Progressing Science, Technology, Engineering, and Math (STEM) Education in North Dakota with Near-Space Ballooning

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The United States must provide quality science, technology, engineering, and math (STEM) education in order to maintain a leading role in the global economy. Numerous initiatives have been established across the United States that promote and encourage STEM education within the middle school curriculum. This study integrated a three-week long Near Space Balloon project into six eighth-grade Earth Science classes from Valley Middle School in Grand Forks, North Dakota. It was hypothesized that after the students designed, constructed, launched, and analyzed their payload experiments, they would have an increased affinity for high school science and math classes. A pre- and post-survey was distributed to the students (n=124), before and after the project, to analyze how effective this engineering and space mission was. The surveys were statistically analyzed, comparing means by the Student's t-Test, specifically the Welch-Satterthwaite test. Female students displayed a 57.1% increase in math and a 63.6% increase in science; male students displayed a 46.6% increase in science and 0% increase in math. Most Likert-scale survey questions experienced no statistically significant change, supporting the null hypothesis. The only survey question that supported the hypothesis was, "I Think Engineers Work Alone," which experienced a 0.24% increase in student understanding. The results suggest that integrating a three-week long Near Space Balloon project into middle school curricula will not directly influence the students' excitement to pursue STEM subjects and careers. An extensive, yearlong ballooning mission is recommended so that it can be integrated with multiple core subjects. Using such an innovative pedagogy method as with this balloon launch will help students master the scientific process and experience real team collaboration, as they did with this successful mission.

Nomenclature

STEM	=	Science, Technology, Engineering, and Math
VMS	=	Valley Middle School
n	=	Number of student participants
$\bar{X}_n$	=	Mean of population size
ω_n	=	Value of the Likert Scale Survey Questions (1-5) responses
s_n	=	Standard variance

I. Introduction

In order to maintain a leading role in the global economy, the United States must maintain its dominance in science, technology, engineering, and math (STEM) education. American education is rapidly falling behind its Asian competitors, providing students with fewer opportunities that could establish cutting-edge innovations[2]. There are many initiatives across the United States that are attempting to improve its K-12 standings in STEM education. New academic reforms are being introduced into the middle school curriculum, providing students with hands-on and engaging activities. In order for the U.S. to become the global leader in education, the students must

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use critical thinking skills and fundamentally understand the scientific method. Once students are able to think critically, they can apply their knowledge in all areas of their education, future careers, and lives.

In an effort to inspire middle school students to STEM subjects, this study provided 124 eighth grade students from Valley Middle School (VMS) in Grand Forks, North Dakota, with his or her own near space balloon (NSB) mission. The North Dakota Space Grant Consortium (NDSGC) provided these middle school students with a unique opportunity to work in teams and develop a scientific experiment. These experiments flew onboard two NSBs, both surpassing 102,000 feet (31 km) in altitude. In twelve teams, the students designed, constructed, and flew science experiments while collaborating together. The NSB project reinforced science content already covered in their science class and modeled how engineering teams interact in real life.

II. Procedure

The pre- and post-surveys were devices that would quantitatively analyze the effectiveness of the NSB project. The eighth graders anonymously completed these surveys. The pre-survey was correlated to the post-survey by the demographic information that the students provided in the first section of the document. The third group of questions was asked using a Likert Scale format.

In order to evaluate the Likert-scale questions, the phrases were given a value of one to five, *Strongly Disagree (1), Disagree (2), Neutral (3), Agree (4), and Strongly Agree (5)*. This way, the calculations were computed accurately, using numerical values. In order to avoid students blindly answering to one side of the spectrum, negatively worded questions were mixed into the survey to increase validity.

Not all of the students responded to every survey question. Some students accidentally skipped them or intentionally did not participate. The students, as instructed in the assent form, were not forced to answer anything they did not want to since the surveys were voluntary.

The total number of student participants (n value) who completed each survey question varied. Therefore, the weighted average was used so that each survey question was averaged proportionally to the value it represented, expressed as $\bar{\chi}$. The weightings determine the relative significance of multiple categories in relationship to each total number of participants. To produce the weighted averages, the following steps were administered for the pre-survey and post-survey data:

$$\bar{\chi} = \frac{\omega_1 x_1 + \omega_2 x_2 + \cdots + \omega_n x_n}{\omega_1 + \omega_2 + \ldots + \omega_n}$$

For each survey question, responses to each of the five Likert values were tallied (x_n) and multiplied by the corresponding weight (Likert scale value, ω_n). The products are all added together and then divided by the total number of participants for that particular survey question, seen in the denominator.

