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Strategies toward the gold medal: Unveiling the anticipatory processes of junior high school olympiad students in geometry problem-solving

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Abstract

The National Science Olympiad (NSO) presents significant challenges for most junior high school students. This qualitative study examines the cognitive processes of gold medal-winning students by analyzing their anticipation strategies in solving geometry problems. Employing a descriptive-exploratory approach, we conducted problem-solving tests (using modified NSO geometry questions) and semi-structured interviews with a gold medalist from SMPN 2 Jember. Our findings reveal three distinct anticipation patterns: (1) positive internalized anticipation - intuitive conceptual application yielding correct solutions (e.g., establishing geometric relationships without procedural calculations in Problem 1), (2) negative internalized anticipation - rapid but erroneous assumptions (evident in angle miscalculations in Problem 2), and (3) analytical anticipation - systematic verification through logical reasoning (demonstrated in ∠POR ratio reevaluation). These results provide empirical evidence of how anticipation strategies influence olympiad performance. The study suggests practical interventions including: (1) diagnostic tools for anticipation profiling, (2) teacher training programs to cultivate positive anticipation patterns, and (3) curricular integration of analytical anticipation as metacognitive strategy. For olympiad preparation, we recommend scaffolded problem-solving tasks with structured reflection to transform negative anticipation patterns. Future research should investigate the domain-specificity of these anticipation processes across mathematical disciplines.

Keywords: internalized anticipation positive; internalized anticipation negative; medal-winning students; national science olympiad

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Introduction

Geometry is a branch of mathematics that provides knowledge about the relationships between points, lines, planes, and spatial objects, as well as their properties and measurements (Amaliyah et al., 2022). Nopriana (2015) states that geometry engages students and fosters intellectual curiosity in classroom learning activities. Therefore, the geometry taught to students is helpful in the present and serves as a long-term preparation for dealing with technological developments.

In line with this rapid development, global competition in education is also intensifying. The global era has provided a positive impetus in Indonesian society, emphasizing that the future progress of Indonesia heavily relies on students' ability to master science and technology to compete healthily on an international level (Rosyid et al., 2020). Thus, mathematics teachers need to be prepared to face the challenges of the Industrial Revolution and adjust their teaching methods according to needs (Zulnaidi et al., 2024), while students must have a competitive attitude and be able to think critically and creatively when solving various problems, one of which is mathematics. It can be achieved through students' participation in various competitions, such as math olympiads, which improve their analytical skills and encourage collaboration through group discussions and teamwork in solving complex problems. In addition, these competitions often involve real-world applications of geometry concepts, such as spatial planning, architectural design, or route optimization, so that students can see the relevance of mathematics in everyday life and build a deeper understanding of the material.

Participation in mathematics olympiads has a positive impact, improving students' thinking skills and potentially developing their ability to solve everyday problems, enhancing their logical reasoning, critical thinking, and creativity (Rahman et al., 2022). Therefore, students trained for mathematics olympiads, especially those who win medals, are considered more capable because they are accustomed to solving problems that require reasoning skills, critical thinking, and creativity. However, the mathematical problem-solving abilities of medal-winning students only sometimes guarantee their ability to solve geometry-related problems, as olympiad problems cover various topics.

When solving mathematical problems, including those related to geometry, students utilize their knowledge to perform mental actions by understanding their brains (Yudianto, 2021). Before solving a problem, students anticipate by understanding it, predicting the solution process, and considering possible solutions, even if the initial solutions are incorrect. Anticipation can be seen as a mental action to imagine a particular assumption without involving detailed steps to achieve that assumption (Lim, 2007; Tasni et al., 2019a). Additionally, anticipation can be interpreted as mental and physical actions carried out by students to overcome uncertain situations (Maswar, 2019; Yudianto, 2017). Anticipation is closely related to prediction and forecasting (Vale et al., 2019). Forecasting is understanding the assumption of an event experienced before carrying out a solution related to that event (Yudianto, 2015). Anticipation occurs when an individual encounters a situation or problem, necessitating the formulation of assumptions or predictions about the appropriate strategies and solutions to address it. This study defines the anticipation process as a sequence of mental and physical actions students undertake to forecast the steps and solutions required for resolving a mathematical problem.

There are five types of anticipation: (1) Impulsive Anticipation, a way of thinking where students tend to be spontaneous, determining actions directly. They act on thoughts without analyzing the problem or considering whether their anticipatory action is appropriate. (2) Rigid Anticipation is a way of thinking where students maintain and do not alter their understanding of a problem. (3) Explorative Anticipation: involves seeking and testing ideas to understand a problem better. (4) Analytical Anticipation involves analyzing problems and setting goals to guide actions. (5) Internalized Anticipation involves students acting spontaneously in problem-solving because they understand their situation and appropriate anticipatory actions (Sunardi & Yudianto, 2015). Given the importance of anticipation in problem-solving, this study aims to reveal the anticipation process of gold medalist junior high school students in solving NSO questions on geometry.

