUT DATA

As mentioned earlier, the survey by the questionnaire has been used to gather the required input data (opinion and hesitance). This questionnaire and the related survey are described in this section.

Structure of the questionnaire

The questionnaire has been built based on the interactive discussion and mutual agreement among the members of the project team from four participating universities. VŠB –

Technical University of Ostrava (Czech Republic), Technical University of Košice (Slovakia), University of Economics in Katowice (Poland) and University of Santarem, (Portugal). The questions were chosen to cover all the important factors that influence the satisfaction of all university stakeholders with the distance learning during the COVID-19 pandemic. The set of questions varies with the stakeholder groups because the whole set is not relevant for all groups.

The following five groups have been considered:

- Teachers (T).
- Students (S).
- University management (M).
- Study affairs office (SA).
- IT staff (IT).

Regardless of the groups, all questions were evaluated using the Likert scale. Value 1 corresponds to the lowest satisfaction with a factor; value 5 corresponds to the highest satisfaction with the given factor. To be able to assess the progress in time, the questions were tied with the three time stages: Before the pandemic (P0), at the beginning of the pandemic (P1), at the realisation of the time of the survey (P2), i.e., more or less at the end of the pandemic, or at the time of a significant reduction of pandemic restrictions. Next, the interviewees could express their level of certainty in provided answers. (0 = I'm absolutely sure with my answer, 1 = I feel a weak hesitance, 2 = I feel strong hesitance and therefore my answer is driven mostly by my feelings). The very last evaluated factor was the weight of each evaluated criterion (1 = weak importance, 2 = medium importance, 3 = strong importance). The list of questions that evaluate satisfaction with past and current states can be found in Table 1.

Question group	Question	Groups of respondents	Periods
Technical issues	Do you consider the quality of the internet sufficient?	S	P1, P2
	Do you consider your HW equipment sufficient?	S, T, IT	P1, P2
	Are you satisfied with the SW platform used at lessons?	S, T, IT	P1, P2
	Are you satisfied with the helpdesk support?	S, T, IT	P1, P2
Teaching issues	Do you find the lessons attractive?	S, T, M	P0, P1, P2
	Do you feel motivated to work hard?	T, S	P0, P1, P2
	Do you find the time demand of your duties adequate?	S, T, IT, SA, M	P0, P1, P2
	Do you think that tests are fair?	S, T, IT	P0, P1, P2
	Do you consider the course evaluation by students at the end of a semester beneficial?	S, T, SA, M	P0, P1, P2
	Do you consider the support by digital study materials sufficient?	S, T	P0, P1, P2
Communication issues	Are you satisfied with the quality of direct communication with students?	T, M, SA	P0, P1, P2
	Are you satisfied with the quality of indirect communication with students?	T, M, SA	P0, P1, P2
	Are you satisfied with the quality of direct communication with teachers?	S, M	P0, P1, P2
	Are you satisfied with the quality of indirect communication with teachers?	S, M	P0, P1, P2
	Are you satisfied with the quality of communication with non-teaching staff?	S, T, M	P0, P1, P2
	Are you satisfied with the communication of information by university management?	S, T, SA, IT, M	P0, P1, P2

Table 1: Questions of the questionnaire with distinguishing groups and time periods.

The triangular fuzzy numbers, representing individual opinions on each question, are established as follows. The core of each number m is equals the selected value from the Likert scale (1 to 5). The support is calculated based on the expressed hesitance level h (from 0 to 2) as an interval:

$$\left[\min\{1, m - h\}, \max\{5, m + h\}\right].$$

That means that the fuzzy number collapses to the crisp value if there is no hesitance in the answer. The bounds are set to respect the levels of the Likert scale.

A fuzzy sets *positive opinion* and *negative opinion* can be found in Fig. 2. The way how these sets have been defined, has been adopted from Zapletal et al. (2023).

Realisation of the survey

The questionnaire has been implemented in Google Forms; see Appendix B. Each university prepared its own language mutation (in Czech, Slovak, Polish, and Portuguese language). All respondents responded voluntarily. All participating students study economics full-time study programmes. Another criterion that had to be met was that all students must be at least in the third year of study (to compare the state before and during the pandemic).

