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Formats for visiting a school mobile exhibition and the quality of educational experience

Research report and recommendations

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Summary

The R&D work carried out under the "Science for You" (*Nauka dla Ciebie*) program in 2019 was aimed at checking whether, by modifying how students and teachers make use of the Naukobus ("Science-bus") travelling exhibition, the educational benefits of this experience could be enhanced. Throughout the course of this work, a team of 8 researchers and educators developed 10 "formats" – that is, modifications that influenced how the exhibition was visited and experienced. These formats were developed in a way which would best aid the development of 21st century competencies, including scientific and technical ones, and learning skills, especially critical thinking and asking questions.

Table 1. Formats employed in this research

No.	Format	Characteristic	Number of students
0	**Control**	**Pupils explore spontaneously.**	**417**
1	Teacher as a mentor	Teacher accompanies and gives advice/explains.	122
2	Teacher as an experimenter	Teacher experiments together with the students.	110
3	Asking a question before the exhibition	Teacher or an educator from the Copernicus Science Center stimulates the students' curiosity before viewing the exhibition. He/she preliminarily asks their students about the physical phenomena that can be observed throughout the exhibit.	154
4	Student explains to his/her peers how an exhibit works and what physical phenomena are demonstrated	Students previously trained in using an exhibit explain the details to other students.	120
5	Copernicus Science Center "explainer" answers questions	An educator encourages and answers questions.	98
6	Copernicus Science Center "explainer" demonstrates an exhibit	Educator shows how to use an exhibit, encouraging students to do the same.	115
7	Questions in the exhibition space	Students are encouraged to answer the questions that are displayed across the exhibition space, e.g. on stands, on exhibit tables, on the floor next to a particular exhibit.	127
8	Students as a scientists	Students were asked to explore an exhibition as scientists do: asking questions, experimenting with an exhibit. To enhance the level of their interaction with the exhibits, they were asked to put on a white lab gowns.	140
9	Worksheets	Students were given a worksheet just before entering the exhibition.	41

The impact of these formats was examined in quasi-experimental studies among visitors of the Naukobus mobile exhibition. The study group encompassed sixth, seventh and eighth grade students (N = 1444) from primary schools located in small towns with up to 130,000 inhabitants.

The results of these quasi-experiments indicated:

- An important role played by the teacher who, taking an expert's perspective, supports students in using the exhibition or experiments with them. Both tested ways (formats) of visiting exhibitions involving the teacher's presence effectively raised the level of positive emotions, with students becoming more "engaged" in the exhibition and more often declaring that the experience gained there would be useful in classes. The presence of teachers aroused the curiosity of children, increased excitement with a scientific event and stimulated thought.
- The formats that were found to particularly strengthen the perception of usefulness of the knowledge acquired were those situations in which an educator from the Copernicus Science Center staff (known as an "explainer") showed children how to experiment with the exhibit or in which children visited the exhibition wearing lab gowns.
- Less involving were those interventions in which the role of an expert was played by a peer or educator, and those where the students were asked a question before the exhibition, for which they sought answers through independent experimentation.

Our results indicate, therefore, that even subtle interventions are able to influence the perception of the cognitive value of an exhibition, to arouse emotions or engage visitors more in the visiting process. Recommendations formulated on the basis of this research are directed towards teachers and relate mainly to the possibility of including the information obtained at the exhibition into the thematic scope of some lessons. Experiencing the exhibition in this way will allow students to better consolidate the knowledge they acquired during the visit.

This year's research represents a certain milestone in our ongoing search for methods to support students in the process of understanding and remembering the knowledge acquired at science-themed exhibitions. This work will be continued in the future and expanded upon, to include the refinement of models for working at school with exhibits created by teachers.

Introduction

Analyzing how visitors function within a science-center exhibition space, either mobile or stationary, is no trivial task. Children or adults move from one exhibit to another, spending a few minutes at each of them, simply taking a quick look at some of them, but spending much longer next to others, trying to more fully grasp how they work. Their faces sometimes evidence boredom, but more often they show interest in what they are experiencing. To assess the quality of visitor experiences while visiting an exhibition, however, it is not enough to carefully observe the visitors. Observing alone is unable to untangle the vast diversity of individual patterns and ways by which children perceive the exhibition.

There were two main goals of this study. The first was to gauge the cognitive and emotional components of student's reactions, in particular: their evaluations of the exhibition, the level of positive and negative emotions, and the extent that they had a firm belief that the exhibition content would be useful at school (lessons/classroom). The second aim was to evaluate the effectiveness of the different formats. For this purpose, each student was assigned to one of ten groups that varied in terms of how they visited and experienced the exhibition. We checked whether and to what extent these methods produced different results in terms of students' satisfaction, exhibition evaluation and general level of engagement.

How should the process of visiting an exhibition be moderated? The effectiveness of various scenarios (formats) of exploration

Under the "Science for You" project, implemented in 2019, we tested how a certain variable affected the general experience of visitors to a travelling exhibition and the overall impact the exhibition had. This variable was the scenario or format by which the visit took place. Students that participated in this project (N = 1444) were assigned to one of ten formats, briefly outlined in Table 1 and described in detail later in the report. Some of them experienced the exhibition together with their teachers, the others were familiarized with the exhibition by their own classmates. Some visitors were given worksheets intended to support the visiting process.

The largest group (417 students, 30%) was assigned to a so-called control format, which was in fact a lack of any specific format. Students visited the exhibition in similar ways to the previous editions of the "Science for You" program. The exhibition visit took place during school lessons and lasted 45 mins (one school hour). The students spontaneously experienced the exhibit, taking their own time moving through the exhibition space without external interference. The influence of educators was limited to providing rudimentary information about the exhibit information and the role of the teachers was limited to observing the pupils.

The resulting study was quasi-experimental, conducted based on a between-group design; "quasi-experimental" because it was not possible to randomize the sample. The number of students varied across the 10 formats (Table 1). The visit format was taken as an independent variable (ranging from 1 to 10) assigned to each participant. To measure the efficiency of particular formats, as dependent variables we measured factors focused around two domains: cognitive and emotional.

Research methodology

After visiting the exhibition, students were asked to fill in a questionnaire meant to gauge the structure and components of their scientific capital (first part of the questionnaire), their perceptions of opportunities and threats related to the future (second part) and their evaluation of the exhibition (third part). To evaluate the exhibition, a 15-item Likert-type scale was used. This questionnaire expanded upon a previous research tool used in 2018, with the necessary revisions. The items are presented in Table 2. We assume these items should be grouped into two scales. The first one pertains to the perceived utility of the exhibition in the learning process. The second dimension, immersion, pertains to the emotional engagement while interacting with the exhibit, and therefore curiosity – being completely immersed in an exhibition and the positive reaction to it.

Table 2. Items used to measure the perceived usefulness/knowledge and immersion.

item	Hypothetical scale
1. I've learned a lot during this class.	Knowledge/usefulness
2. I had to think hard during the contact with the exhibits.	Knowledge/usefulness
3. The time flew during this class.	Immersion
4. I felt I was really into this class.	Immersion
5. I would gladly participate in such classes again.	Immersion
6. Some of the exhibits were very surprising.	Immersion
7. The functioning of some of the exhibits was difficult for me to understand.	Knowledge/usefulness
8. Thanks to this exhibition I have a better understanding of what we learn at school.	Knowledge/usefulness
9. I had a great time here.	Immersion
10. I would gladly come to such classes again, even if they were after school.	Immersion
11. I understand how the exhibits I interacted with worked.	Knowledge/usefulness
12. I think what I've learned today will come useful during classes.	Knowledge/usefulness
13. The exhibits that I visited sparked my curiosity.	Immersion
14. What I saw here today was interesting, but I doubt it might come in handy.	Knowledge/usefulness
15. The knowledge I gained here will be useful to me both in school and outside of it.	Knowledge/usefulness

The assumed theoretical structure does indeed seem to be reflected within the data. Two independent forms of analyses – confirmatory factor analysis and network analysis – showed that it is reasonable to treat immersion (emotion) and knowledge (utility) as two separate yet related variables, highlighting the more emotional (immersion) and more cognitive

(knowledge) aspects of the exhibition evaluation, respectively. As Figure 1 shows, statements about immersion formed one group and statements related to knowledge formed another.[1]

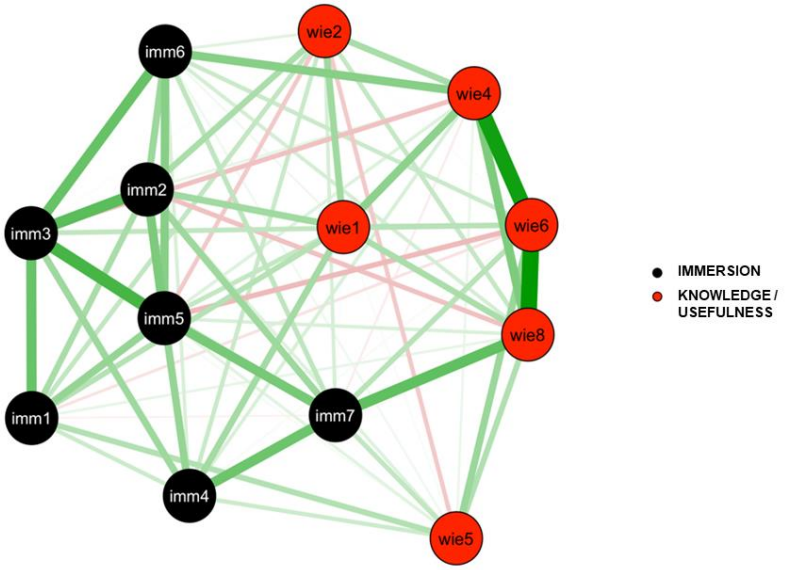

Figure 1: Relationships between the individual statements measuring immersion and the perceived knowledge from the exhibition
Note: elements marked in the picture with different colors and names (imm1-imm7, wie1-wie8) are statements that are part of the immersion scales and perceived knowledge scale. Relationships between the statements were estimated on the basis of pair correlations between them
- green lines indicate positive correlations (i.e. a tendency to respond similarly to certain statements), and red lines
- negative correlations. The line thickness determines the strength of the correlation.

The correlation between immersion and perceived learning utility was strong (r = .62) (see Figure 2). The declared immersion level among the participating students was very high. As for recognition that the exhibition content could be useful, the distribution of responses was more symmetrical. Immersion and usefulness were the primary dependent variables and all further analyses were aimed at verifying how much they depend on the format of visiting the exhibition.

[1] This qualitative view illustrated in Figure 1 is confirmed by the results of the confirmatory factor analysis - the two-factor model with the dimensions of knowledge and immersion was well fit to the data, as illustrated by model fit parameters (*CFI* = .96, *TLI* = .95, *RMSEA* = .068, 90% PU: .062- .075, SRMR = .038).

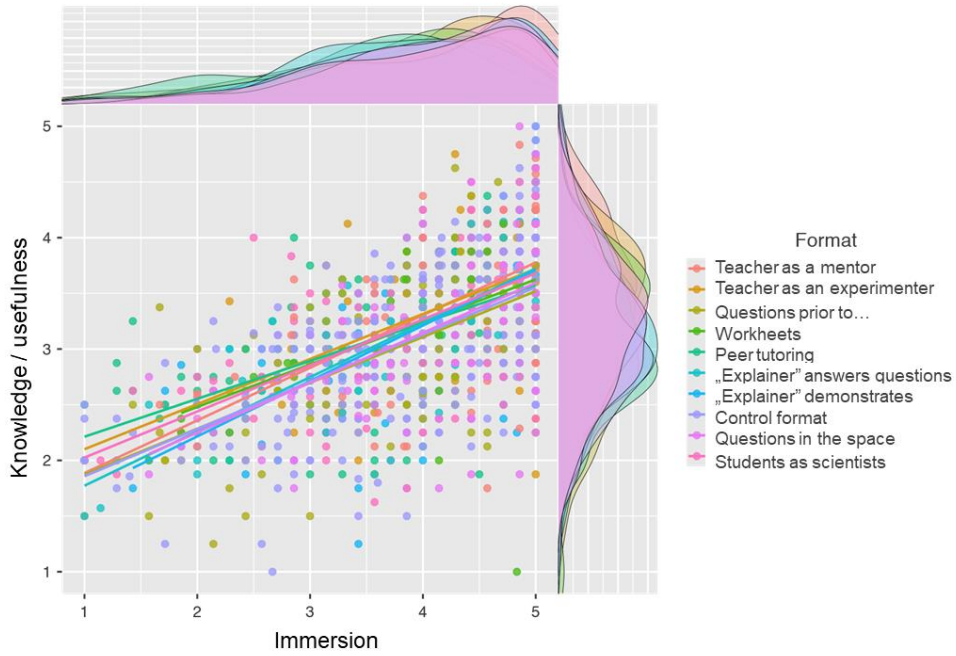

Figure 2. Correlations between immersion and knowledge depending on the format of the exhibition visit
Note: the markers shown in the figure represent the results of individuals on the scales of immersion and perceived knowledge and usefulness of the exhibition, and the color of the marker determines the assignment of the participant to a specific format of the tour. The multicolored lines illustrate the relationship between immersion and knowledge and usability specified for each format - as might be seen, their slope is almost identical, so the relationship between the evaluation of immersion and exhibition usability was very similar regardless of the tour format.

Emotions during visiting the exhibition

Students participating in this study were asked to describe the emotions they felt while visiting the exhibition. A list of 10 emotions was presented: 5 positive (curious, surprised, provoked to think, excited, joyful) and 5 negative (bored, dissatisfied, dull, sleepy, nervous). Each participant could use a three-point scale (1 = rarely, 2 = from time to time, 3 = often or very often) to show the extent that each of these emotions was felt during the exhibition. It was also verified whether the assumed two-factor structure was reflected in the data. The network analysis (see Figure 3) showed a clear grouping of negative and positive emotions.