Methods

This research was descriptive-exploratory with a qualitative approach, which allows for an in-depth exploration of students' anticipation processes. This qualitative approach provides space to understand students' unique mindsets, strategies, and experiences in dealing with NSO questions on the topic of geometry to describe the process more comprehensively and contextually. It was conducted at SMPN 2 Jember, with the subject being a student who was a gold medal winner at the regional mathematics olympiad. There are three instruments in this study: the researcher as the main instrument (Creswell, 2018), a test consisting of two problems modified from NSO problems in mathematics on the topic of geometry, and an interview guideline, which serves as the basic framework for questions asked to the research subjects during interviews. The test instruments and interview guidelines were validated by three experts, including two mathematics education lecturers with expertise in research instrument development and mathematics learning theory and one certified mathematics teacher with 14 years of teaching experience, who provided practical perspectives on the relevance and implementation of the instruments in the classroom. Their expertise ensured that the instruments used had strong theoretical and practical validity. The test instrument and interview guideline received scores of 2.77 and 2.85 on a scale of 3, respectively, and were declared valid after two revisions based on feedback from the third expert.

Data collection was carried out using test and interview methods. The test results included descriptions of students' answers related to solving mathematical problems. Furthermore, interviews were conducted with research subjects to obtain more accurate data related to the anticipation process employed by students. The type of interview used was semi-structured, consisting of core questions developed during the interview process.

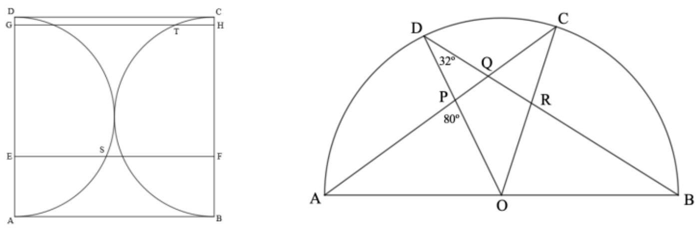
Data analysis was conducted after all data related to tests and interviews with research subjects were obtained and deemed credible, i.e., through a method triangulation process that combines results from tests and interviews. This triangulation ensures that the data obtained support each other and provide a more comprehensive picture of the students' anticipation process, thus increasing the validity and reliability of the research results. This stage involved compiling test results and interview transcripts to conclude the anticipation process used by students in solving the given problems.

Results

There are two problems given to the subject.

Problem 1

There are two semicircular shapes with diameters AD and BC in square $ABCD$. $\overline{EF}$ and $\overline{GH}$ are parallel to $\overline{AB}$. If $\overline{ES} = 7\ cm$, $\overline{TH} = 3\ cm$, and $\overline{EG} = 10\ cm$, then determine the area of square $ABCD$!



(a) (b)

Figure 1. (a) Problem 1 and (b) Problem 2

If it is known that $\angle OPA = 80°$, $\angle ODB = 32°$, and O is the midpoint $\overline{AB}$, then determine the ratio of $\angle PQR$ and $\angle POR$!

Based on the results of data analysis, the following is the data on the achievement of anticipation indicators in each research subject for problems 1 and 2.

Subject anticipation analysis

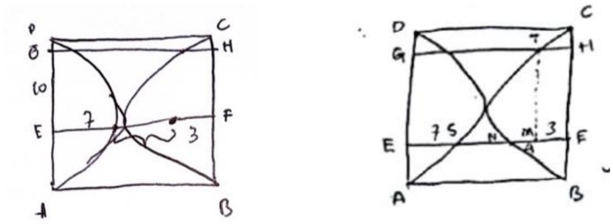
Problem 1

The subject reads the problem without doing other activities and needs time to receive and understand the information well. Furthermore, Subject can determine what is known and what is asked and can explain the information he obtained in detail. This can be seen in the following interview excerpt.

P104 : what information do you get after reading this problem?

S104 : there are two semicircles with diameters AD and BC in square ABCD, (pause for a moment-Internalized anticipation) so AD and BC are diameters, well that's the same as the side of ABCD (explorative anticipation). Then EF and GH are parallel to AB eee… (**Internalized anticipation**), also parallel to CD hehehe (**Exploratory anticipation**). ES is 7 cm, it is also known that TH is 3 cm, EG is 10 cm (**Analytical anticipation**).

The interview excerpt above shows that Subject provides information by reading the problem and confirming it with additional information obtained based on the subject's understanding. Based on the indicators and understanding of the type of anticipation, Subject can be classified into explorative and internalized anticipation at this stage. After that, Subject began to try to solve the first problem by drawing a sketch of the structure. Subject drew two different sketches on the doodle sheet and the answer sheet, as follows.



(a) (b)

Figure 2. (a) Sketch on the scribble sheet and (b) Sketch on the answer sheet

Initially, Subject sketched Figure 2 first. The sketch has complete information regarding the length of the line segments needed to solve the problem. After drawing the sketch, Subject determined the rules that would be used to solve the problem, as seen in the following interview excerpt.

P105 : What kind of rules would you use to solve this problem?

S105 : Hmm (thinks for a moment) just use that, similarity and use algebra **(anticipation of internalization).**

P106 : why do you use those rules?

S106 : because these semicircles are similar, used on line ES and this line (pointing to the extension of line ES on the other semicircle and explaining haltingly **(internalized anticipation).**

Subject can determine the rule immediately after he draws the sketch and considers the information he has. In this case, Subject is classified as internalized anticipation. Next, Subject starts drawing the second sketch on the answer sheet, namely image (b). The second sketch is neater but there is one piece of information that Subject ignores, namely the length $\overline{AD} = 10\ cm$. Subject knows this information but ignores it at the problem-solving stage. This shows that Subject cannot find the relationship between what is known and what is asked. Next, Subject solves the problem as follows.

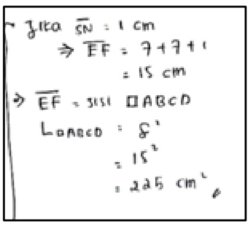


Figure 3. Excerpt 1 answer subject first problem

In the problem-solving step, Subject thinks critically by spontaneously determining the length $\overline{SN} = 1$ but this is done without any calculations and considerations relevant to the problem he has. This can be seen in the following interview excerpt.