Regarding the teachers, no restrictions have been put in place. Most teachers teach economic-orientated courses. However, teachers of mathematics and informatics also participated in the survey. The IT department includes non-teaching staff responsible for IT support (without further specification). The study affairs department consists of checking whether students meet all legislative requirements and duties. The management group consists of the members of the dean's office (presidents)

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and vice-deans (vice-presidents), the heads of institutes and departments, or people who guarantee the study programmes. The number of surveyed individuals at the participating universities and with distinguished respondent groups can be found in Table 2. These numbers respect the size of the institutions surveyed.

No. of respondents	CZ (Ostrava)	SK (Košice)	PL (Katowice)	PT (Santarem)
Students	294	221	333	153
Teachers	55	27	113	52
IT staff	9	2	6	6
Study affairs dept.	10	2	46	27
Management	4	6	12	8

Table 2: Numbers of interviewees

RESULTS

This section presents the results of the survey analysis. To keep the clarity of the outputs, we abbreviated the findings from the participating universities in the following way: VSB – Technical University of Ostrava (CZ), Technical University of Košice (SK) University of Economics in Katowice (PL) and University of Santarem (PT).

The comparison of the revealed levels of satisfaction between universities at a given time period can potentially have some explanatory power. However, one must be very careful with the conclusions. To some extent, the scale's perception can be influenced by the language mutation and other factors. In spite of this fact, a substantially worse evaluation in PT by students, teachers, and IT staff (and the other way around better evaluation by the management) would definitely be worth further investigation. However, we will focus more on the development of the opinions in time. The revealed pattern shows well the impact of distance learning and the pandemic.

By observing the proportion of positive and negative opinions in general, we recorded a decrease in the proportion of satisfied individuals at the beginning of online teaching. At the end of the fully distant teaching period, the proportion of respondents with a positive opinion increased. In many cases, it exceeded the proportion of positive opinion before the pandemic. There are several exceptions where the increase in satisfaction was revealed between all consecutive periods: in the study affairs department in SK and PT, students in PL, management except of PL, and IT department in PL (information about IT staff satisfaction in Slovakia before the pandemic is, unfortunately, missing). These exceptions suggest that the pandemic has been managed extremely well. In the case of the study affairs departments, such development is reasonable since many processes have been digitalised (and thus made more comfortable for the staff). The development from the perspective of the IT department was caused mainly by the significant improvement of IT equipment (and maybe by increased importance of this department during the distance learning period too). The university management is probably very well aware of the demandingness of the COVID period for both teachers and students. Therefore, its increasing trend in satisfaction can be related with the sense of pride towards these groups. It should be noted that the results in CZ have potentially been impacted to some extent by the political cycle. The reason of the pattern in the case of the Polish students is not traceable from the results, but it is for sure good news for both teachers and management of the university in Katowice.

In general, the proportion of students and teachers positive outlook was lower than in the student affairs departments and management at the beginning of the pandemic. It was observed in all countries. The reason might be that processing some bureaucratic issues online is not as demanding as the teaching process. The most significant decrease is recorded in the PT, mainly in case of students. Presumably, in south Europe, people generally prefer direct contact and communication. After the pandemic, in the student affairs department, the proportion of positive opinion is the highest in PL (0.97), while the proportion of positive responses among the students was the lowest in PT (0.72). The positive opinion at the end of the pandemic outperforms the positive opinion before the pandemic, whereas in a few cases, it reaches almost the same value or was slightly below (students in PT). The lowest positive opinion was in the IT department in SK at the start of the pandemic (0.46) and among students in PT (0.63). The maximal positive opinion was recorded in student department affairs in SK and in IT department in PT. The resulting proportion of positive overall opinions is shown in Figure 4.

When one looks at a negative opinion, only in one case most of respondents have a negative opinion: IT department in Slovakia. The main reason is a insufficient level of equipment with technologies and the unfairness of exams in the online environment. In the Department of student affairs, the proportion was highest 0.32 (CZ), among teachers (PT) 0.39, in management 0.41 (PL), among the students 0.47 (PT), and in the IT department 0.86 (SK), which was the highest proportion of negative opinion. All these values were revealed for the beginning of the pandemic.

We recorded similar behaviour among teachers and students (with the exception of Polish and Portuguese students already discussed above). The highest positive opinion is recorded after the pandemic of 0.91 (SK), while the highest negative opinion was 0.32 (PL) at the beginning of the pandemic.