Positive emotions were dominant, the negative ones almost non-existent, and the correlation between them was significant and negative (r = –.36) (Figure 4).

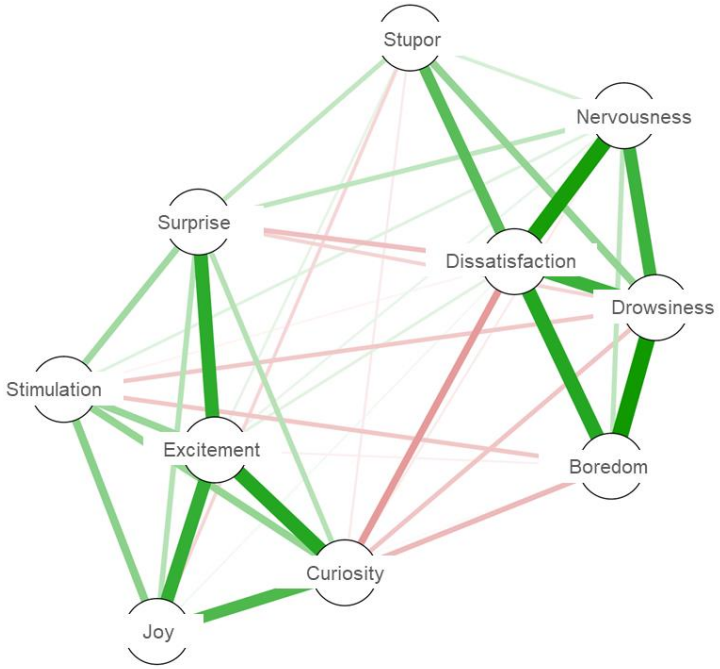

Figure 3: Relationships between statements measuring the intensity of individual emotions
Note: the elements marked in the figure with the names of positive and negative emotions indicate the interrelationship inside groups (strong positive correlations within the group of positive and negative emotions, but negative correlations between groups).

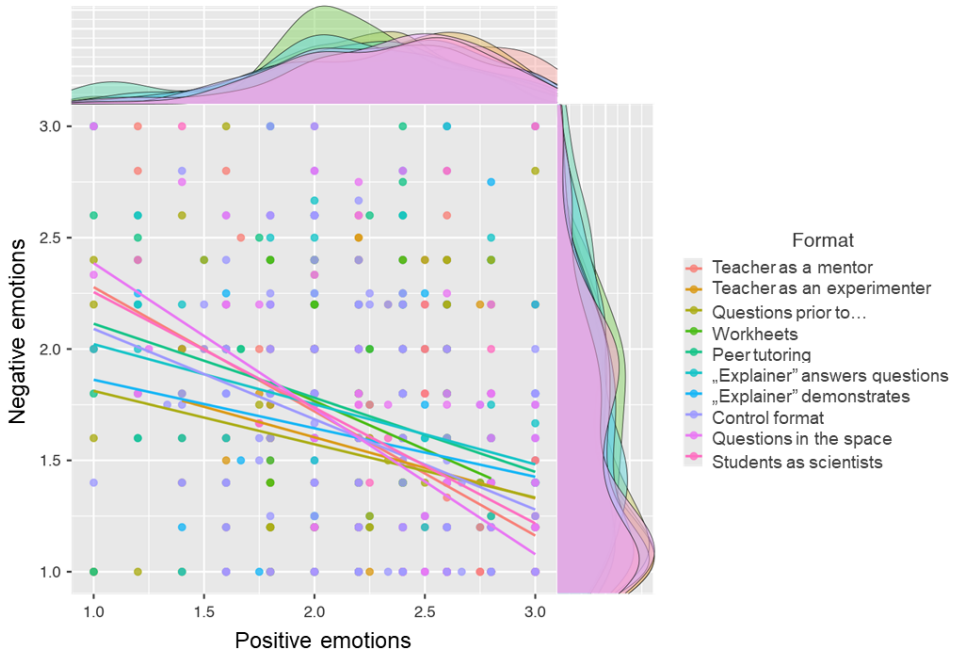

Figure 4: Correlations between positive and negative emotions depending on the format of the exhibition visit
Note: the markers shown in the picture indicate the results of individuals on the scales of positive and negative emotions, and the color of the marker determines the assignment of the participant to a specific format of the tour. The multicolored lines illustrate the negative correlation between positive and negative emotions.

Effectiveness of formats

Did the various formats produce different effects in regard to immersion, perceived utility and induced emotions, both positive and negative? The extensive literature on this issue (see Heath & vom Lehn, 2008; Medved & Oatley, 2010; Mortensen, 2011) clearly shows that that emotional engagement and a feeling of immersion have both an autotelic and instrumental value. The autotelic results of high level immersion come from the presence of positive emotional states while visiting an exhibition. The instrumental value is connected to the positive impact on long-term memory, as empirically demonstrated. Research has shown that visitors who feel more engaged remember specific exhibits and the exhibition itself in greater detail and for longer.

To find out how the particular formats induced positive emotions and engagement in participants, we compared their intensity depending on the visiting format. We used a multivariate analysis of variance with the format as factor and the four dependent variables described above. The overall effect was statistically significant ($p < .001$), and indicated the differences between formats. Those differences were then explored later with four independent analyzes.

In regards to immersion, the formats varied between each other ($p < .001$), although these differences were relatively small as indicated by the standardized difference between the means. Cross-format comparison shows that students considered themselves as the most immersed when visiting an exhibition together with teachers (the "teacher as a mentor" and "teacher as an experimenter" formats) and when relevant questions were displayed in the exhibits' space. Those scenarios generated the highest level of immersion, averaging over 4 on a 1-5 point scale. The control format produced an average of 3.88, which was slightly lower. The only format standing out on the lower end, with an average of 3.42, was the scenario with a fellow student explaining how the exhibits work.

Three other formats also scored lower than the control group: (1) the scenario with an educator/expert answering the student questions, (2) the format with the teacher asking questions before visiting the exhibition and (3) the scenario with worksheets. Note that the differences between these formats and the control one were not statistically significant, thus allowing us to consider their evaluation as similar and equally high.

Table 3. Differences in the immersion induced by different formats

			95% Confidence Interval	
Format	Mean	Standard Error	Lower	Upper
Teacher as a mentor	4.18	0.09	4.00	4.35
Teacher as an experimenter	4.07	0.09	3.89	4.25
Asking questions prior to exhibition	3.71	0.08	3.55	3.87
Worksheet	3.79	0.15	3.50	4.09
Peer guides other peers	3.42	0.09	3.25	3.59
Copernicus Science Center "explainer" answers questions	3.69	0.10	3.49	3.89
Copernicus Science Center "explainer" demonstrates an exhibit	4.01	0.09	3.83	4.19

Table 3. Differences in the immersion induced by different formats

Format	Mean	Standard Error	95% Confidence Interval	
			Lower	Upper
Control format	3.88	0.05	3.79	3.97
Questions in the exhibition space	4.06	0.09	3.89	4.22
Students as scientists	3.95	0.08	3.79	4.11

The analysis of perceived exhibit content usefulness also showed statistically significant differences between formats ($p < .001$), although even smaller in magnitude ($\omega^2 = .02$). Again, the formats that scored the best were those with the teacher playing an active role—either being a mentor during the visit or experimenting along with the students. The lowest-scoring format here was the one where the teacher began the process of visiting by asking questions to guide student exploration.

Table 4. Differences in the perceived knowledge provided by the exhibition depending on the format

Format	Mean	Format	95% Confidence Interval	
			Lower	Upper
Teacher as a mentor	3.39	0.06	3.27	3.51
Teacher as an experimenter	3.34	0.07	3.22	3.47
Asking questions prior to exhibition	3.00	0.06	2.89	3.11
Worksheet	3.16	0.11	2.96	3.37
Peer guides other peers	3.04	0.06	2.92	3.16
Copernicus Science Center “explainer” answers questions	3.09	0.07	2.96	3.23
Copernicus Science Center “explainer” demonstrates an exhibit	3.22	0.06	3.09	3.34
Control format	3.08	0.03	3.01	3.15
Questions in the exhibition space	3.17	0.06	3.05	3.29
Students as scientists	3.25	0.06	3.13	3.36

Positive emotions showed similar effects ($p < .001$, $\omega^2 = .03$). The most positive ones were reported by students who experienced the exhibits together with an advising or experimenting teacher, the least positive when visiting the exhibition together with peers, with another student acting as a tutor.

Table 5. Differences in the intensity of positive emotions depending on the format

Format	Mean	Standard errpr	95% Confidence Interval	
			Lower	Upper
Teacher as a mentor	2.41	0.04	2.33	2.50
Teacher as an experimenter	2.39	0.04	2.31	2.48
Asking questions prior to exhibition	2.21	0.04	2.14	2.28
Worksheet	2.21	0.07	2.07	2.35
Peer guides other peers	2.10	0.04	2.02	2.18
Copernicus Science Center "explainer" answers questions	2.20	0.05	2.11	2.29
Copernicus Science Center "explainer" demonstrates an exhibit	2.31	0.04	2.23	2.40
Control format	2.29	0.02	2.25	2.33
Questions in the exhibition space	2.35	0.04	2.27	2.43
Students as scientists	2.33	0.04	2.25	2.40

Negative emotions were rarely reported. This time differences between formats were present ($p < .001$, $\omega^2 = .02$) and significant, but very small in magnitude. The most negative emotions occurred while visiting the exhibition together with peers or with worksheets. The fewest negative emotions were reported while visiting with teachers.

Table 6. Differences in the intensity of negative emotions depending on the format

Format	Mean	Standard Error	95% Confidence Interval	
			Lower	Upper
Teacher as a mentor	1.49	0.05	1.40	1.59
Teacher as an experimenter	1.50	0.05	1.40	1.60
Asking questions prior to exhibition	1.52	0.04	1.44	1.60
Worksheet	1.70	0.08	1.54	1.86
Peer guides other peers	1.75	0.05	1.66	1.84
Copernicus Science Center "explainer" answers questions	1.70	0.05	1.59	1.80
Copernicus Science Center "explainer" demonstrates an exhibit	1.58	0.05	1.48	1.67
Control format	1.57	0.03	1.52	1.62
Questions in the exhibition space	1.50	0.05	1.41	1.59

Format	Mean	Standard Error	95% Confidence Interval	
			Lower	Upper
Students as scientists	1.57	0.04	1.48	1.65

A more synthetic analysis of the formats' effectiveness (see Figure 5) indicates that the scenarios which scored best, i.e. those that were able to both effectively draw students into visiting (high immersion) and convinced them of the import and usability of the knowledge conveyed, were the two "teacher" formats—with the teacher as a mentor and the teacher experimenting with the students. The formats that scored worse were those having students tutoring and scenarios involving the presence of adults ("explainer" or teacher) who were more passive during the exhibition—either asking students questions beforehand, or helping them out only when asked. The format in which students used worksheets produced weaker emotional involvement (low immersion), but quite a strong belief in the usefulness of the content.

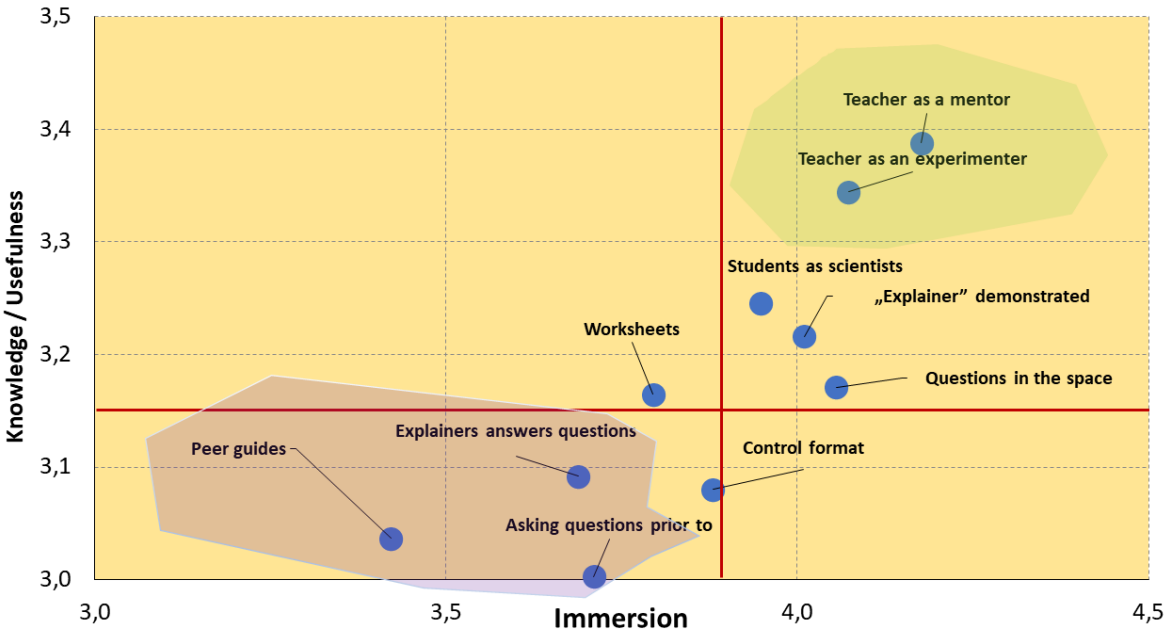

Figure 5: Effectiveness of formats on the dimensions of immersion and perceived knowledge (Note: for both scales theoretical range 1-5)

The correlation between the perceived positive and negative emotions was negative—those formats that generated the negative emotions obviously built up fewer positive emotions, and *vice versa*. Although positive emotions clearly dominated over the negative ones, some formats generated a relatively high level of negative emotions (see Figure 6), especially the scenario with the main roles played by peers. In this particular case, the level of negative emotions was almost as high as that of positive ones.