In order to determine if the change in $\bar{\chi}$ between the pre- and post-survey was statistically significant, the following Student's t-Test was implemented[3]:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{s_{\bar{X}_1 - \bar{X}_2}}, \text{ where } s_{\bar{X}_1 - \bar{X}_2} = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$$

A Student's t-Test compares the means of two categories of data. The Welch-Satterthwaite t-Test was the specific type of Student's t-Test used in this study. The Welch's t-Test compares two independent samples from the pre- and post- survey populations that also have unequal variances[2].

The first and second sample sizes, $n_1$and n_2 are each drawn from a population size with a mean of $\bar{X}_1$and $\bar{X}_2$ and variance $s_1^2$and s_2^2, respectively[4].

In Microsoft Excel, these calculations can be performed with the Welch's TTEST function for unequal variances: "=TTEST (array1, array2, tails, type)". The distinguishing difference between Welch's t-Test and the equal measurements t-Test is entering "3" for "type" instead of a "2"[2]. The "3" computes a calculation with two series with unequal standard deviations, whereas a "2" computes two series with equal standard deviations[5].

Excel's TTEST function returns p, which is the probability that the null hypothesis ("the NSB project did not influence the students") is correct. Since a 95% confidence interval was selected for this experiment, any p value greater than 5% (alpha) signifies that the results are due to random chance and then the null hypothesis is stated. For questions where the p value is less than 5%, the null hypothesis was rejected.

A. Contacting a Middle School

The NDSGC and the Space Studies Department at UND conduct numerous STEM outreach activities and are continuously pursuing new collaborations. It was after the NSBC launches that a balloon-based learning activity with an entire grade from a single school was pursued. Over the summer of 2013, Valley Middle School of Grand Forks Public School System was contacted: assistant superintendent of Teaching and Learning, Mr. Jody Thompson, VMS Principal, Mr. Barry Lentz, and eighth-grade Earth Science teacher, Mr. Brent Newman. Newman was very enthusiastic about integrating a ballooning activity into his astronomy and meteorology unit during science class.

A web-conference was held in August of 2013 with Dr. Ron Fevig, of the Space Studies Department; Dr. Gail Ingwalson, of the Education department; and Caitlin Nolby, the NDSGC Coordinator. It was here that both UND and VMS solidified their interest in the proposed collaboration. General details were discussed, such as approximate dates, curriculum plans, and important Institutional Review Board (IRB) deadlines.

B. Presentation/Introduction Workshop

The introductory presentation took place on October 31, 2013 for all six classes. Before initiating the presentation discussion, an assent form and a pre-survey were distributed to the students (n = 124). The pre-survey would quantitatively assess the initial level of STEM interests the students had prior to the NSB project.

Delivered via PowerPoint, the engaging 20-minute presentation summarized everything the students would be working on for the next three weeks. It covered:

1. What is a near-space balloon?
2. Why are balloons useful? What can we study?
3. How high and how far do balloons travel?
4. Past images and videos of UND NSB missions

In their groups, the students selected their desired payload sensors and wrote a short proposal of what natural phenomena they would study with it. The available sensors that the students could chose from were: temperature, wide-range temperature, acceleration (two sensors, one for each balloon), magnetic field, carbon dioxide, oxygen, pressure, ultraviolet B, a videocamera, and two digital cameras.

Some student groups were interested in launching secondary experiments. One group wanted to launch a banana. They provided a thorough scientific proposal, looking to observe the effects the stratosphere and solar radiation had upon the banana. They had prior knowledge of bananas turning dark and “mushy” that sparked their curiosity. Newman asked how they were going to quantitatively analyze the changes to the banana. They recalled one of Newman’s past lessons on variables and control groups. They decided to keep a control banana on the ground to use it as a comparison for the space banana.