P110 : why do you equate SN to 1?

S110 : hehe… (laughs a little while thinking) **(Impulsive anticipation)** is actually made up, because it is small **(impulsive anticipation)**

P111 : What do you mean?

S111 : hmm **(Internalized anticipation**) means because I have calculated (pointing to temple) **(Internalized anticipation)**

Based on the definition and indicators of anticipation, some of the explanations above show that Subject has impulsive and internalized anticipation. Furthermore, in Figure 3 it can also be seen that Subject determines the length $\overline{EF}$ without writing down which line segments are added. This is because Subject has internalized it well in his mind, so he is reluctant to write it on the answer sheet. Based on his thinking process, Subject is included in internalized anticipation. Apart from solving the problem, Subject also thinks about other alternative solutions, but there are obstacles in its application. Subject considers that there are errors in the problem solving he did, but he did not re-check either the problem-solving steps or the final results he got. This is in accordance with the following interview excerpt.

P114 : What other alternative solutions do you think of?

S114 : Hmm, how about this (Hesitation with a frown) (**Internalized anticipation**), I thought about looking for the fingers first (**Exploratory anticipation**), but it turned out I couldn't (**Impulsive anticipation**).

P116 : Are you sure about this answer? Or do you want to check it again?

S116 : Hmm, I'm not sure (Hesitation with a frown) (**Internalized anticipation**), but it's enough, no need to check it again (**Internalized anticipation**).

Based on the preceding explanations, Student Subject employs various anticipatory strategies to address the first problem, including impulsive, internalized, and explorative anticipation. However, Student Subject predominantly exhibits characteristics of internalized anticipation. Consequently, Subject approach to solving the first problem can be categorized primarily as internalized anticipation.

Problem 2

In the second problem, Subject read the problem without doing other activities such as pointing or underlining the problem. Subject read the problem repeatedly, but when reading he tended to focus only on the information that he considered important. Subject could not determine what was being asked precisely, because of that Subject also could not find the relationship between what was known and what was being asked. This can be seen in the following picture.

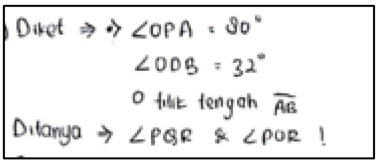


Figure 4. Answer subject second problem

In addition, subject also did not describe the second problem in detail as seen in the following interview excerpt.

P104 : what information do you get after reading this problem?

S104 : it is known that $\angle OPA$ is $80°$, $\angle ODB = 32°$ and O is the midpoint of AB, then determine the ratio of the magnitude of $\angle PQR$ and $\angle POR$ (**Explaining fluently**) (**Analytical Anticipation**)

P105 : is there any other information that you get besides that?

S105 : um… it seems like that's all (**Internalized anticipation**)

In the interview excerpt above, Subject answered the question by reading the problem on the test sheet, but he did not analyze what he read and ignored the information in the picture, resulting in a discrepancy between the information conveyed verbally and in writing. This indicates that at the problem-understanding stage, Subject demonstrates a tendency toward both Analytical and Internalized anticipation. Furthermore, Subject is able to determine the rules or procedures needed to solve the problem according to the objectives set, such as determining the values of $\angle PQR$ and $\angle POR$, solving the problem as shown in the following picture.

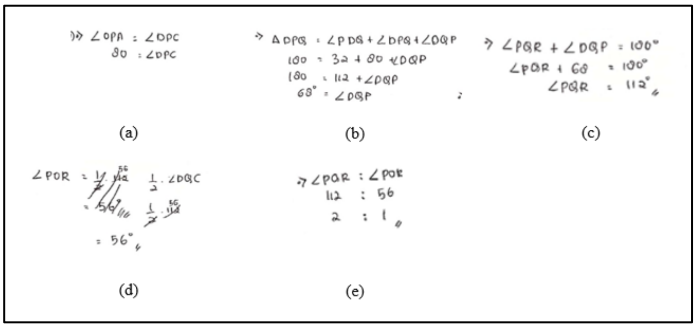


Figure 5. Continuation of subject answer to second problem

In the first step, shown in Figure 5 (a), Subject immediately wrote down the magnitude of $\angle DPC$ without providing any information or steps he used to obtain the angle's magnitude. However, Subject understood the concept and was able to clearly explain the method he used to determine the magnitude of $\angle DPC$ using previously planned rules. This aligns with the following interview excerpt. It shows that Subject has internalized the results of his work and is reluctant to write it down again because he already understands and is confident in the results. This explanation indicates that Subject exhibits internalized anticipation. Furthermore, in the fourth step, shown in Figure 5 (d), Subject knows which formula to use, but he does not yet completely understand the concept of the formula. Consider the following interview excerpt.

P107 : What is the formula?

S107 : As I recall earlier, umm (pause) (**Internalized Anticipation**) if you look for this angle (pointing to ∠POR) that means half of the angle in front of it, so that's ∠DQC. (**internalized anticipation**)

P111 : Are you sure you want to find ∠POR using the formula for finding the central angle?