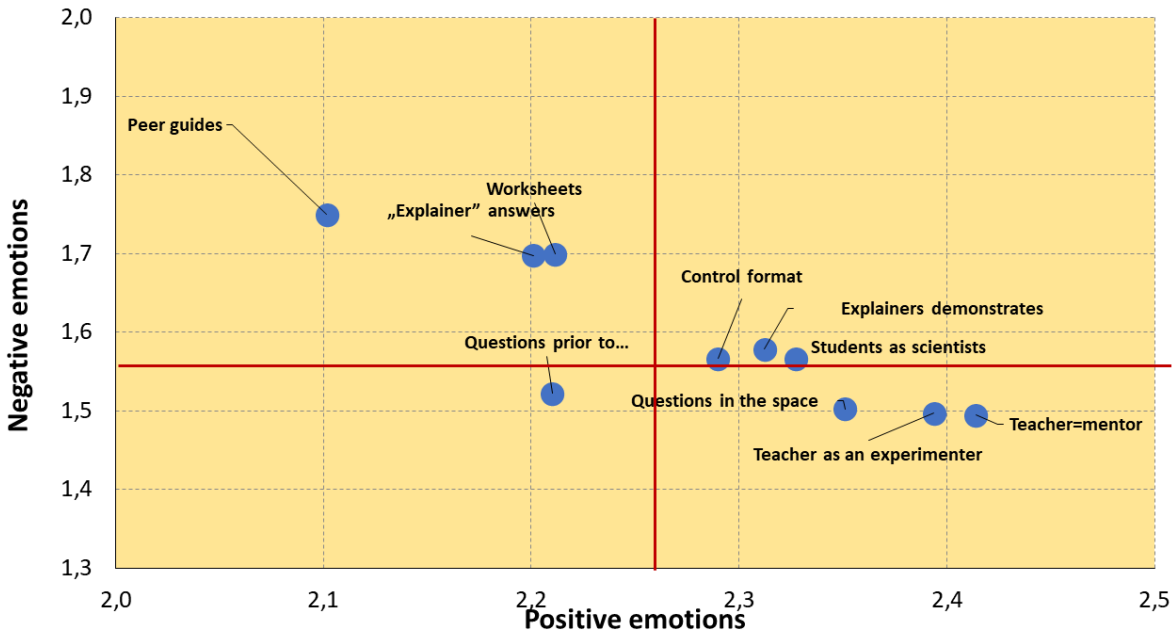

Figure 6: Effectiveness of formats on the dimensions of positive and negative emotions (Note: for both scales theoretical range 1-3)

Even though the general exhibition evaluation was high, a detailed analysis of students' responses indicates differences between formats. The hierarchy of statements listed in Table 7 indicates that the sense of having a good time was stronger for students while visiting than the belief in the content promising to be useful in classes later on (although many students agreed that the exhibits did arouse their curiosity).

Table 7. Percentage of responses "I strongly agree" or "rather agree" to statements describing the evaluation of the exhibition depending on the format of the tour)

Statement	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	Total
I had a good time here.	**85%**	82%	**67%**	79%	66%	72%	81%	80%	**84%**	74%	77%
I would like to take part in such activities again.	78%	79%	75%	79%	**60%**	69%	79%	74%	**83%**	76%	75%
Some of these exhibits were very surprising.	**80%**	**84%**	66%	**62%**	67%	68%	75%	73%	79%	75%	74%
The time during these classes was very quick for me.	**80%**	**81%**	66%	68%	56%	**48%**	78%	77%	75%	70%	72%
These classes really drew me in.	**78%**	**77%**	62%	**58%**	**51%**	66%	67%	65%	**77%**	68%	67%
I understand how the exhibits I worked with worked.	68%	**71%**	**56%**	63%	67%	**59%**	67%	67%	65%	65%	65%
The exhibits I had contact with stimulated my curiosity.	**76%**	68%	**59%**	68%	**53%**	61%	64%	63%	67%	71%	65%
I would be happy to come to such classes again, even if they took place after the lessons.	**67%**	**66%**	58%	54%	**38%**	**49%**	64%	55%	62%	65%	58%
I learned a lot during these classes.	**66%**	**61%**	**30%**	47%	**38%**	45%	54%	47%	46%	56%	48%
At this exhibition I gained knowledge that will be useful to me in or out of school.	53%	**60%**	40%	50%	**39%**	**38%**	50%	40%	42%	53%	45%
I think what I have learned today will be useful to me at school.	54%	54%	**39%**	**63%**	40%	43%	53%	**39%**	32%	**56%**	45%
It was difficult for me to understand how some exhibits work.	**49%**	41%	41%	36%	35%	**33%**	37%	**33%**	**34%**	46%	38%
Thanks to this exhibition I understand better what we learn at school.	**55%**	39%	**27%**	**57%**	**28%**	29%	39%	33%	32%	42%	36%
What I saw here today was interesting, but it is rather useless to me.	**38%**	**22%**	36%	29%	34%	28%	37%	37%	28%	31%	33%
During the contact with the exhibits I had to think hard.	**47%**	**40%**	**23%**	**19%**	31%	26%	33%	24%	36%	27%	30%

Note: values are sorted in descending order of total categories. The bold type is the one/two formats with the highest ratings and the red type is the format with the lowest ratings. The control format is marked with a grey background.

F1 = Teacher as a mentor (N = 122)
F2 = Teacher as an experimenter (N = 110)
F3 = Asking questions prior to exhibition (N = 154)
F4 = Worksheet (N = 41)
F5 = Peer guides other peers (N = 120)
F6 = Copernicus Science Center “explainer” answers questions (N = 98)
F7 = Copernicus Science Center “explainer” demonstrates an exhibit (N = 115)
F8 = Control format (N = 417)
F9 = Questions in the exhibition space (N = 127)
F10 = Students as scientists (N = 140)

Below is a more detailed description of the different formats, including an analysis of their effects on immersion, perceived knowledge and positive/negative emotions.

Format 1. Teacher as a mentor (*N* = 122)

In the first format, the teachers' working with students on a daily basis played the main role. Each of them was asked whether or not they wanted to accompany the students while visiting an exhibition and explain the complexity of the exhibits. Teachers under this scenario did not experiment actively, but only explained, instructed and asked questions.

A day before the exhibition, teachers were trained at using all the exhibits and explaining the phenomena that they present. Results indicated that such efforts on the part of the teacher—actively supporting (scaffolding) the process of visiting an exhibition—clearly had a positive effect. As Figure 7 shows, compared to the control format (without any interventions), students visiting the exhibition together with their teacher declared the highest level of positive emotions and lowest level of negative ones. They also felt more immersed in visiting (a higher immersion rate), and convinced that the knowledge conveyed may prove useful at school. The differences illustrated in Figure 7 which pertain to immersion, positive emotions and perceived usefulness are statistically significant ($p < .05$).

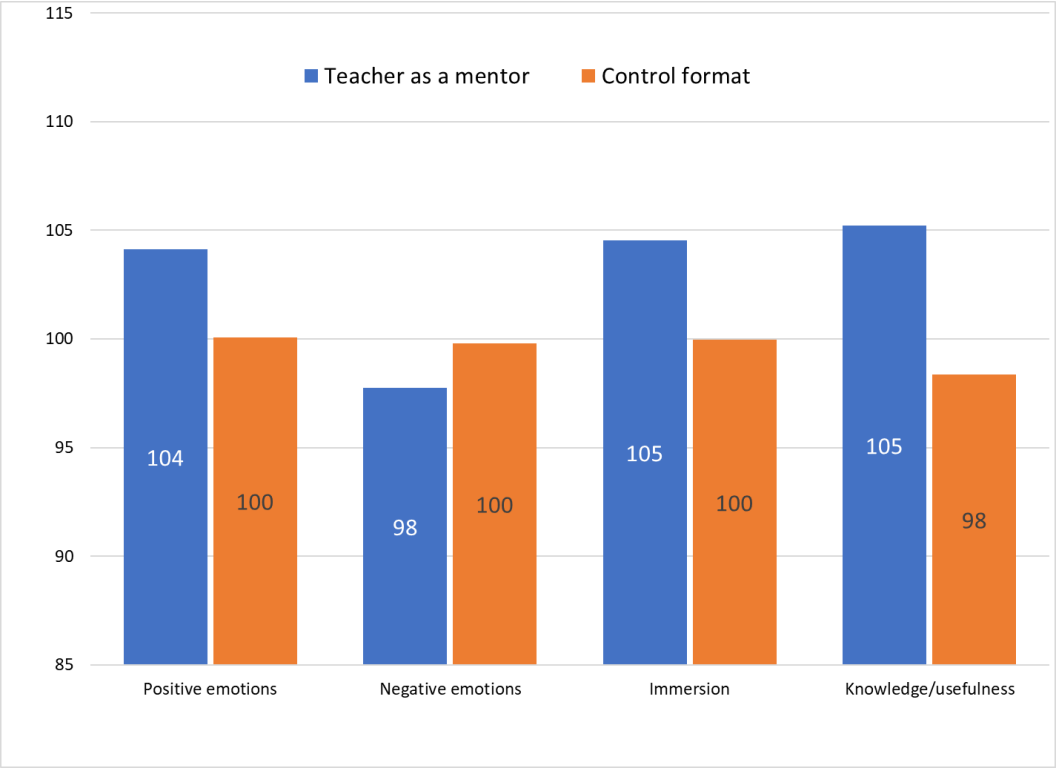

Figure 7: Effectiveness of the "Teacher as mentor" format (Note: for greater legibility, the results have been scaled so that the average for all formats in the range of each dependent variable is 100 and the standard deviation 15)

What emotions accompanied students who visited the exhibition with their teacher? As compared to the control scenario and the other formats, as shown in Figure 8, this scenario did not generate the highest level of joy but the all other positive emotions were clearly highest. Students in this format declared excitement more often and also described the exhibition as thought-provoking. The exhibits were also more often perceived as surprising. Generally, the level of negative emotions was very low, and also the presence of the teacher successfully eliminated students' boredom.

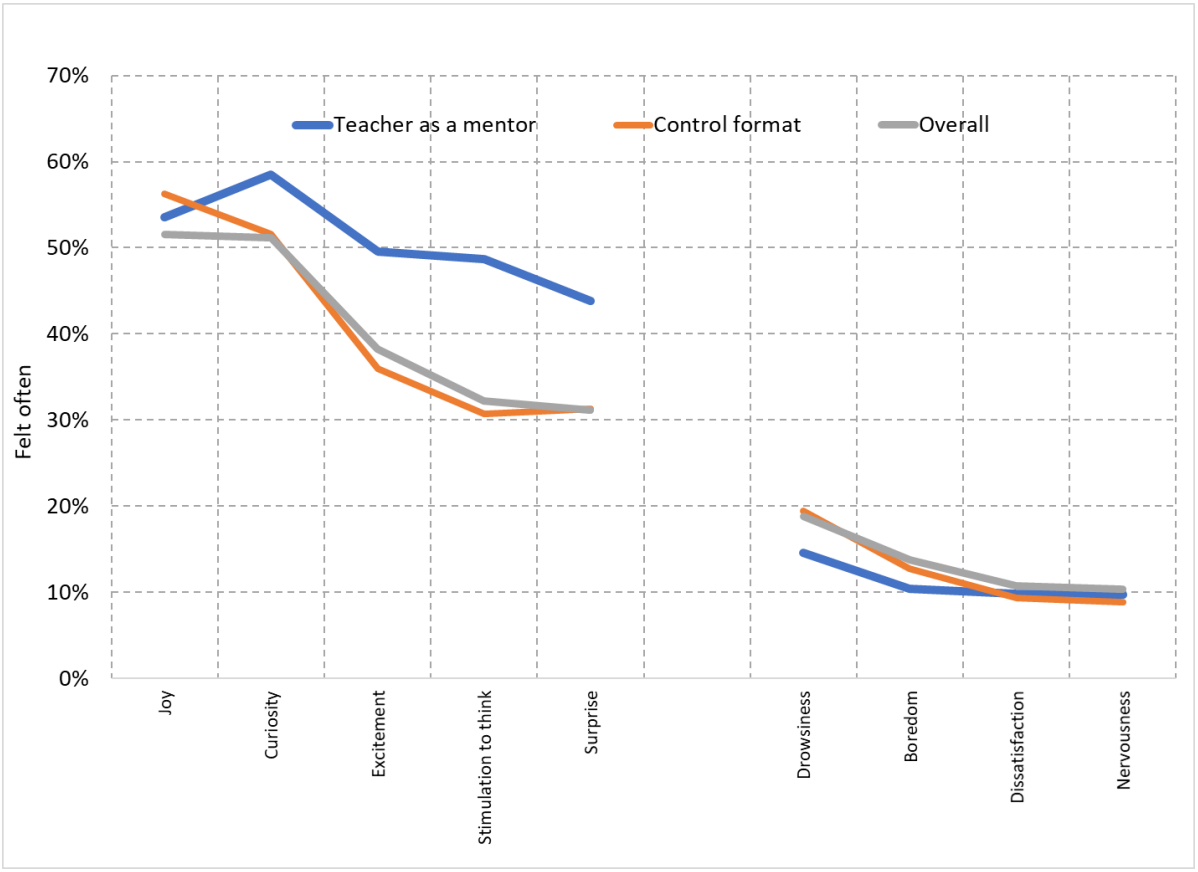

Figure 8: Emotions felt by students visiting the exhibition with a mentor teacher)

Format 2. Teacher as an experimenter (*N* = 110)

Here the teacher also experimented together with the students and self-reported his/her experiences and could also ask questions aloud (e.g. "What happens if I drop the ball this way?"). The teacher did not explain how the exhibits work (if he himself/herself came to conclusions about how they work, it was expressed as an assumption, e.g. "this probably works like this…"), he/she did not act as a mentor, did not explain the phenomena presented by the exhibits. The researchers worked with school management to identify which classes would be selected for this format and which teacher (or teachers) would be tasked with the role of experimenter. Then the desired teacher behaviors were discussed: primarily the behavior of a naturally interested participant. The teachers could:

- actively test the exhibit,
- start by reading the instructions first, or just start experimenting without it,
- ask questions ("how does this work?", "can it even be solved?"), report what they experience ("I couldn't do it...", "I did it!"),
- encourage the students to experiment ("do you want to try now?"), but without pointing at specific students.