The resulting proportion of negative overall opinions are shown in Figure 5, respectively.

At the end, let us take a look at the impact of the hesitance in the provided evaluations. For this reason, the results have been recalculated ignoring the effect of the uncertainty, i.e., like all respondents were sure about their answers. This is reflected in the aggregated level on the whole respondents' groups managed by the quantifier *most of* (5). For instance, students in PT have more positively rated all the stages when considering hesitance than those without this option (Figure 6). Interestingly, the same observation was recognised in the other
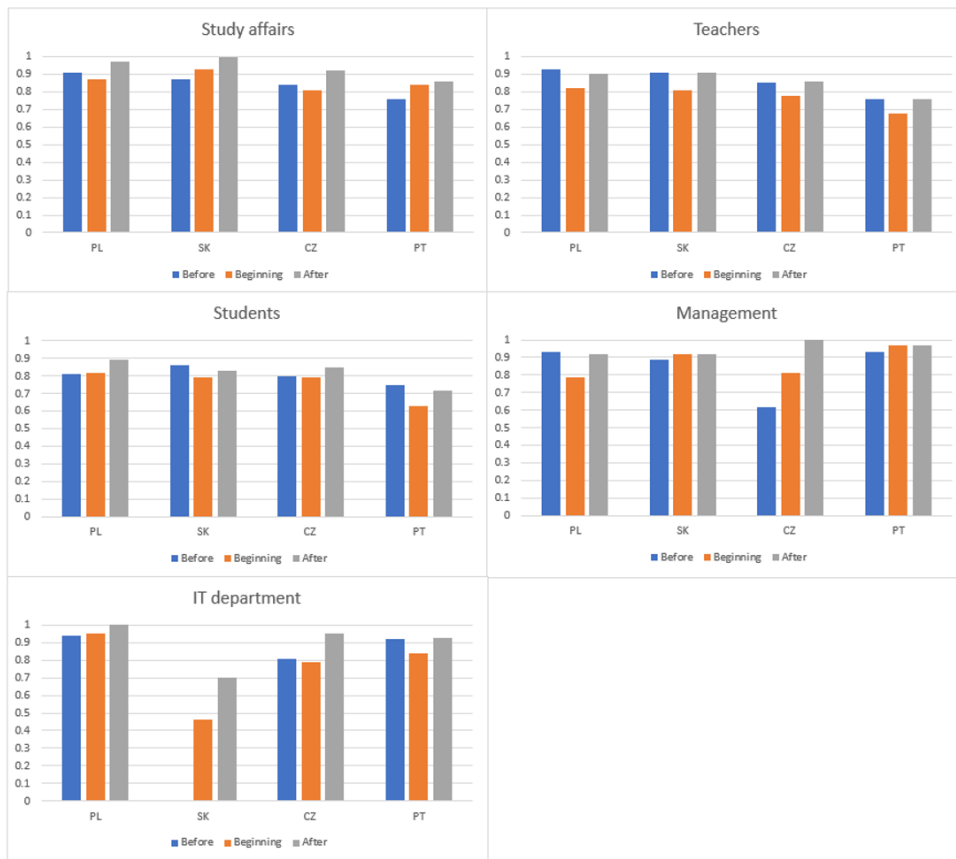
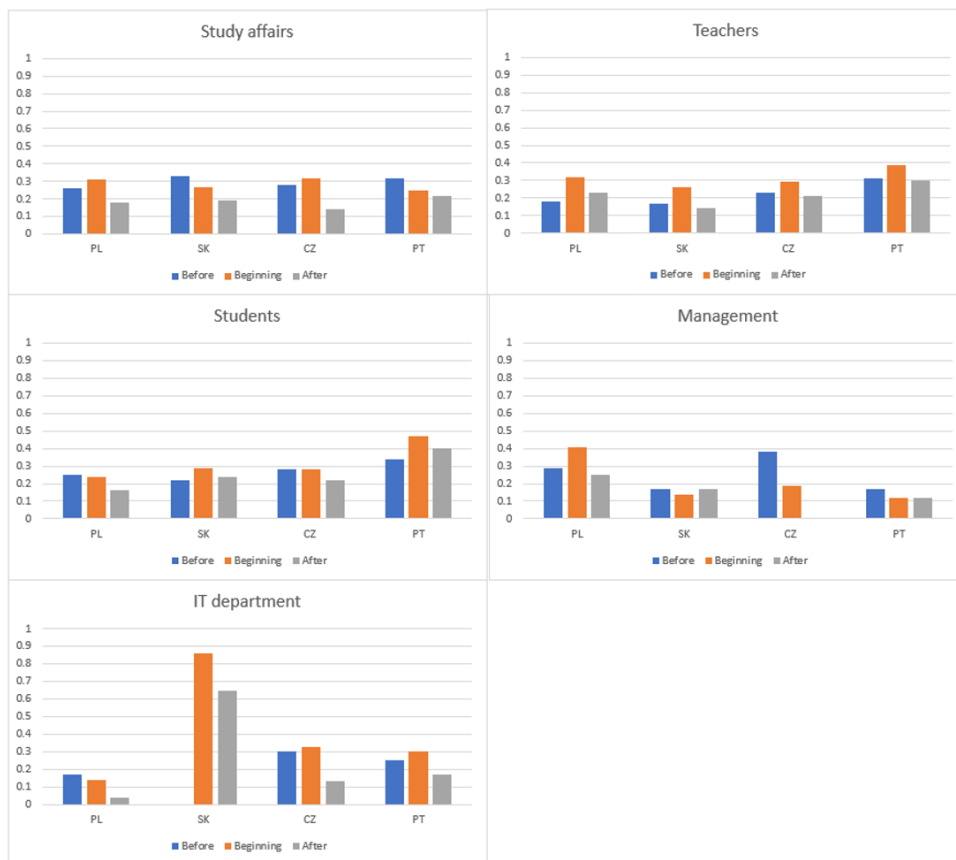**Figure 4: The overall result of the survey among different stakeholder groups – positive opinions.**