S111 : um yeah sure use that formula. (**internalized anticipation**)

In this excerpt, Subject attempts to find $\angle POR$ which is the central angle, but uses the formula for the inscribed angle instead. Additionally, when determining ∠POR, Subject does not use the inscribed angle but instead uses the angle located opposite the central angle ∠POR, namely ∠DQC. Subject confidently maintains his problem-solving procedure, as seen in the interview excerpt, with the statement, "Um, yes, I'm sure using that formula." This explanation indicates that at this step, Subject exhibits internalized anticipation. Subject has an understanding of which information he should use to determine the size of the central angle, although this understanding needs to be revised. At the final problem-solving stage, Subject does not test a suspected solution with a specific number but instead reanalyzes the problem. This is evident in the following interview excerpt.

P115 : Are you sure about the answer?

S115 : not yet, wait a minute (re-analyze) (**Internalized anticipation - Analytical**). Wait a minute, I'll add (**analytical anticipation**)

The re-analysis performed by Subject allows him to identify errors that need correction so that he can redefine his goals to guide his actions. Therefore, after re-analyzing, Subject can write the final step in Figure 5 (e), namely determining the ratio of $\angle PQR$ and $\angle POR$. This explanation indicates that at this step, Subject can be classified as having analytical anticipation. Based on the explanations above, Subject uses various anticipatory strategies to solve the second problem. However, the indicators of anticipation tend to align more closely with analytical anticipation. Thus, it can be concluded that when solving this second problem, Subject is classified as exhibiting analytical anticipation.

Visualization based on the flow of thinking process of the gold medalist subject in solving problems 1 and 2, the flow of thinking process of the subject is obtained as in Figures 6 and 7 below.

Problem 1

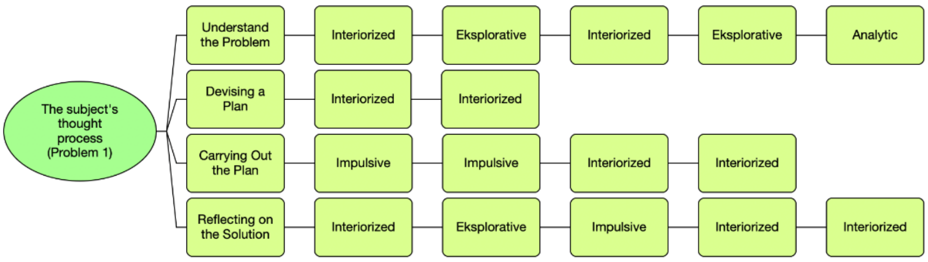


Figure 6. Mind map of the subject's thought process for problem 1

In solving problem 1, subjects often activate interiorized anticipation.

Problem 2

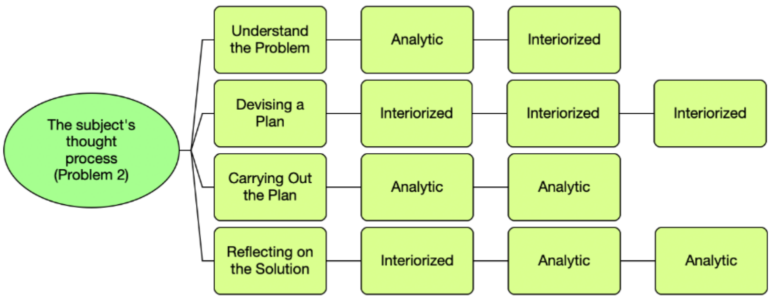


Figure 7. Mind map of the subject's thought process for problem 2

In solving problem 2, the subject also often activates his interiorized anticipation.
The conclusion of this study involved the use of NVIVO software to qualitatively analyze the subject's anticipation process in problem-solving. Researchers utilized a specific NVIVO tool called the Word Frequency Query to monitor the frequency of specific words in detailed interview transcripts with the subject. This analysis shows a compilation of commonly occurring terms in the interview data, as illustrated in Figure 8.

Figure 8. Word cloud from subject's

Discussion

Based on the analysis results from the NSO problem test on the topic of geometry, various types of anticipation are evident at each stage of Polya's problem-solving process. This observation aligns with the findings of (Pradana & Ismail, 2019), which indicate that individual students exhibit distinct capacities and characteristics in their anticipatory strategies.

Anticipation problem solving 1

Problem 1: during the problem-understanding stage, the subject successively uses internalized anticipation, explorative anticipation, internalized anticipation, explorative anticipation, and analytic anticipation. The activities carried out by the subject include repeatedly reading the problem without engaging in other activities, enabling them to correctly identify the information given. This aligns with Maswar (2019) view that reading is an effort to obtain new information from the problem being read. At the devising-a-plan stage, the subject consistently uses internalized anticipation. The subject begins by sketching the structure according to the information obtained in the previous stage and is able to determine the rules or procedures to solve Problem 1.

At this stage, the subject uses internalized anticipation through exploration activities during the understanding stage. This is unique, considering a person's anticipation typically does not branch out to carry out an activity. During the carrying-out-the-plan stage, the subject successively uses impulsive anticipation twice, followed by internalized anticipation twice. The subject follows through with the plan until arriving at the final value of the problem. In the reflecting-on-the-solution stage, the subject successively uses internalized, explorative, impulsive, and internalized anticipation twice. At this stage, the subject does not recheck the problem-solving steps or results because he feels satisfied with what has been done.

Additionally, the subject does not test a problem-solving hypothesis with a specific number but does not maintain the results obtained, as he is still considering the possibility of errors in the problem-solving process. Therefore, in Problem 1, the subject primarily uses internalized anticipation.