The results showed that this type of scenario, where the teacher experimented but did not suppress the students' curiosity with explanations, clearly served to inspire their engagement. As shown in Figure 9, it particularly stood out in terms of instilling a belief that the obtained knowledge is useful even outside the exhibit environment (the difference compared to the control format was significant at p <.001). Compared to the control format, students also

declared greater immersion (p = .049) and a higher level of positive emotions (p =.028), while the declared negative emotions showed no statistically significant differences.

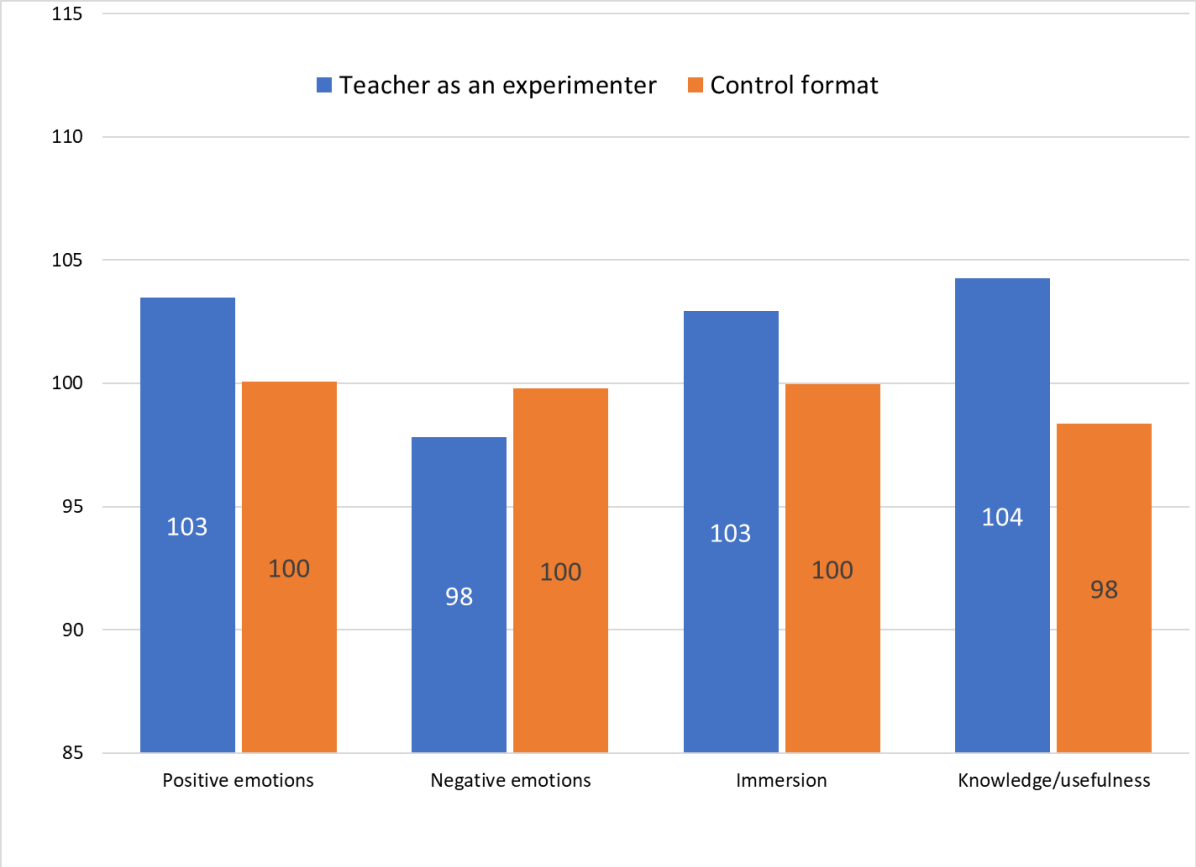

Figure 9: Effectiveness of the "Teacher as an experimenter " format (Note: for greater legibility, the results have been scaled so that the average for all formats in the range of each dependent variable is 100 and the standard deviation 15)

The presence of the experimenting teacher had a positive effect, especially by stimulating the students' curiosity and their perceptions of being positively surprised (the highest differences with control format and other formats). However, as Figure 10 shows, the level of reported positive emotions was also generally significantly higher, while that of negative ones – especially sleepiness and boredom – was lower than was observed under control conditions.

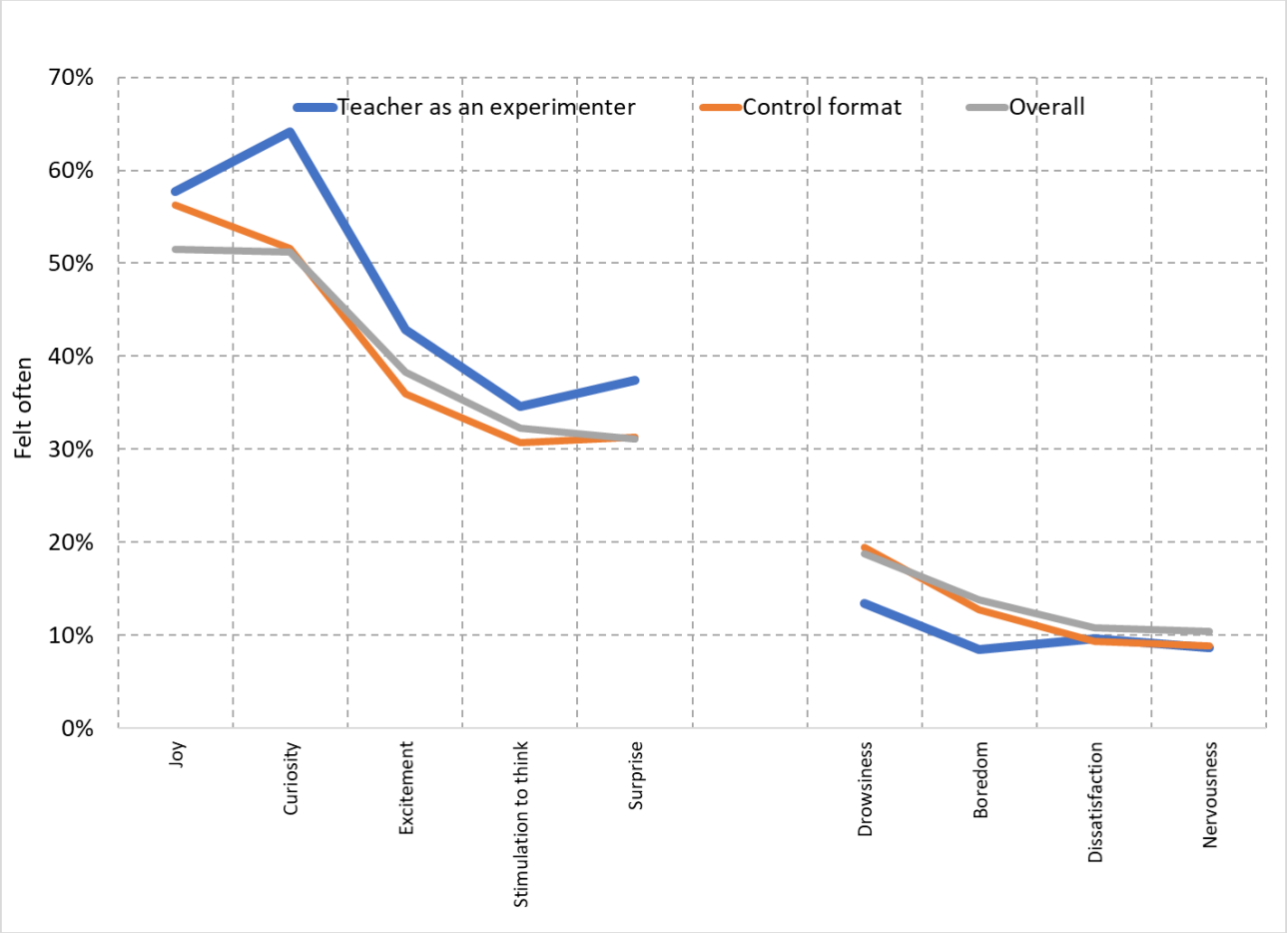

Figure 10: Emotions felt by students visiting the exhibition with an experimenter teacher

Format 3. The teacher or "explainer" asking a question before the exhibition (*N* = 154)

In this procedure, before visiting the exhibition, teachers asked the students to try while visiting to find exhibits that illustrate phenomena known to them from their everyday lives.

Results showed that this type of scenario, where a teacher or "explainer" (an educator from the Copernicus Science Center) asked questions before the students started exploring, turned out to be one of the less effective ones. Compared to the control format, the students here declared a significantly lower level of positive emotions (p = .006) and did not feel very immersed (p = .08). Evaluation of content usefulness and the increase in negative emotions were similar in both formats.

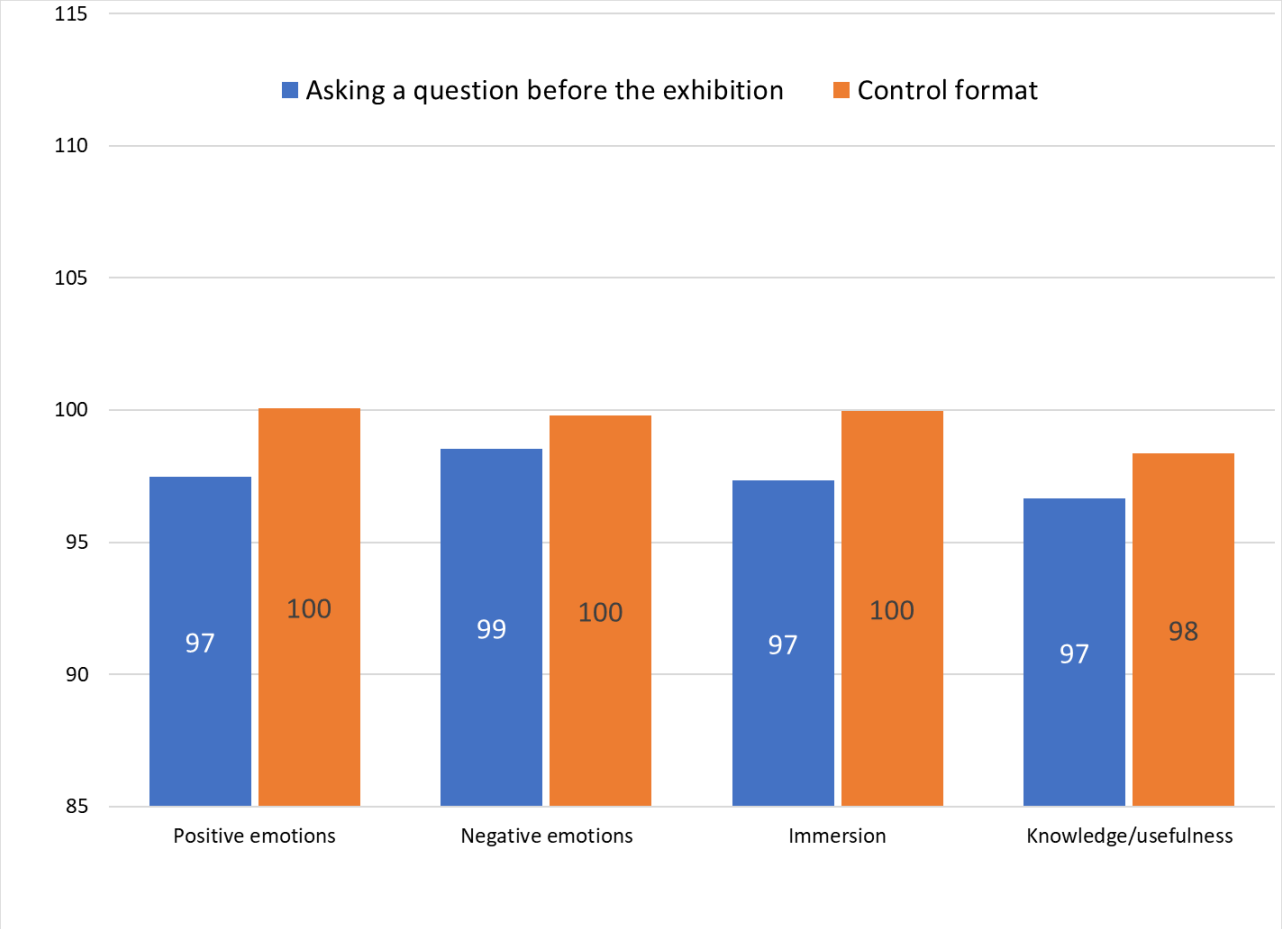

Figure 11: Effectiveness of the "Teacher as explainer asks questions before" format (Note: for greater legibility, the results have been scaled so that the average for all formats in the range of each dependent variable is 100 and the standard deviation 15)

A more detailed inspection of the emotions declared here suggests that such questions actually worked contrary to their intended purpose – they did not stimulate thinking at all (or at least less so than the other formats or control format, without such questions). The format also translated into a much lesser feeling of joy when visiting the exhibition – it is possible that the “task” which the questions implied caused the exploration process to be less spontaneous and ultimately constrained it. It should be noted that this format did not generate strong negative emotions, but reduced enthusiasm and spontaneity.