C. Design Workshop

Newman created a worksheet on which the students stated their desired experiments, and most importantly, why they chose that experiment. He had previously covered the scientific process earlier in the school year, including the hypothesis, procedure, results, data analysis, and conclusion. The NSB project was a real-world example of how a team of space scientists and engineers would have to work together to produce research results. The students realized how important the design is to the overall success to the mission. The payload container had to house their selected sensor, giving it insulation, protection, and durability. They considered air resistance and drag, preparing the structure for the ascent and descent.

With no formal direction from instructors, the design team created the blueprint for their payload on November 1, 2013. They saw an example payload that the author brought to the introduction workshop. They were given advice, such as to make sure the sensor *and* the battery fit inside. They were told to consider the function of the sensor: cameras would need a window to the outside whereas sensors such as acceleration would not.

D. Construction Workshop

The construction workshop took place on Tuesday, November 5, 2013. It was up to the design team to create their payload shape and monitor the progress of the construction team. Only the design and construction team members were allowed in the science laboratory classroom, where the construction took place. The hypothesis and final report team had this class period to research the full capabilities of their data logger. The students involved in the final report team watched the design and construction teams’ progress, taking pictures for their PowerPoint conclusion.

The students worked well together and handled the construction equipment with care. They respected the two sharp box cutters, dangerous tools that could have easily brought this activity from the classroom into the emergency room. It was quickly noted that when 124 eighth-grade students use Styrofoam, it is extremely messy.

None of the students finished constructing their payloads during the in-class workshop. They had the option of continuing operations before and after school on Wednesday, November 6 and Thursday, November 7. They had a hard deadline of Thursday at 4:00 P.M. to finish their payload. The payloads were returned to UND on Friday morning to undergo final inspection and assembly.

E. Launch Day

In the early hours of Wednesday, November 13, preparations began for the dual-balloon launch. Winds aloft data was used with Balloon Track, a program that simulates the trajectory and landing site of the balloons due to jet stream conditions. Transferring this information into a GPS Visualizer, the estimated landing site was recorded and distributed to Newman and every chase vehicle.

Arriving at the football field of VMS, the graduate student launch team set each payload string on separate tarps. Each payload sensor had to be turned on and secured into the appropriate payload container. At 9:00 AM, the anticipated launch time, the team was still securing payloads and inflating the balloons. Students were entertained by an educational balloon physics lesson by Dr. Ron Fevig.

Unanticipated delays arose from some technical errors. One of the two filling hoses developed a leak, which left the team with only one filling system for both balloons. Even with this delay, filling was not suspended, just decelerated. Second, two student sensors had to be placed together into another container, due to malfunctioning battery packs. The students were informed of this switch after the launch was complete, experiencing the unpreventable challenges that occur in real scientific missions. The empty containers were still utilized by housing the SPOT trackers.

The SPOT trackers and HAM radios were all turned on and their transmissions were confirmed. Another impediment occurred while the team installed the primary tracking computer into the chase school bus. They realized the AC to DC cigarette-lighter adapter was missing, and the launch team attempted to establish an alternate charging method. Ultimately, there was no solution, leaving the school bus without an operational tracking platform.

At 9:15 AM, the first balloon was completely filled and ready to launch. Team members secured it for fifteen minutes, until the second balloon was filled. With everything tied off, taped up, and ready to fly, twelve eighth-grade volunteers were allowed to hold the payloads, six per payload train. When all spectators had backed up from the launch site, the balloons were launched, one after the other. Both balloons were released at 9:50 AM.

Joyous applause, celebrations, and running ensued: the 12 eighth-graders participating on the chase ran to the school bus and the tracking team members left in three vehicles. The school bus was able to monitor Balloon 2 by following the first chase vehicle and monitoring the online SPOT website. On the bus, the author shouted out balloon altitudes to the students after receiving phone calls from the first chase vehicle.

Figure 1: Balloon Trajectories. *Balloon 1 reached 102,500 feet and Balloon 2 reached 102,050 feet. The student chase vehicle tracked Balloon 2.*

The middle school students were able to immediately locate the payload chain. It was found near a dirt road, easily accessible to the large school bus. The bright orange payloads were seen in the distance, luckily avoiding a dense patch of trees, a few yards away. After the graduate students obtained permission to go on the land and retreieve the payloads, the middle school students were able to examine their structures on the bus ride home.