Problem 2: In the problem-understanding stage, the subject uses analytic anticipation followed by internalized anticipation. The subject reads the second problem without engaging in other activities and does not describe the problem in detail. The subject cannot find a relationship between what is known and what is asked but ultimately obtains the desired results. At the devising-a-plan stage, the subject uses internalized anticipation three times in succession. He can determine the rules and solve the second problem according to the plan by recalling previously acquired knowledge. This aligns with the opinion of Rahman et al. (2020) who state that in compiling a problem-solving plan, students will recall memories in the form of material and select the appropriate formula. During the carrying-out-the-plan stage, the subject uses analytic anticipation twice in succession, employing logical thinking to analyze and answer the problem. The procedures that have been devised are all executed. In the reflecting-on-the-solution stage, the subject uses internalized anticipation followed by analytic anticipation twice in succession. The subject conducts the fourth step, which involves rechecking the problem-solving process, but does not test a suspected solution with a specific number and does not maintain the results, considering the possibility of errors made when determining the size of $\angle POR$. Therefore, in Problem 2, the subject uses internalized anticipation and analytic anticipation.

The explanation above shows that gold medal-winning students tend to activate internalized anticipation in Problem 1 and both internalized anticipation and analytic anticipation in Problem 2. The conclusion drawn from the explanations above is that medal-winning students at regional mathematics olympiads, who have high problem-solving abilities, tend to have internalized anticipation. This can also be seen in the following figure.

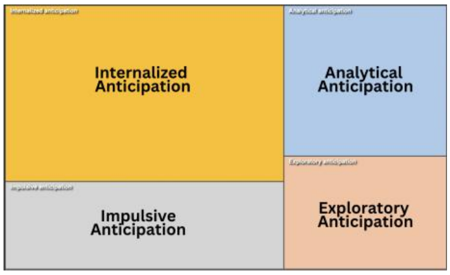


Figure 9. Visualisasi treemap coding for nodes

Based on the data above, there is a tendency for subjects to use interiorized anticipation in the problem-solving process. This can be observed in the comparison diagram in Figure 10 - 15.

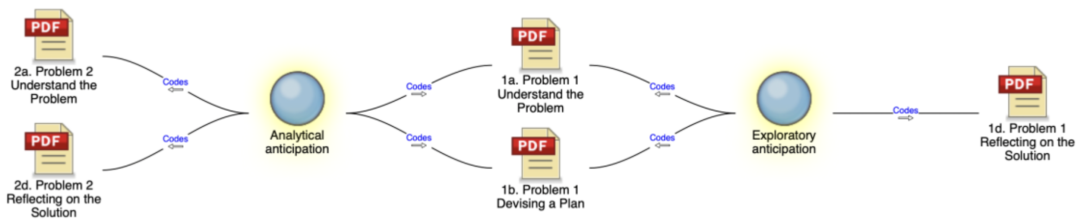


Figure 10. Comparison between analytic & explorative anticipation

Figure 10 compares the two types of anticipation used by the research subjects, namely analytic and explorative anticipation, in solving geometry problems. The results of the NVIVO analysis showed that subjects tended to use analytic anticipation more often than explorative. Analytic anticipation is characterized by a systematic approach, such as step-by-step verification and the use of mathematical logic, while explorative anticipation is more trial and error ideas without detailed planning. At the problem understanding stage (Problem 1a and 2a), the subject relied more on analytic anticipation to identify key information, while explorative anticipation emerged when the subject searched for alternative solutions (Problem 1d). This comparison corroborates the finding that the subject, as a gold medalist, predominantly used a structured (analytic) approach although remained flexible with exploration when needed.

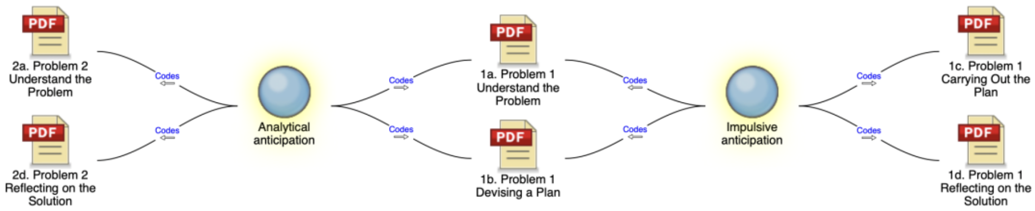


Figure 11. Comparison between analytic & impulsive anticipation

Figure 11 compares the frequency of using analytic and impulsive anticipation by the research subjects in solving geometry problems. The results of the NVIVO analysis showed that the subjects applied more analytic anticipation, which was characterized by systematic planning and logical evaluation, such as at the problem understanding (Problem 2a) and solution reflection (Problem 2d) stages. Meanwhile, impulsive anticipation appeared sporadically, especially when the subject made spontaneous assumptions without detailed calculations, such as at the plan execution stage (Problem 1c). This comparison indicates that although the subject tends to be dominant with an analytical approach, there are moments where he relies on quick intuition (impulsive), especially when he feels confident in his conceptual understanding. This finding is in line with the characteristics of internalized anticipation observed in the subject.