Figure 5: The overall result of the survey among different stakeholder groups – negative opinions.

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Printed ISSN
2336-2375

Electronic ISSN
1803-1617

ERIES Journal
volume 16 issue 3

universities for students and teachers (where the differences are lower). When applying the quantifier *most of* to the negative opinions, the resulting membership degree is equal to 0 for all stakeholder groups. That means that we can be sure that there is no group where most of individuals agree.

Generally, the results with and without hesitance do not change significantly. This is not so surprising result, because the target respondent groups are involved in university activities, i.e., they are more or less familiar with this environment. The results with hesitance have shown a slightly stronger positive opinion than the results when respondents were not able to express hesitance. We recorded that those who responded who are more involved in the survey under evaluation and are more experienced have a lower difference in answers.

This raises a question for future research. It would be welcome to realise survey considering hesitance among the general public for, e.g., topics related to the activities in cities.
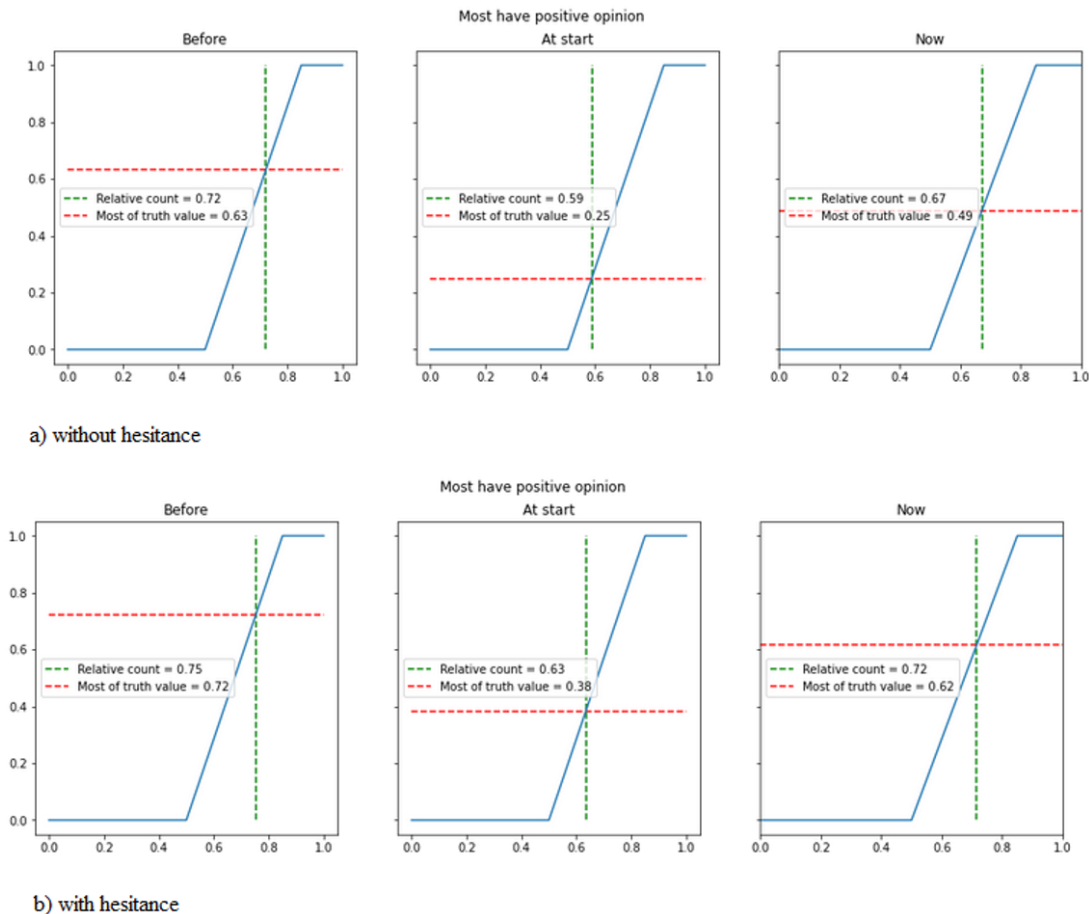