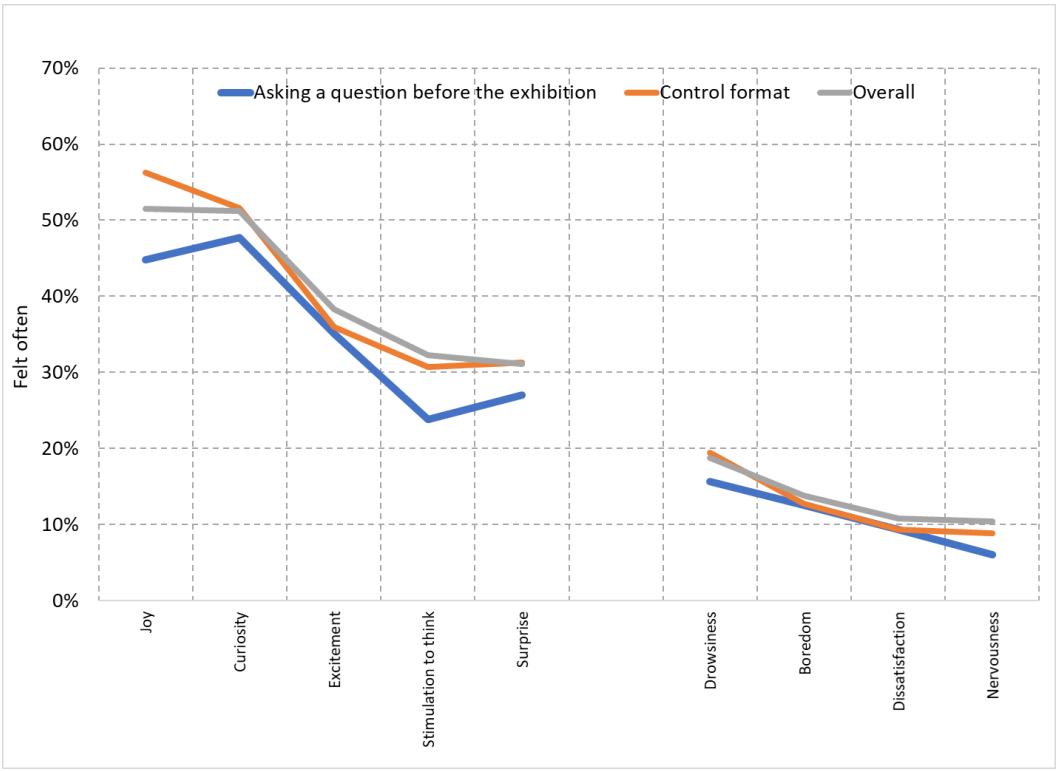

Figure 12: Emotions felt by the students visiting the exhibition in the format "Teacher asks before"

Format 4. Selected student assists peers in experimentation (*N* = 120)

For this format, several students were trained to present the exhibits. They were assigned to the selected exhibits and helped their peers to experiment independently.

Surprisingly, results showed that such a scenario, in which peers guided the visitors through the exhibition, proved to be the most controversial among those tested. Although it might seem that the application of peer-learning during the exhibition visit should help narrow the social distance between students and maximize their positive feelings, it in fact had the opposite effect. The visiting students here declared a significantly lower level of positive emotions (p = .001) and a higher level of negative emotions (p = .001) than the control condition. The immersion rate also turned out to be significantly lower than the control condition (p = .001). There were no differences in the perceived usefulness of the content in the school context (p > .05) (Fig. 13).

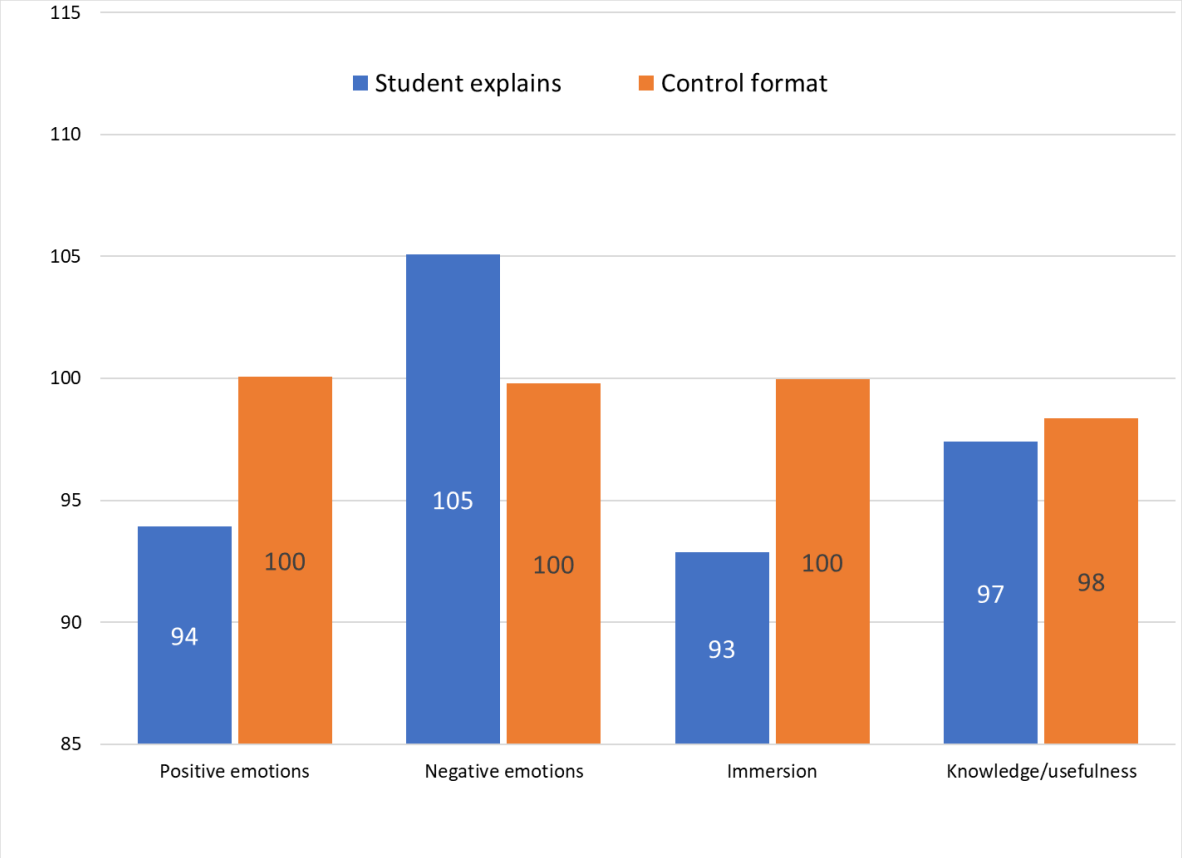

Figure 13: Effectiveness of the "selected student assists" format (Note: the results have been scaled for greater readability, so that the average for all formats in the range of each dependent variable is 100 and the standard deviation 15)

Although it might be difficult to formulate a definite conclusion regarding the reasons for these results, the information presented in Fig. 14 suggests that the chosen students were not performing well enough in the role of tutors. Compared to students experiencing the control format, the visitors guided by their peers felt a lot more bored and sleepier, and demonstrated less positive emotions like curiosity, excitement, and being provoked to think. It can therefore be concluded that the mere fact of designating a fellow student as an “exhibition guide” is insufficient to stimulate engagement within the audience. This role is clearly more demanding and requires competencies that children often lack.

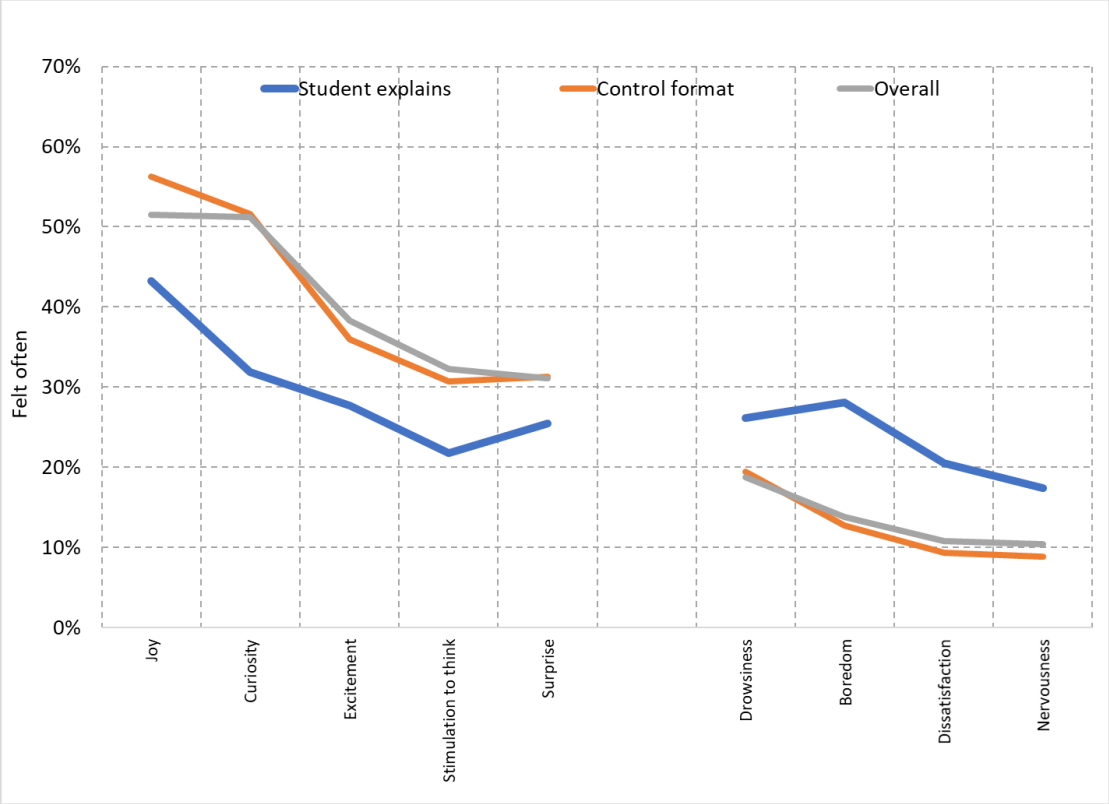

Figure 14: Emotions felt by the students visiting the exhibition in the "selected student assists" format

Format 5. Expert educator answers questions (*N* = 98)

The next format featured “explainers” (educators from the Copernicus Science Center) involved in the process of visiting. They encouraged the students to ask questions, but that was all – this was more of a suggestion than an order. As a result, this format proved to be only moderately effective.

Results showed that the level of negative emotions felt by pupils was significantly higher than in the control condition (p = .03) and that the other differences, although not statistically significant, also trended toward the lower assessment of this visiting format. In particular, less positive emotions (p = .09) and less immersion (p = .08) were observed (Figure 15).

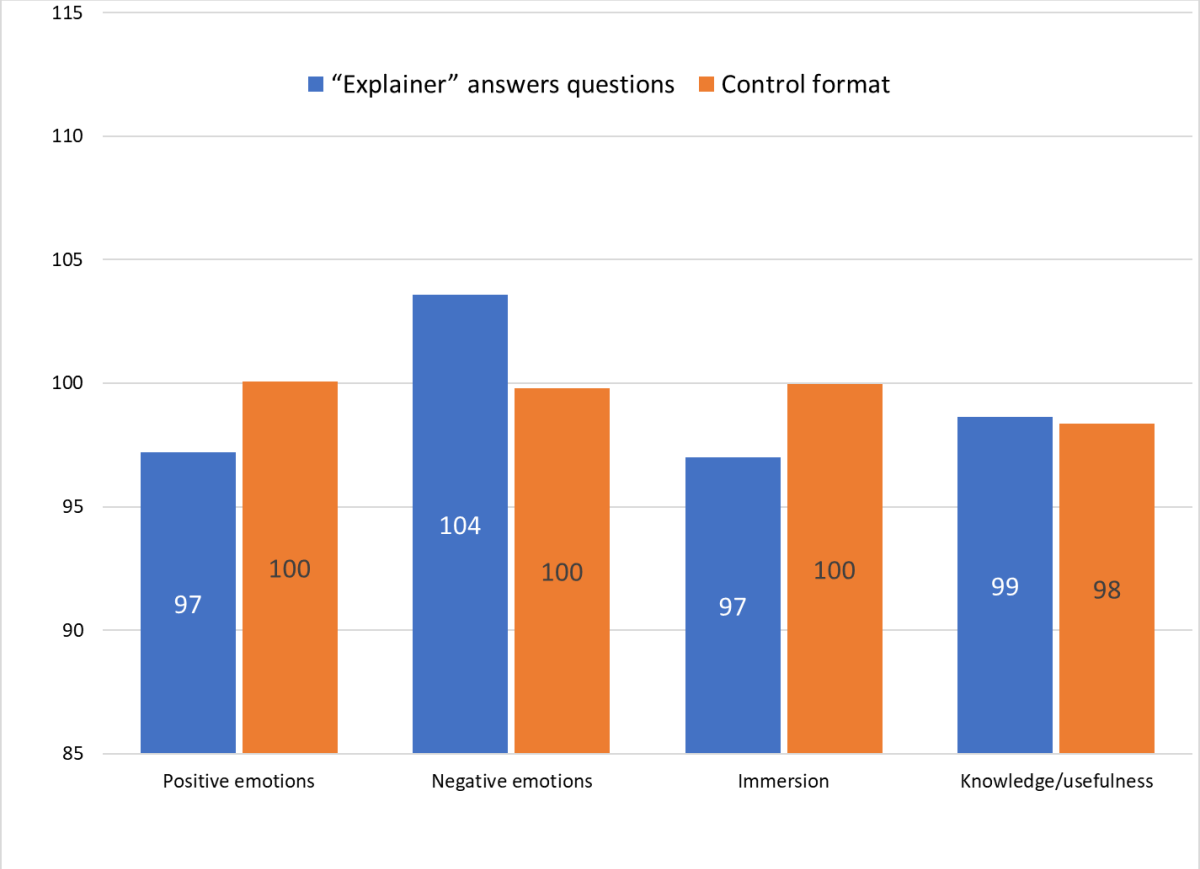

Figure 15: The effectiveness of the "CSC explainer answers questions" format (Note: for greater legibility, the results have been scaled so that the average for all formats in the range of each dependent variable is 100 and the standard deviation 15)

The emotional response graph of students assigned to this scenario is interesting (Figure 16). Differences are particularly noticeable, with a clearly lower level of curiosity – so although pupils were motivated to ask questions, it had quite the opposite effect than intended. The scenario also features lower levels of enjoyment, and bigger boredom.