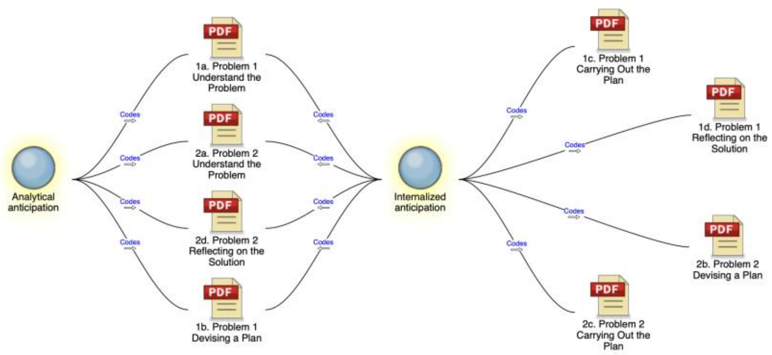


Figure 12. Comparison between analytic & internalized anticipation

Figure 12 compares the frequency of using analytic and internalized anticipation in the research subjects. The results of NVIVO analysis show that subjects tend to use internalized anticipation more often, especially when determining rules or procedures spontaneously without detailed explanation. Analytic anticipation appeared when the subject performed systematic verification, such as at the problem understanding stage (Problem 2a) and solution reflection (Problem 2d). This comparison revealed that although the subject relied on structured (analytic) thinking, his internalized ability enabled quick and intuitive problem solving. This finding is in line with the subject's characteristic as a gold medalist who combines both for solution effectiveness.

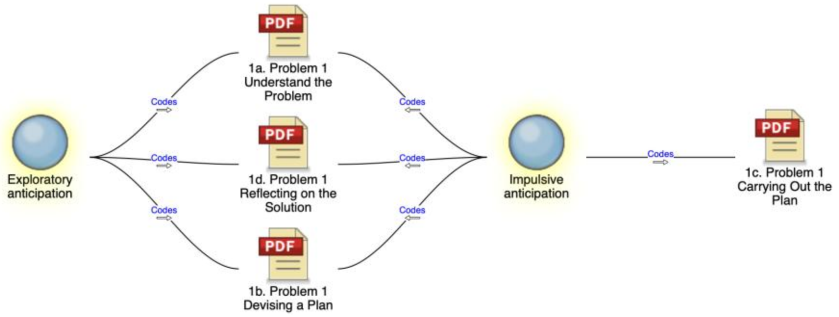


Figure 13. Comparison between explorative & impulsive anticipation

Figure 13 visualizes the difference in the use of explorative and impulsive anticipation. Subjects predominantly used explorative anticipation, especially when searching for alternative solutions (Problem 1d), characterized by the trial of new ideas. Meanwhile, impulsive anticipation appeared sporadically, such as when the subject made spontaneous assumptions without detailed calculations (Problem 1c). This graph shows that subjects tend to avoid unplanned impulsive decisions, but remain flexible in exploring various approaches. This reflects the balance between creativity and discipline in the problem-solving process.

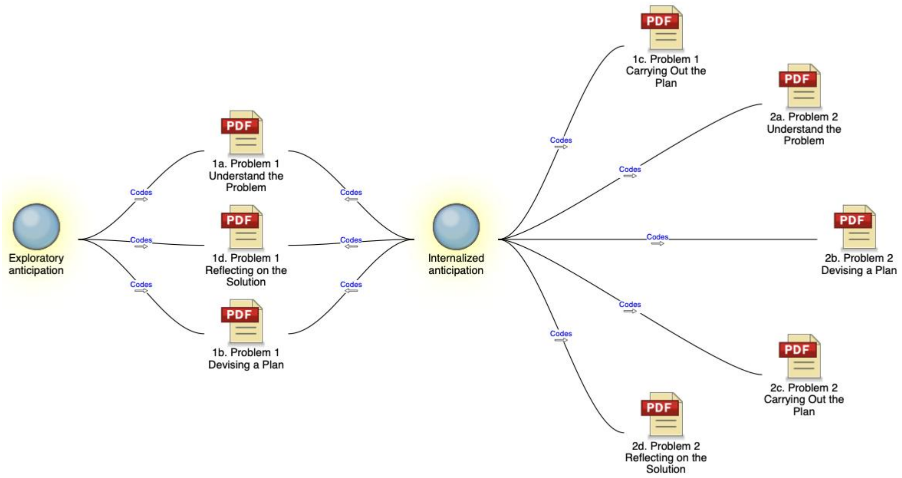


Figure 14. Comparison between explorative & internalized anticipation

Figure 14 shows that internalized anticipation is more dominant than explorative. Subjects relied on intuitive understanding (internalized) to simplify the solution steps, while explorative anticipation was used when facing an impasse (e.g., Problem 1d). This combination confirms that subjects not only follow standardized procedures but are also adaptive in exploring new ideas when needed. This finding reinforces the idea that high-achieving students are able to internalize concepts while remaining open to solution experimentation.