Each balloon followed a similar trajectory, floating due east and surpassing 102,000 feet (Figure 1). Balloon 1 was filled with a little less helium than Balloon 2, causing it to ascend slower, travel farther to the east, and reach the peak altitude of 102,500 feet. Balloon 2, the balloon that the middle school students recovered, reached an altitude of 102,050 feet. It was fortunate that the students chased the balloon with the shorter float time.

F. Data Analysis Day

On Friday, November 15, 2013, the videos, images, and NeuLog sensor data were brought into the classroom and presented to all six classes. The students were astonished with the footage and data that *they* obtained. The students were able to include the videos, photographs, and graphs in their final reports.

The balloon burst video was shown to the students, in real time and slowed down, frame by frame. It was rewarding to watch the students silently await the "pop" of the balloon. At this point, the 30-foot-diameter balloon spun silently against the dark backdrop of space while every pair of eyes – students, teachers, and staff visitors – avidly stared at the screen, awaiting the burst.

Some class periods received the unfortunate news that their experiment had malfunctioned. They understood this is an unavoidable obstacle while working on a science mission. The students realized that even though their inquiry-based project failed, they still received valuable information. If launched again, they would consider the errors in their design and ultimately perfect their payload.

III. Results

Two of the most valuable questions in the pre- and post-survey were the *Most Anticipated Classes* (Figure 2) and *Least Anticipated Classes for High School (*Figure 4*)*. These survey questions were vital to the thesis question that will prove or disprove if the students' outlook on STEM education was impacted positively or negatively.

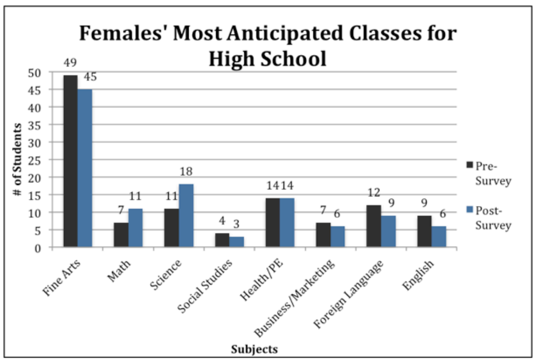

Figure 3: Females' Most Anticipated Classes for High School. *Math experienced a 57.1% increase. Science experienced a 63.6% increase.*

The female responses for *the Most Anticipated Classes for High School* (Figure 2) displayed a sharp spike in Fine Arts. The female students wanted to take Fine Arts, before and after the ballooning experience. Fine Arts surpassed all the other subject areas with 49 pre-survey counts and 45 post-survey counts. The target subjects, math and science, both increased from the pre-survey to the post- survey, supporting the hypothesis. Seven and eleven female students defined math and science, respectively, to be their most anticipated class in high school. After the ballooning experience, 11 and 18 female students defined math and science, respectively, as their most anticipated high school class. Overall, math increased by 57.1 percent and science increased by 63.6 percent.

The targeted survey topics, math and science, displayed quite distinctive results. Math remained constant from before and after the ballooning activity. Fifteen male students confirmed that they were eager to study science in high school in the pre-survey. After the ballooning experience, 22 male students had a strong interest in science, producing a 46.6 percent increase.

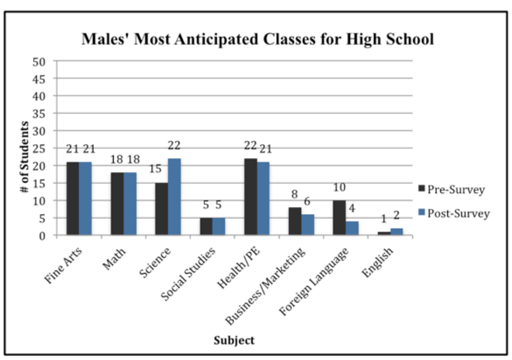

Figure 2: Males' Most Anticipated Classes for High School. *Math experienced a 0% increase. Science experienced an increase by 46.6%.*

The total number of female students (n = 107) who answered the survey question, "*the Least Anticipated Classes in High School"* was identical for the pre-and post-survey. The female students displayed a clear dissatisfaction when they thought of learning high school math, as seen in Figure 5. There is a prevalent spike in math compared to the other subject choices. After comparing the post-survey results to the pre-survey, math displayed a decrease by -2.9 percent.