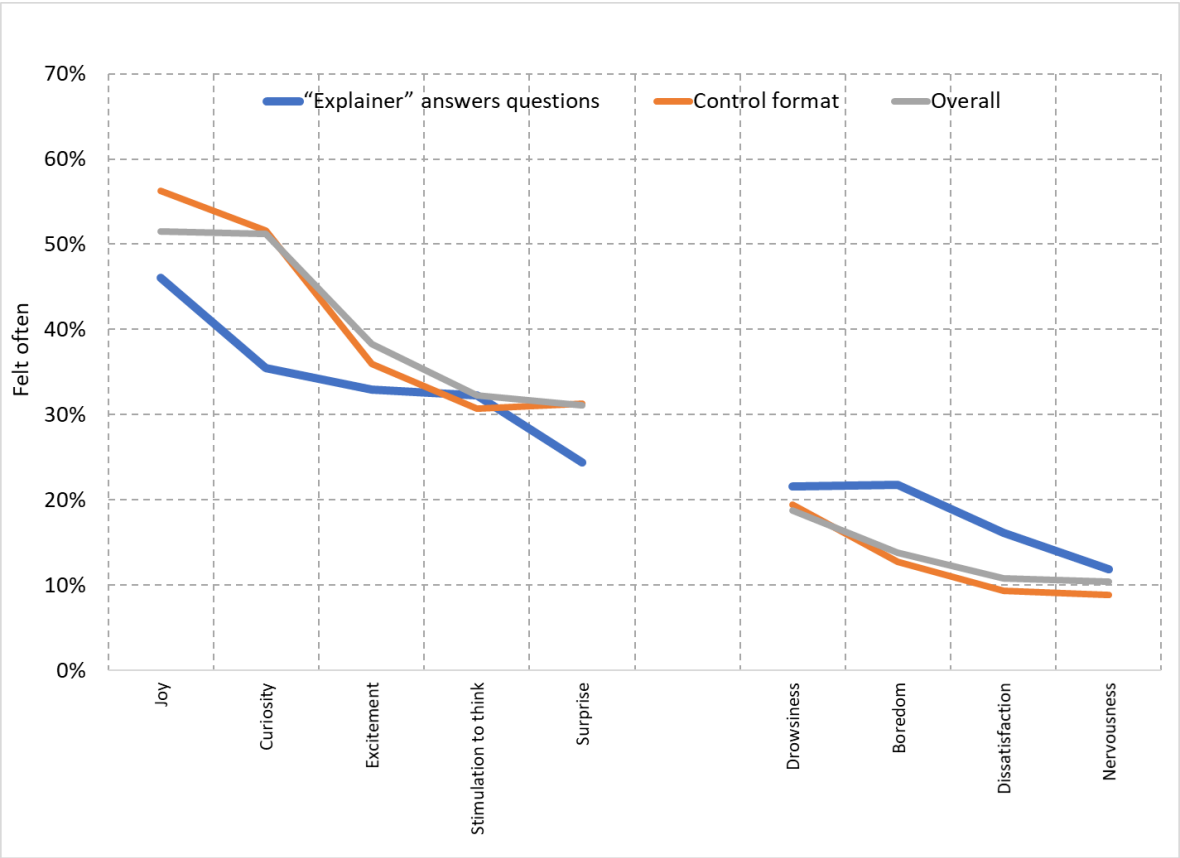

Figure 16: Emotions felt by students visiting the exhibition with an expert explainer

Format 6. "Explainer" demonstrates exhibit (*N* = 115)

The sixth visiting format involved a more extensive participation of the Copernicus Science Center educator, who attempted to shape the students' inquisitive attitude and behavior at the exhibits. Demonstrating one of the exhibits ("The fastest slide"), the educator explained how to ask questions and make assumptions about the possible outcomes of the activities. He also asked the students, during their visit, to adopt the same attitude and ask questions themselves, to experiment and try to draw conclusions either alone or together with peers.

As the results in Figure 17 show, such intervention by the "explainer", as compared to the control format, essentially did not change the emotions felt toward the exhibition. Both created positive and negative emotions regarding the exhibition on similar level. The behavioral modeling engaged the students into the visiting process to a similar degree than without it, but the students did declare more often that the knowledge gained would be useful in school. This result was only visible at the trend level (p = .06) and is not statistically significant.

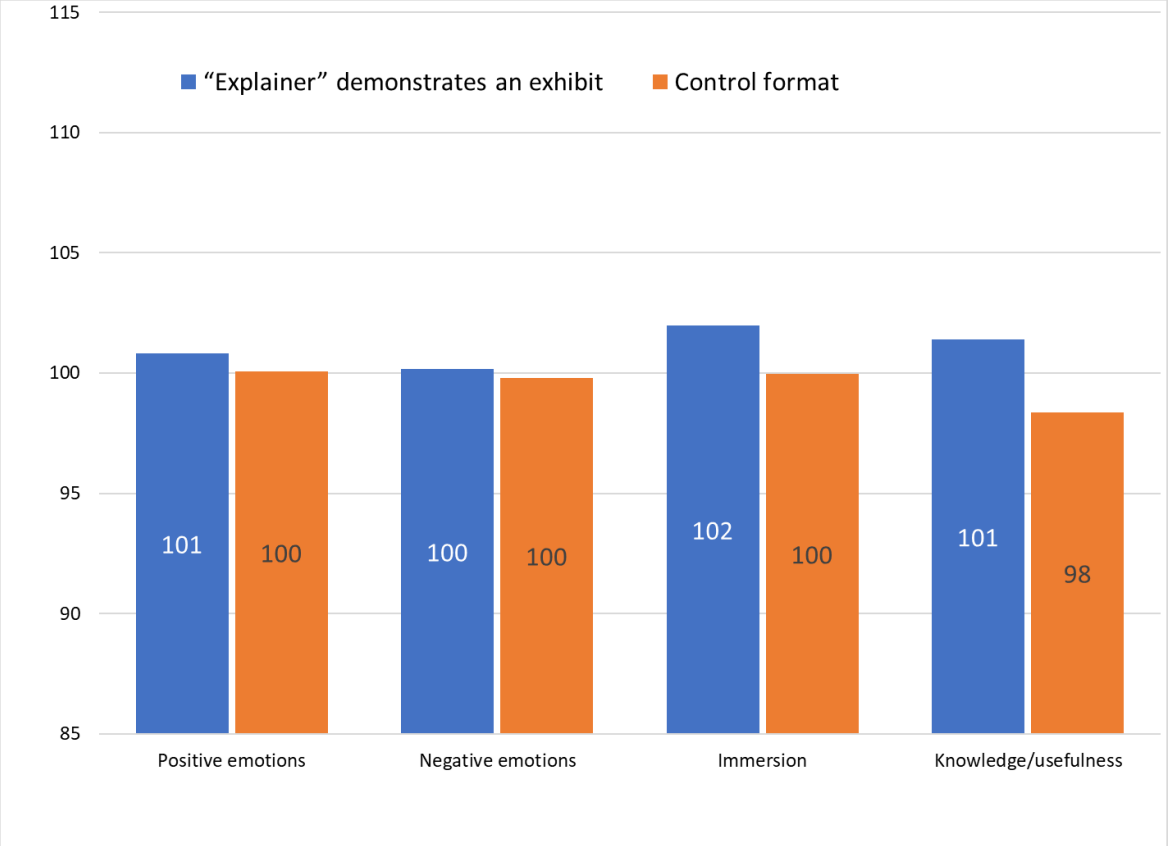

Figure 17: Effectiveness of the format "Explainer demonstrates" (Note: for greater legibility, the results have been scaled so that the average for all formats in the range of each dependent variable is 100 and the standard deviation 15)

What emotions did students feel when they visited the exhibition in this format? The educators demonstrating the behavior at the exhibits completed the task successfully – they sparked students' interest and excitement with the exhibition. Such demonstrated behavior, however, undermined the visiting satisfaction and the positive surprise effect. Being taught how to experiment with the exhibits reduced the related boredom and staleness, increasing the feeling of being energized (greater anxiety). The guidance given by the educators on how to use the exhibit and how to link it to school knowledge increased the tendency to identify the exhibition as relevant. This instructional element lowered the level of surprise and satisfaction, but at the same time it increased the curiosity and made the content feel more practical (Figure 18).

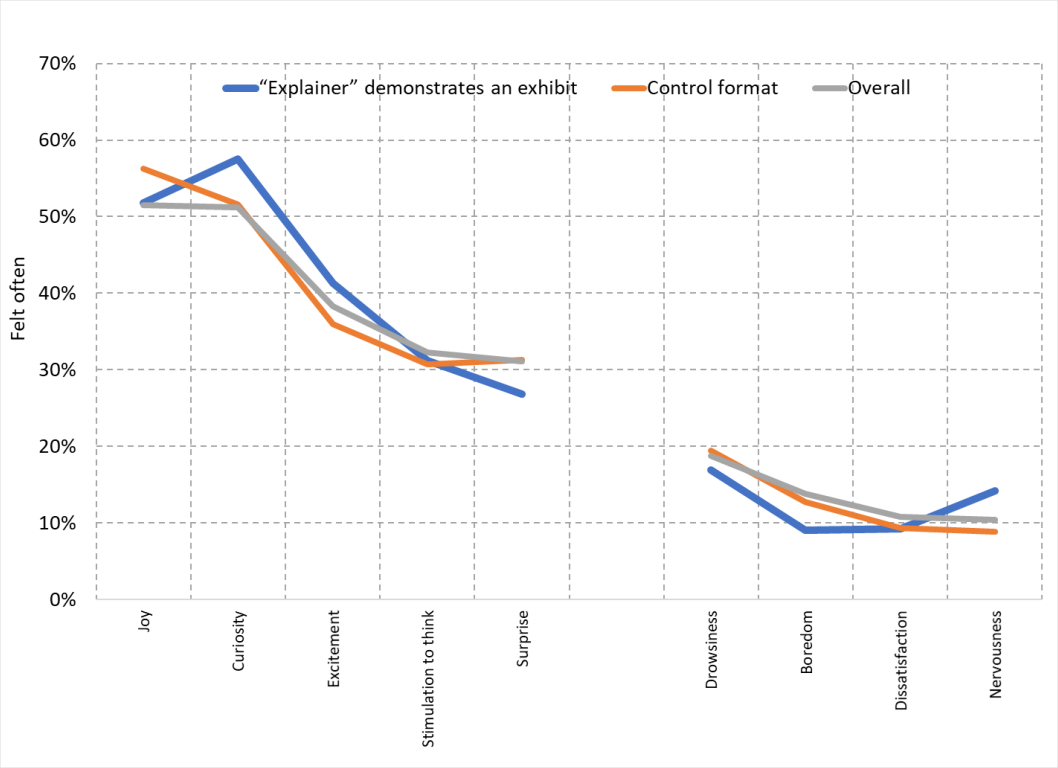

Figure 18. Emotions felt by students visiting the exhibition with an explainer

Format 7. Questions in the exhibition space (*N* = 127)

The next format featured modifications within the exhibition space itself. For each exhibit additional questions were displayed next to it, and visitors could answer them by experimenting in a specific way. The example questions placed next to the "suspended ball" exhibit were: "How does the air flow around it?" or "What happens if you place your hand in the air stream while the ball is suspended?".

Results showed that the space modification did not result in any significant differences pertaining to the emotional impact or sense of usefulness, as compared to the condition without intervention (the control format). However, significant differences were noted for immersion ($p < .05$). The questions retained students at the exhibits for a longer time, deepened their contact and enabling them to be more immersed in the visiting process (Figure 19). Experimenting as a means of answering the exhibit's questions significantly increases the time spent working with an exhibit, presenting the students with a clear objective and channeling their activity.