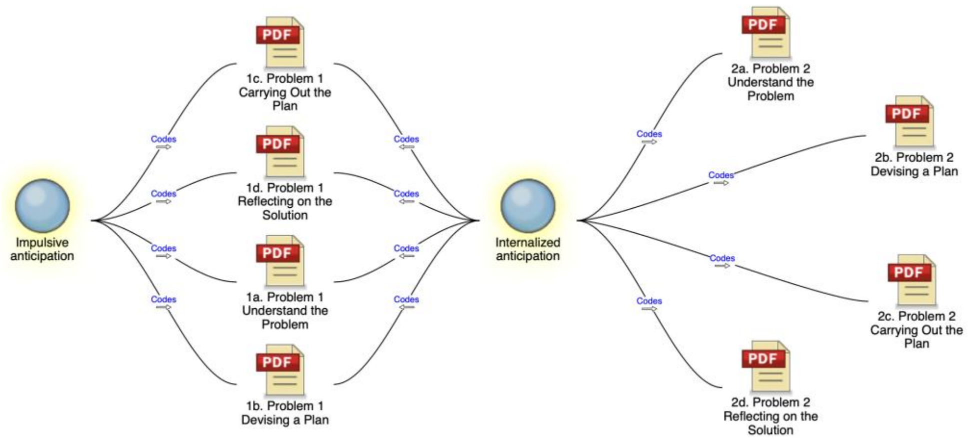


Figure 15. Comparison between impulsive & internalized anticipation

Figure 15 underlines the contrast between impulsive and internalized anticipation. Subjects hardly used impulsive anticipation, except in certain situations (Problem 1c), where decisions were made quickly without in-depth analysis. In contrast, internalized anticipation dominated, especially when subjects were confident in their understanding (Problem 2b). This graph confirms that subjects rely more on internalized anticipation based on concept mastery, reducing reliance on impulsive actions that risk errors. This reflects metacognitive maturity in solving geometry problems.

From the display of Figures 10 to 15, it is evident that interiorized anticipation is frequently used by the subjects in solving Problem 1 and Problem 2. Interiorized anticipation, which initially tends to be spontaneous and resistant to change in decision-making, was originally considered a negative trait. However, the findings of this study reveal that interiorized anticipation can also lead to effective problem-solving. This aligns with Latifah et al. (2018) opinion that students accustomed to participating in mathematics olympiads are classified as students with high mathematical abilities. It also corresponds with Yudianto (2021) view that students with high abilities belong to the internalized anticipation group. The figure below illustrates the framework of thinking initiated by Rosen related to the anticipation system (Louie, 2010).

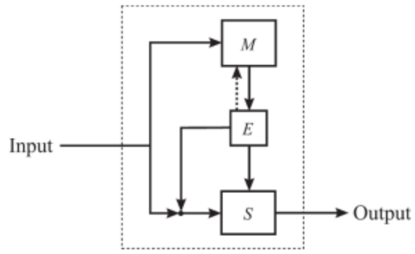


Figure 16. Anticipatory system

The relationship between Rosen's anticipation schema and Lim's classification reveals that rigid, impulsive, and internalized anticipation all share the characteristic of spontaneous thinking, leading directly to outcomes (S) (Yudianto et al., 2017, 2021). However, solutions based on these anticipatory approaches often lack precision. Internalized anticipation, in particular, begins with spontaneous thought but then transitions into establishing systematic procedures for problem-solving (Krishnan & Robele, 2024; Louie, 2010; Rosen, 2022).

Interestingly, this study found contradictions in how internalized anticipation functions in practice. For Problem 1, the gold medalist's use of internalized anticipation produced accurate results despite theoretical predictions suggesting otherwise. Similarly, in Problem 2, the subject's combination of internalized and analytic anticipation led to correct solutions, challenging conventional expectations. These findings contrast with Ivanova & Temnikova (2018) assertion that internalized anticipation consistently aids effective mathematical problem-solving through intellectual integration.

The research also aligns with Simon et al. (2016), framework of mathematical concept development, which identifies two key stages. The participatory stage involves completing tasks through direct engagement but struggles with broader application, while the anticipatory stage allows for abstract concept recall without needing to revisit initial learning activities. This progression, combined with reflective practice and strategic application, enhances mathematical problem-solving capabilities (Tasni et al., 2019b; Vale et al., 2019; Yudianto, 2017).

A significant contribution of this study is the proposed distinction between positive and negative internalized anticipation. Positive internalized anticipation enables accurate problem resolution, whereas its negative counterpart leads to incorrect solutions. This nuanced classification provides deeper insight into how different forms of anticipation influence problem-solving outcomes in mathematical contexts.

The limitation of this study is that the subjects were only observed when working on geometry problems according to the NSO syllabus published by the National Achievement Center in Indonesia. This would indicate the possibility of different anticipation classifications if the gold medal-winning subject were to tackle problems other than geometry, as the subject may have varying abilities for each topic they have studied. However, focusing on geometry in this study can help students understand the basic concepts frequently appearing in the NSO. Therefore, there is no need to worry about the potential for different anticipation classifications. This is in line with (Sari & Roesdiana, 2019), who states that students' understanding of each mathematical topic is sometimes different, resulting in different difficulties for each student.

Conclusion

This study reveals that gold medal-winning students predominantly employ internalized anticipation (both positive and negative types) and analytical anticipation when solving geometry problems in the National Science Olympiad. These patterns were evident through detailed analysis of problem-solving tests and interviews, where students demonstrated spontaneous rule determination and systematic verification processes. Identifying positive internalized anticipation (leading to correct solutions) and negative internalized anticipation (resulting in errors) offers a nuanced understanding of how cognitive strategies influence olympiad performance.

The findings have practical implications for olympiad training: (1) Diagnostic tools can help teachers identify students' anticipation profiles, enabling targeted interventions; (2) Training programs should emphasize analytical anticipation to mitigate negative internalized tendencies; and (3) Curricula could integrate metacognitive strategies to enhance problem-solving flexibility. However, the study is limited by its focus on geometry problems within a single competition context. Future research should explore whether these anticipation patterns persist across other mathematical domains (e.g., algebra or number theory) and cultural contexts to generalize the findings. To translate these insights into practice, we propose developing a teacher guidebook on fostering positive anticipation patterns. It could revolutionize olympiad preparation by shifting focus from rote practice to cognitive strategy development, ultimately nurturing critical thinking and creativity in mathematics education.