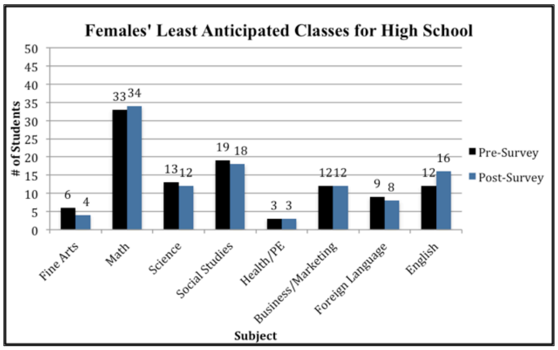

Figure 5: Females' Least Anticipated Classes for High School. *Math experienced a 2.9% decrease. Science experienced a 8.3% increase.*

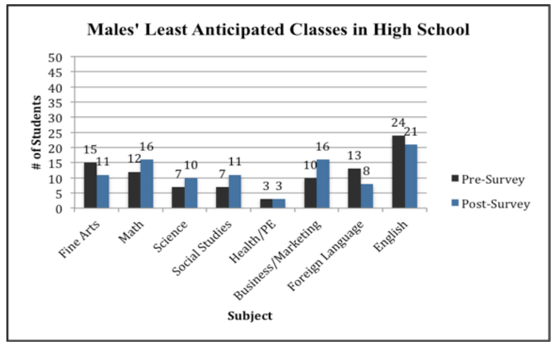

Figure 4: Males' Least Anticipated Classes in High School. *Math experienced a 25% increase. Science experienced a 30% increase.*

Focusing on high school science class data, female students displayed equal sentiments before and after the ballooning experience. With 107 participants, 13 showed discomfort with science on the pre-survey and 12 on the post-survey. The one-student difference is statistically insignificant and it can be deduced that the science category was not affected by the experiment. The post-survey results were intended to decline in the math and science regions, proving the students have a stronger apposition to the STEM subjects.

The least anticipated class that male students have for high school is English. One key result from the post-survey was the increase in both Math and Science. The goal of the balloon experiment was to introduce the students to a non-intimidating, fun side of Math and Science. The consensus for Math increased from 12 to 16 males, a change of 25 percent, and Science increased from 7 to 10 males, a change of 30 percent.

There were eight additional survey questions, all delivered using a Likert-scale, ranging from Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree. The eight survey questions were:

1. I plan on joining a science-related extracurricular activity.
2. I want to go to college.
3. I want to go to UND.
4. I think astronomy is interesting.
5. I think engineers work alone.
6. If I want to work in a STEM field, I must work solely for NASA.
7. I hope to get a job in a science field when I'm older.
8. I have a specific career in mind.

The only survey question that supported the original hypothesis was the "I Think Engineers Work Alone". Before the students collaborated together on their NSB project, they were uncertain if engineers worked alone on projects, producing a census closer to *Neutral*. After the NSB project, the students understood that as space scientists and aerospace engineers, they had to collaborate with their peers, similar to professional engineers ($\bar{X}_1$= 2.44, n = 118; $\bar{X}_2$= 1.86, n = 113; p = $1.16 \; x \; 10^{-6}$, α = 0.05). Figure 6 was the only student poll that resulted in a significant change, supporting the hypothesis.

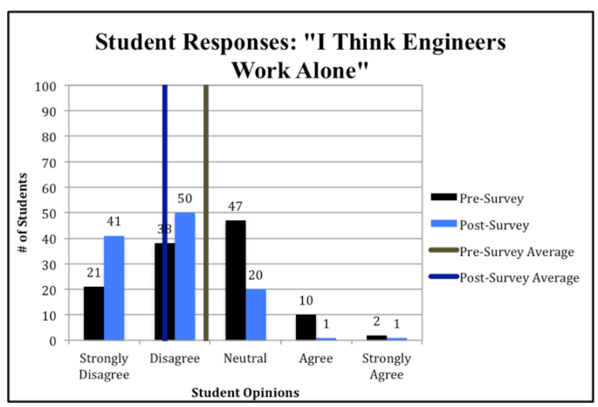

Figure 6: "I Think Engineers Work Alone"

The last section of the post-survey had open-response questions. The first question was, "*Please describe how you felt about the entire ballooning experience*". The students formulated their own vocabulary, phrases, and opinions without the accidental bias from a survey. This section gave the students complete freedom to illustrate their true disposition towards the NSB project. There were many positive phrases, including: *I enjoyed coming to science class, I felt honored, and this was a one-time experience*. Contrary, there were negative phrases that will be considered for future in-class balloon workshops. These included: "*waste of time, rushed, hectic, and boring*".