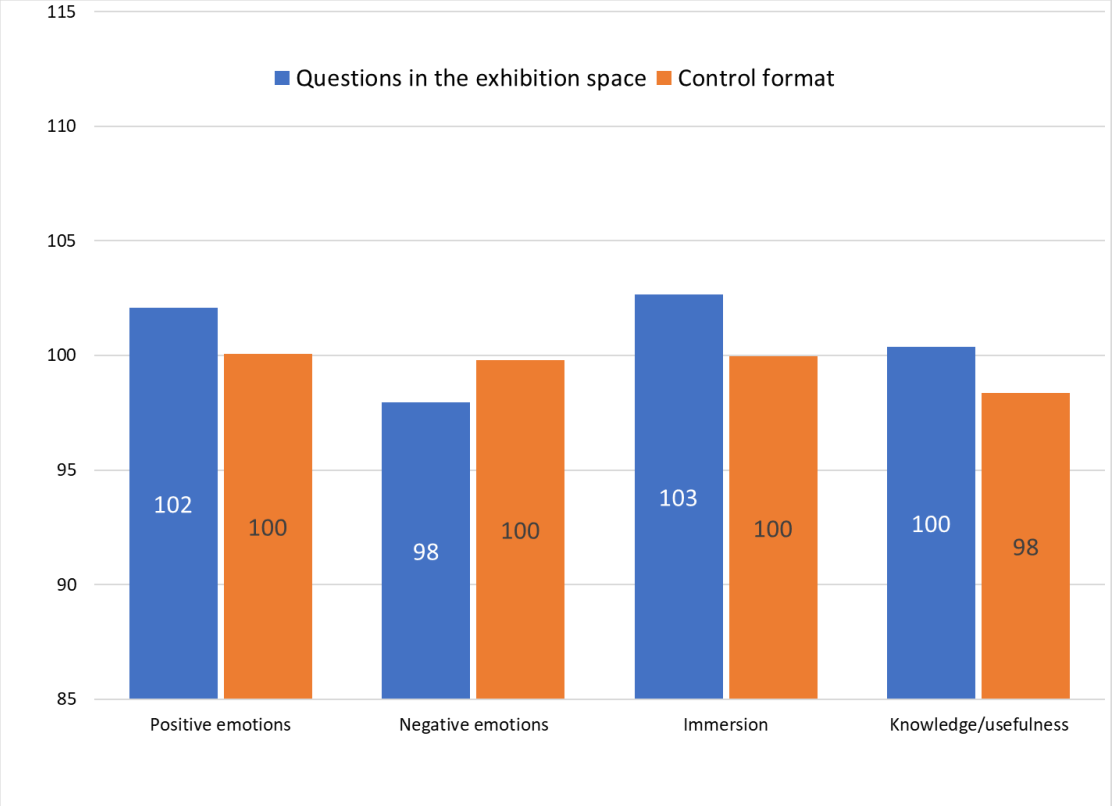

Figure 19: Effectiveness of the "questions in the exhibition space" format (Note: for greater legibility, the results have been scaled so that the average for all formats in the range of each dependent variable is 100 and the standard deviation 15)

Compared to the control format, here more visitors felt curious and excited. Placing questions within the exhibition space also encouraged students to think on their own. The prospect of finding answers to the question motivated the students to work with the exhibit on their own, resulting in less of them reporting boredom, sleepiness or discontent (Figure 20).

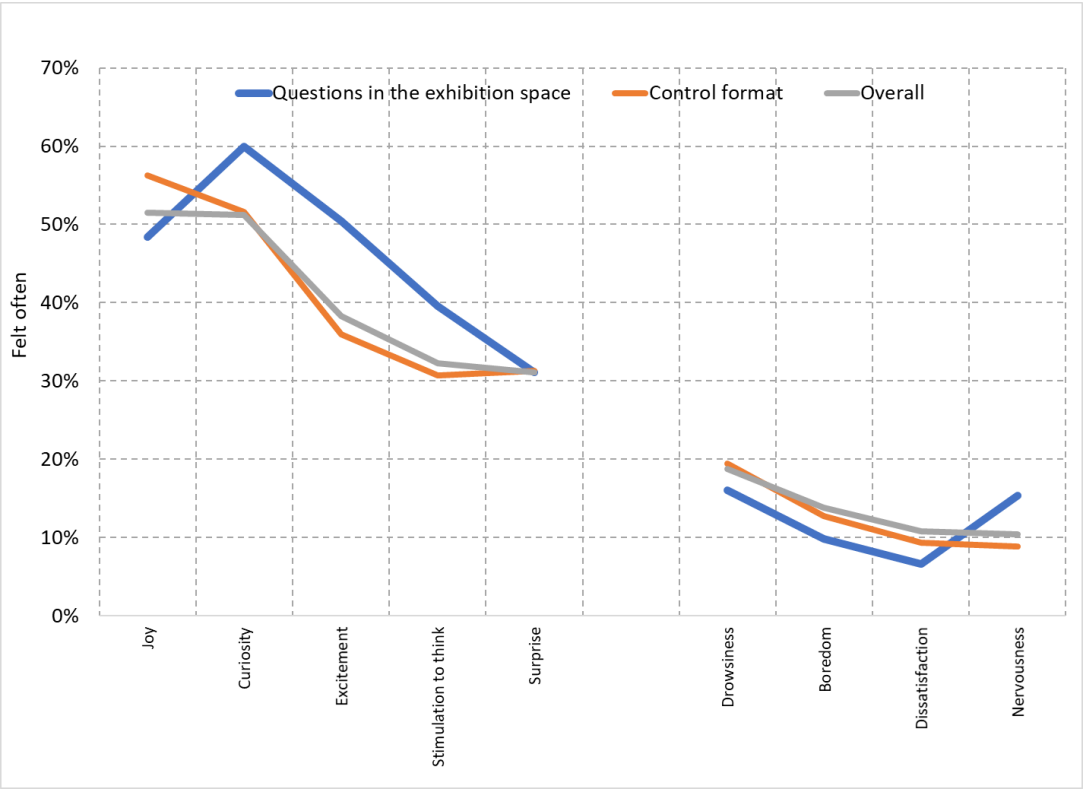

Figure 20: Emotions felt by the students visiting the exhibition in the "Questions in the exhibition space" format

Format 8. Students as scientist (*N* = 140)

This next format prompted the students to visit the exhibition while wearing laboratory gowns. Students were asked to put on the coats like those of doctors/scientists, and visit the exhibit wearing them.

Visiting the exhibition in lab gowns did not result in any significant differences in either emotional experience or immersion, as compared to conditions without this modification. Statistically significant differences were reported in the perceived exhibition usefulness with respect to regular classes ($p < .01$)—wearing the laboratory gown highlighted the practical and scientific aspect of the exhibition.

In terms of emotions, results showed that somewhat more visitors—as compared to the conditions without intervention—declared they had felt curiosity and excitement while visiting, and that the exhibition was thought-provoking. Note that a small group of visitors also experienced a slight increase in dissatisfaction. Taking on the role of a scientist induced interest in a group of them, which can be explained by the fact that activities like these are unusual during daily classes.

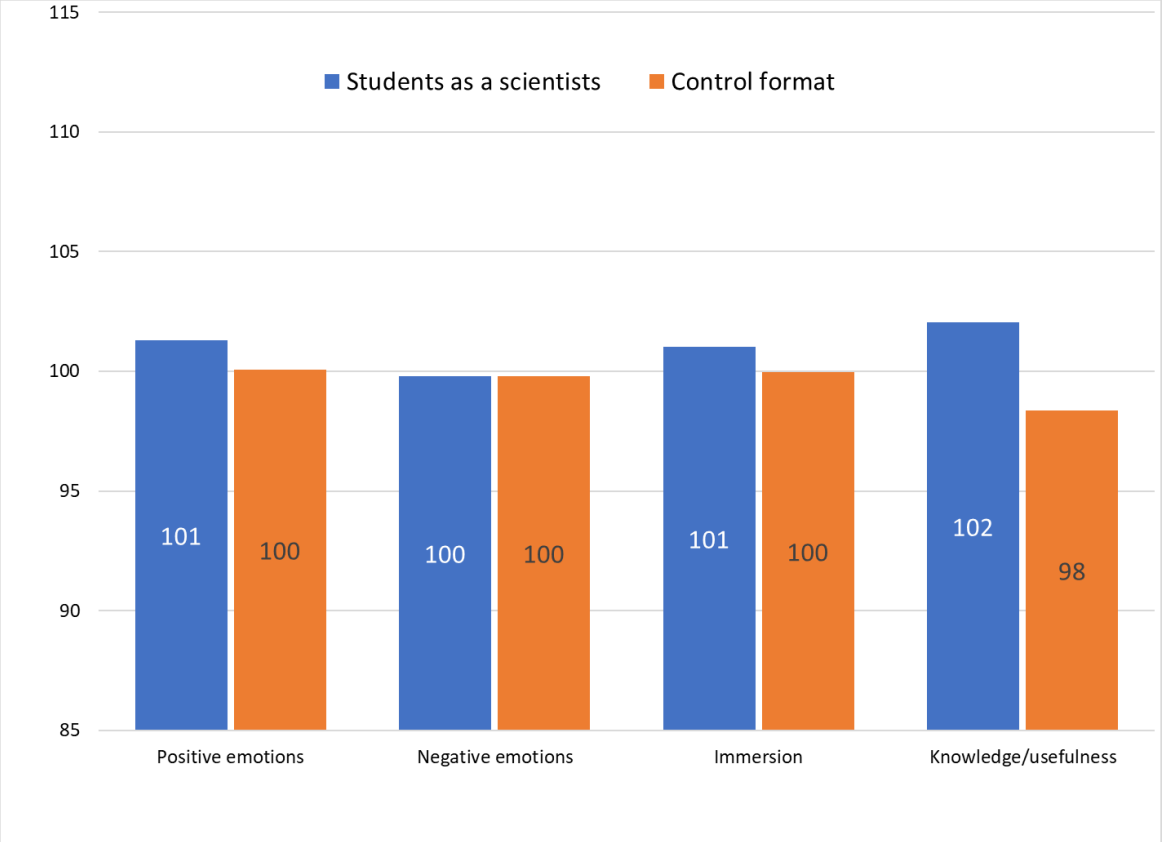

Figure 21: Effectiveness of the 'Students as scientists' format (Note: for greater legibility, the results have been rescaled so that the average for all formats in the range of each dependent variable is 100 and the standard deviation 15)

As for those students that reported increased dissatisfaction, it might have been caused by a reluctance to adapt to these conditions (non-typical situation), which would justify their polar opposite emotions (Figure 22).

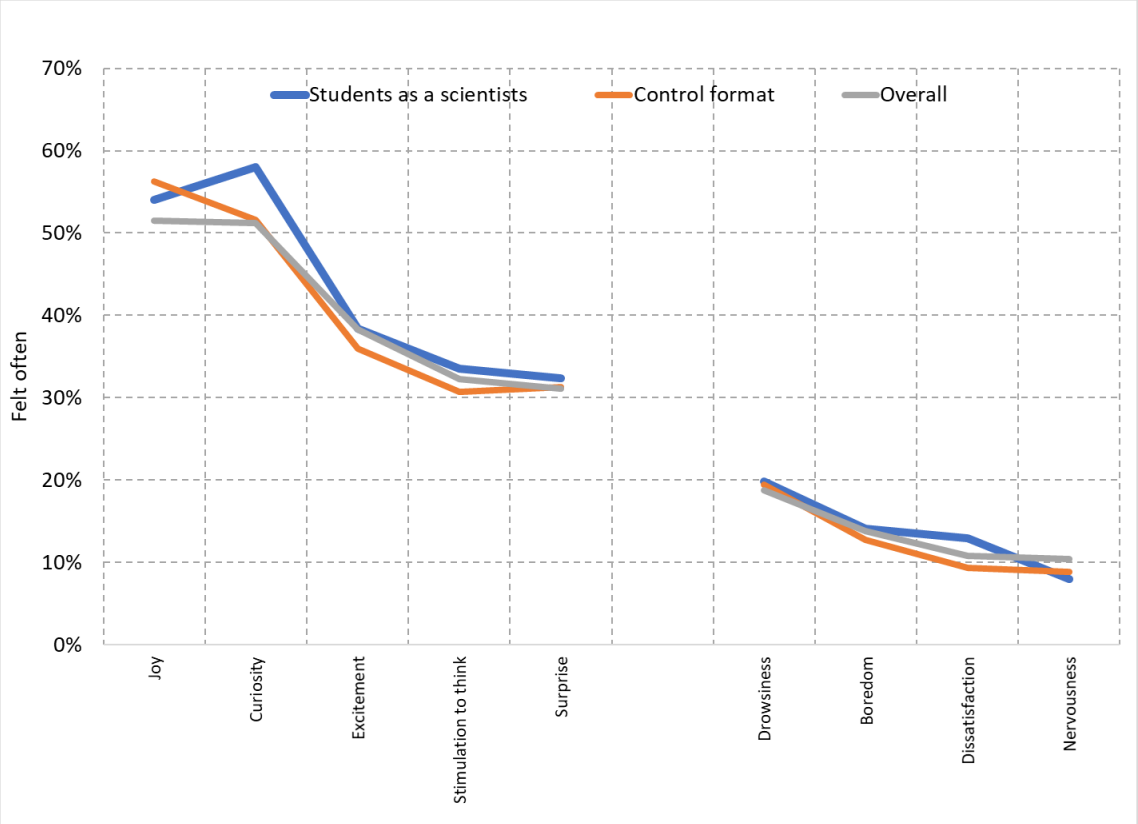

Figure 22: Emotions experienced by students visiting the exhibition in the format "Students as scientists"

Format 9. Worksheets (*N* = 41)

The last format tested was a visit with worksheets. Here the Copernicus Science Centre researcher handed the students worksheets which contained questions and tasks related to selected exhibits. Examples from the exhibit “Annoying echo”:
Sing “For he’s a jolly good fellow”.
Count from 1 to 10 then back from 10 to 1.
Did you manage to do it without mistakes?
Why do you think reading is difficult? Note down your answers.

Visiting the exhibition with worksheets showed no significant differences compared to the control format. Both formats produced similar results in terms of inducing negative and positive emotions, visiting process engagement and perceived usefulness of the knowledge obtained during classes.