Figure 6: The results of quantified aggregation *most of the students have positive opinion* for students in Portugal: a) without hesitance, and b) with hesitance.

Detailed discussion on the results

To support the aggregated results and explain them better, let us explore more the results of the selected questions. As for the drops of the overall satisfaction between the pre-pandemic period and the beginning of the pandemic, and their return back up (regardless whether below or above the original level), the following issues contributed the most:

- The motivation to work hard decreased rapidly after switching to the online regime for both students and teachers. For all universities except for SK, the values improved (however, not up to the original level). This exception is not so surprising since the teaching process had still been kept partially online in SK. This general pattern indicates how demanding the beginning of the pandemic was in all universities. This result is in line with Gonçalves et al. (2020), Ferraro et al. (2020), and Lassoued et al. (2020).

- The motivation discussed above is strongly related to the attractivity of the lessons. Both these factors followed more or less the same pattern of development. No study has been found that included the attractivity of the lessons in the online environment. However, Chen et al. (2020) revealed a substantially decreased engagement of the students in the lessons, which can be regarded as one of the factors of attractivity.

- University teachers revealed increased time at the beginning of the pandemic (unlike students whose satisfaction in terms of this factor remained almost the same when going online). Due to a lack of experience with online teaching, teacher evaluation is highly reasonable. This result is supported by the study performed by Marek et al. (2021).

- Students and teachers are aware of the better availability of study materials. This factor is rather objective because teachers were forced to write down new materials quickly to make the teaching process manageable for students. Lassoued et al. (2020) concluded their study with the recommendation to provide more online materials to keep the quality and satisfaction of students when learning online.
- All questioned groups (students, teachers, IT staff, management) expressed that the exams online are far from being fair as in the face-to-face regime. This conclusion is fully in line with the analysis by Gonçalves et al. (2020), where Portuguese students were surveyed.
- The quality of direct communication with students decreased rapidly at the beginning of the pandemic at all universities. Some students could feel lost after the sudden switch, demotivated, and the phenomenon of a black passenger can also be one of the reasons. On the other hand, the satisfaction with the direct communication of students with teachers remained more or less the same in time. The only exception is Poland, which can at least partially explain the extraordinary satisfaction of Polish students discussed at the beginning of this section. Worse communication between students and teachers was mentioned in the list of the main obstacles of distance learning by Gonçalves et al. (2020).
- All questioned groups (students, teachers, IT staff, management) are aware of improvement in technical support since the beginning of the pandemic: hardware and software equipment. Universities and students have invested significant financial resources to bridge the pandemic as smoothly as possible. It is a great benefit that this equipment is still available for users even for the future. The issue of bad technical equipment is emphasised especially in studies performed in the developing countries, like Lassoued et al. (2020), but this study confirms that this aspect should not be underestimated in developed economies too.