IV. Conclusion

It was vital for the students to collaborate in a team environment. The survey question, "*I Think Engineers Work Alone"* targeted their teamwork and critical thinking skills. Originally, students may have believed scientists require solitude in order to complete research, but had an increased understanding of teamwork after the NSB project.

The most critical aspect in the students' learning experience was having them master the engineering process. The eighth graders were introduced to the scientific method earlier in the school year and the NSB project was the ultimate reinforcing tool. In the student comment section, many agreed that this "once-in-a-lifetime experience" made them feel like a real scientist and able to collaborate on a real space mission. The pre- and post-survey was designed to evaluate if the balloon project improved the students' STEM dispositions.

The females' least desirable high school class was math, before and after the NSB project. This reflects the research stated above in the literature review. One goal of the balloon project was to lessen the intimidation factor of math concepts and dissuade the females' from avoiding higher education math classes. Unfortunately, with the limited amount of time allocated to the project, the students retained their original feelings towards STEM subjects.

It is important to note that the male students who enjoyed science before the NSB project experienced an increase, yet the males' who did not enjoy science, experienced a decrease. This may suggest that the NSB experiment polarized their opinions to STEM. If they enjoyed studying science before the project, they really liked it after; if they did not enjoy studying science before this project, they really did not like it after.

A. Limitations

Analyzing the socioeconomic status of the school district was pertinent for the validity of the surveys. With assistance from Dr. Ingwalson, it was discovered that many students at VMS qualify for reduced or free lunches every year. A free or reduced lunch is provided to students who are eligible for the government's program that subsidizes meals for children from low-income households[6]. In 2010, the USDE reported 51 percent of VMS students were eligible for reduced or free lunches, compared to the 27 percent state average. At the district level, 35 percent of students were eligible, placing VMS above both averages[6]. With an estimated population of 67,472 citizens, 16.5 percent of the individuals are under the poverty line[7].

The top four occupations in Grand Forks consist of: Management, Sales, Transportation, and Construction[7]. In 2010, the median household income for Grand Forks was $46,392[7]. In 2010, almost 75 percent of all of Grand Forks employees were salary workers[7]. This demographic information may not have been able to support the thesis objective of calculating how influential the parents' roles in STEM were to the students, since the students would not have been raised in a STEM environment at home. It is essential to consider these socioeconomic demographics when analyzing the degree of STEM influence in this specific study.

B. Future Work

There are a few procedural alterations that are recommended for any future NSB projects. First, it is suggested that the overall length of the design and construction workshops be augmented. The student design and construction teams require a prolonged workshop in order to complete their payloads. Both teams need at least two full class periods to complete their project stress-free. This will benefit the overall payload structures, engineering concept investigation, team collaboration, and allow their critical thinking skills to develop.

The project's effectiveness may increase if the date of the launch is changed. The 2013 VMS launch was during a cold mid-November day. At 9:00 AM, the temperature was 34 degrees Fahrenheit; 48 degrees F at 10:00 AM; and by noon, the temperature had reached 52 degrees F[8]. In the post-surveys, many students complained about filling the balloons outside for so long in such cold temperature. Instead of a late-fall launch, the students would benefit from a spring launch.

Besides a much warmer environment, which would help facilitate any idle moments, the students would be launching at the end of the academic year, not the beginning. More opportunities would arise if teachers could amalgamate the entire year's lessons into the ultimate "capstone launch project". All eighth grade teachers could prepare the students for the launch, including history. With over eight months of forewarning, every teacher could form his or her own connections to the launch, with their preexisting lesson plan. Also, potentially all students would be able to attend the balloon chase. Acquiring early parent permission and finalizing bus logistics would alleviate last minute stress and chaos.

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