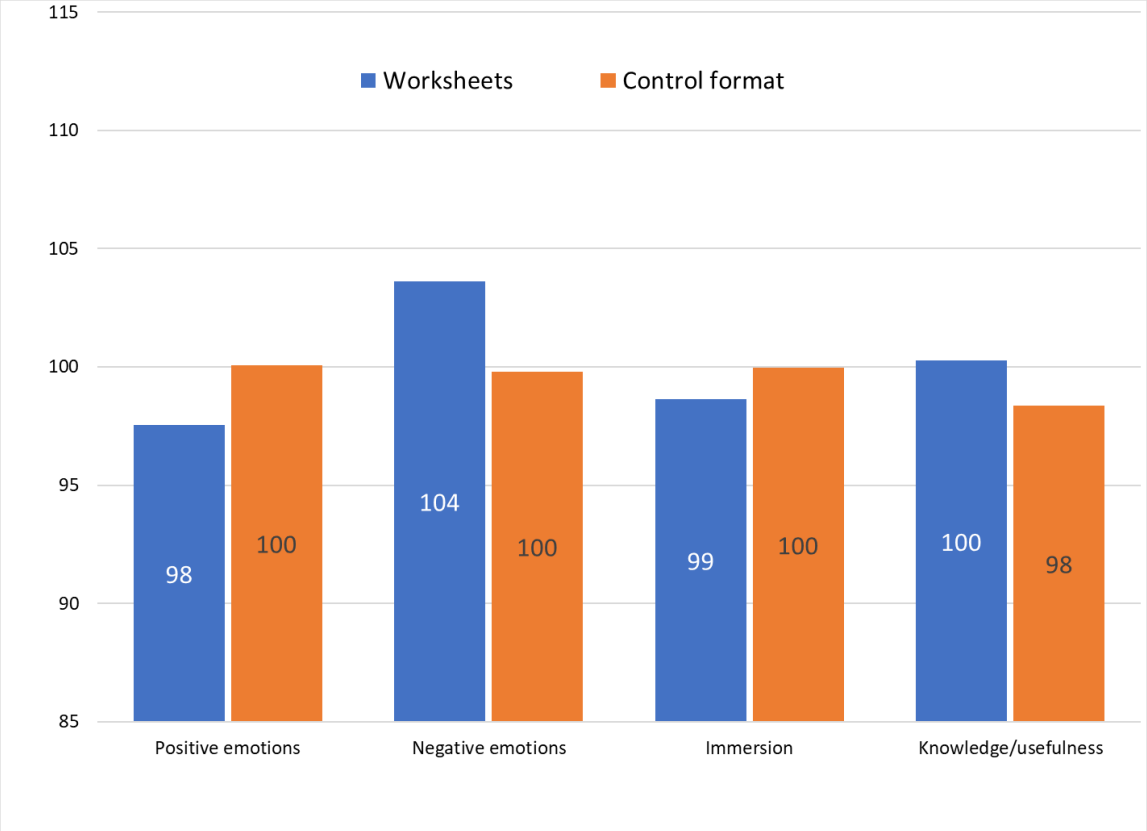

Figure 23: Effectiveness of the "Worksheets" format (Note: for greater legibility, the results have been scaled so that the average for all formats in the range of each dependent variable is 100 and the standard deviation 15)

The necessity to fill in the worksheets resulted in a decrease in positive emotions. The students less often felt joy, curiosity and excitement while visiting, as compared to the control format. The worksheet-filling chore bolstered the feeling of sleepiness and boredom. The level of dissatisfaction and anxiety was relatively lower, which might have resulted from the fact that the students might be used to this form of work during classes (Figure 24).

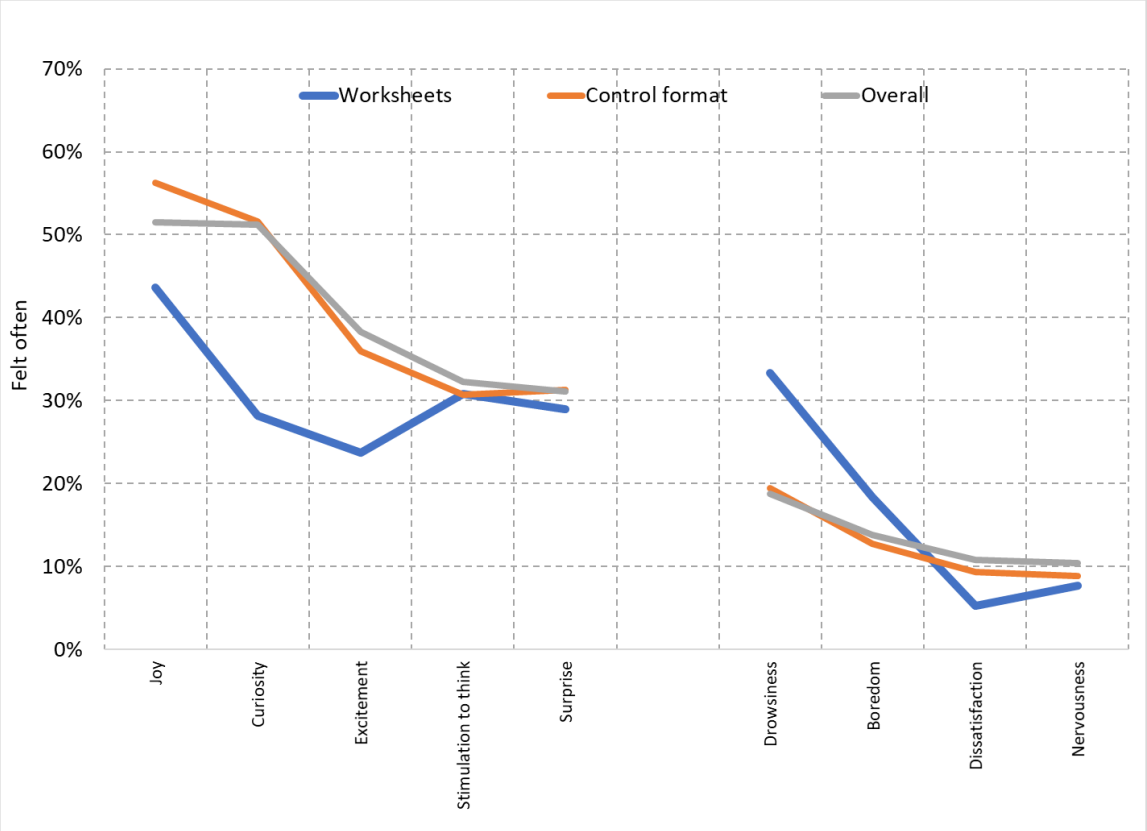

Figure 24: Emotions felt by the students visiting the exhibition in the format of a "Worksheets"

Recommendations

Based on the results of the study, recommendations were made both for exhibition creators and for educators. The main guidelines are targeted at teachers who, when visiting science centers, want to add value to the visit and help students understand and remember the knowledge gained at scientific exhibitions. The study formulated both general conclusions regarding the effectiveness of the different formats and detailed recommendations regarding the application of a particular format to assist the pupils while visiting the exhibition.

Format 1. Teacher as a mentor
Recommendations for teachers
This format somewhat resembles normal classes and can thus be used as a special form of class, including deeper explanations and visualization of theoretical problems. It requires, however, fairly good substantive and practical preparations on the teacher's part, i.e. knowledge of the phenomena presented by the exhibits and the ability to work with the exhibits.
When should this format for visiting science centers be applied?

- as an extension of regular classes, activities that present or summarize the introduction of a selected topic.
- as a means of visiting exhibitions to boost student engagement and strengthen the perceived usefulness towards further school education.

How should this format for visiting science centers be applied?

- By drawing meaningful comparisons and valuable analogies towards the observed phenomena, asking students to describe and explain them and asking in-depth

questions about both the exhibit and the phenomena, the teacher can induce curiosity and provoke thought.
- The teacher should study the exhibition prior to visiting it with the students. Acquiring the necessary knowledge will allow the teacher to relate it to particular topics taught in classes and draw comparisons that will help students remember the content. Paying a visit to the exhibition is highly recommended before taking the class to it.
- One limitation of this format appears to be that students experiment on their own relatively less, moving them closer to just observing the conducted experiments.

Format 2. Teacher as an experimenter
Recommendations for teachers
This format can be used when, like previously, the teacher intends to highlight the connections between the science center visit and the regular classes, as well as to increase students' engagement into the process of collective learning. It requires the teacher to step out of the usual academic-authority role, providing instead an opportunity to learn together, without the burden of the student-teacher relation.

When should this format for visiting science centers be applied?
- To strengthen the positive relations between teacher and students.
- To encourage the students to experiment and share the knowledge.
- To strengthen the students' involvement into the visiting process.
- To open the students' minds towards experimentation.

How should this format for visiting science centers be applied?
- The teacher, being an equal partner, can ask the students to explain how exhibits and phenomena work.
- The teacher, by experimenting on his/her own can motivate the students towards similar engagement.
- Together with the students, the teacher can express his/her positive and negative emotions and share honest opinions.

Format 3. Teacher or animator asks a question before the visit
Recommendation for teachers
Using this format is most suitable in cases when the teacher decides to include the visited exhibit(s) as part of future classes. The perspective of an inspiring conversation after experiencing the exhibition can serve as an additional motivation to engage and pay attention during the visit. Conducting classes with students being able to share their observations, enhanced with their own conclusions and the teacher's knowledge, can further aid and solidify the knowledge obtained during the visit.

When should this format for visiting science centers be applied?
- To increase the students' engagement into the visiting process and correlate the visiting experience with a particular domain or topic.
- To stimulate the process of linking theoretical to practical knowledge.

How should this format for visiting science centers be applied?

- Visiting the exhibition should act as an integral part of the classes, being later enhanced and continued, with students being able to share their experience from the science center while tackling the appropriate topic in school.
- The teacher, while stating the question prior to visiting the exhibition, should relate it to phenomena observed in everyday life, thus increasing the effectiveness of the visit and learning at school.

Format 4. A fellow student assist to experimentation
Recommendations for teachers

Our study found that the peer-to-peer format reduced the engagement and increased the negative emotions, thus it's not recommended to use it as-is, towards aiding the visiting process.

When should this format for visiting science centers be applied?

If such peer-to-peer tutoring starts naturally during a visit it can be an effective tool to support learning.

How should this format for visiting science centers be applied?

- If the teacher wants to use peer tutoring at the exhibition, the tutor should be additionally trained in presenting the knowledge, asking questions and giving feedback. Perhaps a more suitable form of tutoring at the exhibitions would be one-on-one, or in small groups.
- The peer tutor should take an equal position to his colleagues and trigger the learning-supportive process whenever he/she feels competent.

Format 5. "Explainer" answers questions
Recommendations for teachers and educators

Based on our results, this format cannot be recommended in strengthening student engagement and promotion positive emotions and thus it should not be used in this form.

When should this format for visiting science centers be applied?

- To slightly motivate students to think, taking into account the potential decrease in positive emotions.

How should this format for visiting science centers be applied?

- The presence of a science center educator ("explainer") should only be used when absolutely necessary, to explain the problem and broaden knowledge.
- The ability to access the educator's help in a flexible way, without creating the necessity for interaction, should positively influence the exhibition's emotional experience.

Format 6. "Explainer" demonstrates exhibits
Recommendation for teachers and animators

The science-center educator's overall guidance and instructions on how to work with exhibits can be used to introduce the students to the visit. To a certain degree, this format supports

the exhibition's usefulness in a school context, and thus can be used when there is a need to link a visit with teaching in school.

When should this format for visiting science centers be applied?

- As an opening element for visiting an exhibition, to make pupils aware of the space and exhibits and to familiarize them with the way the process works.
- To further link the exhibition with the knowledge presented in school.

How should this format for visiting science centers be applied?

- At the beginning of the visit, the educator from the science center can present the methods of experimenting with the exhibits.
- The educator can demonstrate the ways of handling the various exhibit types, especially those that appear less intuitive to use.

Format 7. Questions in the exhibition space

Recommendation for teachers and creators of exhibits descriptions

This form of space modification is most effective when we want to increase engagement towards self-experimentation, without the significant support of educators or teachers.

When should this format for visiting science centers be applied?

Drawing the students' attention towards questions and information located within the exhibition space will help visitors to induce their engagement and unassisted work with the exhibits.

How should this format for visiting science centers be applied?

- The teacher should draw the students' attention towards the additional information located across the exhibition space, as it may enhance their experience with the exhibits.

Format 8. Students as scientist

Recommendation for teachers and science center's employee

This format can be used to increase student engagement towards working with the exhibits. It can also be combined with any other effective format, to further boost the results and raise the level of positive emotions.

When should this format for visiting science centers be applied?

- To solidify the conviction that experiments within the exhibition space are tied to the school education.
- To make the visiting more attractive.

How should this format for visiting science centers be applied?

- This format can be combined with any other effective format of exhibition visiting.

Format 9. Worksheets
Recommendations

Format with worksheets is useful in supporting in- school learning. Visiting the exhibition with worksheets can be a special kind of lesson. Interesting tasks related to the exhibits can increase the student engagement in working with worksheets.

When should this format for visiting science centers be applied?

- To use the exhibition space for teaching lessons similar to regular classes, focused around particular goals.

How should this format for visiting science centers be applied?

- The form of the tasks is particularly important here, because different kinds of tasks support various processes (from memorizing, to understanding and creative thinking). For the selected group of exhibits, it will be worthwhile to apply the scientific method: presenting a hypothesis, verifying it and attempting to explain the results obtained.

Conclusion

As in past years, in this edition of the project the arrival of the Naukobus was always met with an overwhelmingly positive reception from school students – both in terms of emotions (feeling of immersion, many positive and few negative emotions), and the perceived usefulness of the exhibit content in their school classes. It appears that even a brief period of contact with the exhibition instills a positive attitude and presents students with methods of learning unlike those used during typical classes. Even with the passing nature of this effect, it still creates perspectives for sparking curiosity, supporting the growth of twenty-first century skills and proving to students that gaining knowledge can in fact be an active process.

In this year's study, we found that differences in visiting formats, although often involving subtle interventions, still resulted in differences in students' engagement and visiting experience. Certain differences in the impact of the different formats were found to be statistically significant. However, at the same time the effects were relatively slight, considering the differences generated by the various formats. In other words, although the formats did vary in terms of effectiveness, the differences in impact were small enough to potentially be considered practically insignificant. The rather pessimistic tone of this conclusion is weakened, however, by the nature of the study. It should be kept in mind that the study was not conducted in a tightly controlled lab-like environment, potentially eliminating all the disruptive factors, but it was rather a quasi-experiment conducted in a natural environment, obviously under the unavoidable influence of uncontrollable variables – ranging from the visiting day weather conditions, all the way to the specific nature of the schools that hosted the Naukobus travelling exhibition. For this reason, all the results presented herein should be treated as merely a first step towards further, more controlled research.