Unfortunately, it is not possible to compare the aggregated results, since almost no study also compared the opinions for the return to the on-site regime after the pandemic. Almendingen et al. (2021) is an exception where the (positive) progress in satisfaction during the pandemic is revealed. This progress was also confirmed to some extent in this study. It can be expected that some other studies devoted to this issue will be conducted soon. In general, the decrease in satisfaction (despite not being as aggregated as it is presented here) in the case of students and teachers is a common conclusion of most studies, see, e.g., Ferraro et al. (2020) where the quantified decrease in terms of some factors was revealed, or see other studies cited in state of the art analysis in Section 2.

A note to the possible further work

Research has focused on distance learning from various perspectives. But what is still missing is the evaluation of the perspective of disabled students (Rakovská and Kanáliková, 2019). The proportion of disabled students is significantly lower and due to different kinds of disability, creating suitable

surveys (past experiences and future preferences) is very demanding.

Another issue, which has not been considered in this study, and which was discussed by some other researchers, is the impact of online learning on the health of stakeholders, see Jakubowski and Sitko-Dominik (2021). Many studies confirmed the increased level of stress and disorders caused by learning and teaching in the online regime; see Marek et al. (2021) or Chen et al. (2020).

If we want to get the overall overview of a university (and compare universities), considering all respondents categories, we should consider so-called coalitions of groups. For example, in the evaluation of the content of (online) teaching, students and teachers are more relevant than technical staff and the student affairs department. When evaluating technical support, the situation is the opposite.

Assigning weights to groups is a problematic and oversimplified solution because it does not consider weights of the aforementioned sets of groups. The answer could be applying so-called capacities by fuzzy measures and aggregation by Choquet integral, see Grabisch (2009). The special cases of this integral are arithmetic and weighted arithmetic mean (in the case when all groups are equally important, or importance is different considering each group independently, respectively). Hence, we will be able to cover the simplified as well as more complex requirements for evaluation among groups by one function. This way is also promising for evaluation. Thus, it is an important topic for future research.

In our work, we applied the possibility measure (4). The possibility measure expresses an optimistic answer's matching degree to the concept. On the other hand, the necessity measure expresses pessimistic, i.e., is significantly restrictive (Galindo, 2008), which might in many cases lead to a degree equal to 0. A convex combination of these two measures could be a solution. But it raises the question of adjusting the parameter value expressing the position between possibility and necessity in the form

$$\mu(A, FC) = \lambda \cdot \mathrm{Pos}(A, FC) + (1 - \lambda)(Nec(A, FC)), \quad (5)$$

where $\lambda \in [0,1]$ and $Nec(A, FC) = \inf_x \max\left(1 - \mu_A(x), \mu_{FC}(x)\right)$. It leads to a more complex form of evaluation. Anyway, it is a topic for future research.

CONCLUSIONS

The performed survey brought multiple contributions. First, a very robust model portable to any university (and after some modifications also to secondary schools) has been developed. Second, all important university stakeholders have been asked to get a better picture of the situation. As Duraku and Hoxha (2021) claimed, the satisfaction of different stakeholder groups is expected to be significantly dependent. Third, we allowed the respondents to express their feelings very detailedly since they could answer how hesitant they feel in their answer and how important a given factor is for them.

As for the results, it is quite surprising that all partner universities revealed a similar pattern in the responses. We confirmed the conclusions presented by Shim and Lee (2020) and Means and Neisler (2020), which showed that it is more

difficult to keep the motivation of students and teachers in the online regime than the regular face-to-face option. Overall satisfaction decreased with switching to the online environment and increased at the end of the lockdown but to different degrees. In some cases, the increased values do not reach the initial values. The reasons should be revealed in future works. On the other hand, the results showed significant progress during the pandemic regarding almost all considered criteria.

The conclusions were further confirmed by the results from Slovakia where distance learning was still partially applied even at the time when the survey was launched. It was the only country where satisfaction did not return to pre-pandemic levels in most areas. We can only guess whether the decrease in satisfaction during the pandemic corresponds to the negative impact on mental health, as Akour et al. (2020), and Hoofman and Secord (2021) claimed in their studies. Despite the decrease of overall satisfaction with distance learning, we should emphasise several important benefits: better support by digital materials, better skills with distant communication, improved software and hardware support. In the future, the aggregation of the opinions of particular stakeholder groups would be worth exploring. This would give rise to the complete ranking of the evaluated units (universities or, e.g., faculties).

ACKNOWLEDGEMENT

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APPENDIX A – PYTHON CODE

Fuzzify and aggregate distance learning survey results

We start by importing required libraries

```python
import csv

import numpy
from matplotlib import pyplot as plt
```

We tell Jupyter where to find the survey results

```python
FILE_PATH = '../tram_residents.csv'
```

We start the processing by loading the responses. Each line in the CSV file contains the answers of a single respondent. `csv.reader` automatically creates a Python tuple for each row.

```python
respondents_answers_raw = []

with open(FILE_PATH, 'r') as fd_survey_results:
    csv_reader = csv.reader(fd_survey_results)
    csv_reader.__next__()
    for respondent_raw in csv_reader:
        respondents_answers_raw.append(respondent_raw)
```

Now we use the text-number maps to transform the answers of all respondents to a numerical form This will create a `(degree_of_agreement, hesitance)` tuple for each aswer.

```python
def answers_to_numbers(respondent_answers):
    num_questions = int(len(respondent_answers[1:]) / 2)
    answers = [respondent_answers[i*2+1] for i in range(num_questions)]
    hesitances = [respondent_answers[i*2+2] for i in range(num_questions)]
    answers = list(map(int, answers))
    hesitances = list(map(int, hesitances))
    answers = list(zip(answers, hesitances))
    return answers

respondents_answers = list(map(answers_to_numbers, respondents_answers_raw))

for r in respondents_answers:
    print(r)
```

```python
def fuzzify_answer(answer):
    core = answer[0]
    spread = answer[1]
    left = max(1, core - spread)
    right = min(5, core + spread)
    return left, core, right

def get_mean(answers):
    core = numpy.mean([a[1] for a in answers]) # Simply the mean of all cores
    left = numpy.mean([a[0] for a in answers]) # Simply the mean of all left borders of all supports
    right = numpy.mean([a[2] for a in answers]) # Simply the mean of all right borders of all supports
    return left, core, right

respondents_answers_fuzzy = list(map(lambda r: list(map(fuzzify_answer, r)), respondents_answers))
respondents_means = list(map(get_mean, respondents_answers_fuzzy))

for i, r in enumerate(respondents_answers):
    print(i, 'Answers:', r, 'Mean:', respondents_means[i])
```

```python
for i, answers in enumerate(respondents_answers_fuzzy):
    plt.title('Respondent %d' % i)
    plt.figure(figsize=(10, 5))
    for answer in answers:
        plt.plot(answer, [0, 1, 0], color='#5588ff', label=str(answer))
        plt.fill_between(answer, [0, 1, 0], color='#5588ff', alpha=0.3)
    plt.plot(respondents_means[i], [0, 1, 0], color='#ff8855', label=str(respondents_means[i]))
    plt.fill_between(respondents_means[i], [0, 1, 0], color='#ff8855', alpha=0.3)
    plt.xlim(0.5, 5.5)
    # plt.legend()
    plt.show()
    plt.close()
```

APPENDIX B − SELECTED QUESTION OF THE QUESTIONNAIRE IN GOOGLE FORMS

Question 1/17: Do you feel motivated enough to work hard?

Part 1: Study affairs

Did/do you feel motivated enough to work hard? *

	Absolutely yes	Rather yes	Neither yes nor no	Rather no	Absolutely no	I have no opinion
Before the pandemic	○	○	○	○	○	○
At the beginning of the distance learning	○	○	○	○	○	○
Now	○	○	○	○	○	○

Do you feel any hesitance in your evaluation? *

	No, I'm completely sure with my evaluation.	Yes, I slightly hesitate.	Yes, I feel strong hesitance and my answers were driven by feelings.
Evaluation of the past situation.	○	○	○
Evaluation of the current situation.	○	○	○

How important is this issue for you? *

	1	2	3	
Lowest	○	○	○	Highest

Do you see some proposals for improvement?

Your answer

Back   Next   Clear form