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Conflicts of Interest

Authors have no competing interests. In addition, the writers have addressed ethical concerns like plagiarism, misconduct, data fabrication and falsification, double publishing and submission, and redundancy.

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Author Contributions

Erfan Yudianto: Conceptualization, original draft writing, methodology, formal analysis, editing, investigation, and NVIVO coding; **Reza Ambarwati:** Validation, writing–review, and visualization; **Fina Yatul Lusiana:** Drafting the introduction, assisting with interview coding, formal analysis, and visualization; **Nihassuna Hayiduerapu:** Writing–review & editing, and design; **Hutkemri Zulnaidi:** Writing–review, editing, and final review.

References

Amaliyah, A., Uyun, N., Fitri, R. D., & Rahmawati, S. (2022). Analisis kesulitan belajar siswa pada materi geometri [Analysis of student learning difficulties in geometry]. *Jurnal Sosial dan Teknologi*, *2*(7), 659–664.

Creswell, J. W. (2018). *Educational research* (C. Robb, Ed.; FourthEdition). Pearson.

Ivanova, V., & Temnikova, M. (2018). Anticipation in the structure of the solving problems skill. *European Scientific Journal*. https://doi.org/10.19044/esj.2018.c5p2

Krishnan, A., & Robele, S. (2024). Anticipatory development foresight: An approach for international and multilateral organizations. *Development Policy Review*, *42*(S1). https://doi.org/10.1111/dpr.12778

Latifah, I. W., Sugiarti, T., Fatahillah, A., & Murtikusuma, R. P. (2018). Profil berpikir siswa peserta olimpiade matematika dalam menyelesaikan masalah aljabar [Thinking profile of students participating in math olympiad in solving algebra problems]. *Kadikma*, *9*(2), 145–154.

Lim, K. H. (2007). *Improving students' algebraic thinking: The case of Talia*. https://www.semanticscholar.org/paper/6e4681256421000067 37e532ff97ffb79943ccdf

Louie, A. H. (2010). Robert Rosen's anticipatory systems. *Foresight*, *12*(3), 18–29. https://doi.org/10.1108/14636681011049848

Maswar, M. (2019). Profil antisipasi siswa SMP/MTs dalam memecahkan masalah aljabar ditinjau dari kemampuan matematika [Profile of junior high school students' anticipation in solving algebraic problems in terms of math ability]. *Indonesian Journal of Mathematics and Natural Science Education*, *1*(1), 37-52 https://mass.uinkhas.ac.id/index.php/mass/article/view/5

Nopriana, T. (2015). Disposisi matematis siswa melalui model Ppembelajaran geometri van Hiele [Students' mathematical disposition through van Hiele's geometry learning model]. *Fibonacci*, *1*(2), 80–94. https://doi.org/10.24853/fbc.1.2.80-94

Pradana, M. A. M., & Ismail, I. (2019). Profil antisipasi siswa dalam memecahkan masalah aljabar ditinjau dari kecerdasan linguistik dan kecerdasan logis-matematis [Profile of students' anticipation in solving algebraic problems in terms of linguistic intelligence and logical-mathematical intelligence]. *MATHEdunesa*, *8*(3), 559–568. https://doi.org/10.26740/mathedunesa.v8n3.p559-568

Rahman, L., Rilianti, A. P., & Najwa, W. A. (2022). Studi deskriptif model pembinaan olimpiade di MI muslimat NU Sidoarjo [Descriptive study of the Olympic coaching model at MI Muslimat NU Sidoarjo]. *Ibriez*, *27*(1), 67–82. https://doi.org/10.23917/warta.v22i2.8619

Rahman, R. V., Parta, I. N., & Susanto, H. (2020). Proses berpikir siswa SMP dalam memecahkan masalah matematika [Junior high school students' thought process in solving math problems]. *Jurnal Pendidikan*, *5*(5), 706–713.

Rosen, J. (2022). Robert Rosen's Anticipatory Systems Theory: The science of life and mind. *Mathematics*, *10*(22), 4172. https://doi.org/10.3390/math10224172

Rosyid, A., Noor, M., & Sutisna, A. (2020). Peningkatan kemampuan matematika siswa dalam pembinaan olimpiade MIPA SD di gugus Ahmad Yani Kuningan [Improving students' mathematics skills in coaching elementary MIPA Olympics in Ahmad Yani Kuningan cluster]. *Jurnal Pengabdian pada Masyarakat*, *5*(2), 335. https://doi.org/10.30653/002.202052.290

Sari, R. M. M., & Roesdiana, L. (2019). Analisis kesulitan belajar siswa SMA pada pembelajaran geometri [Analysis of high school students' learning difficulties in learning geometry]. *Aksioma: Jurnal Matematika dan Pendidikan Matematika*, *2*(2), 209–214. https://doi.org/10.26877/aks.v10i2.4253

Simon, M. A., Placa, N., & Avitzur, A. (2016). Participatory and anticipatory stages of mathematical concept learning: further empirical and theoretical development. *Journal for Research in Mathematics Education*, *47*(1), 63.

Sunardi, S., & Yudianto, E. (2015). Antisipasi siswa level analisis dalam menyelesaikan masalah geometri [Anticipation of analysis level students in solving geometry problems]. *AdMathEdu*, *5*(2), 203–216. https://doi.org/10.12928/admathedu.v5i2.4776

Tasni, N., Nusantara, T., & Hidayanto, E. (2019a). Anticipating failure of students' productive connective thinking transformation in solving mathematical problems. *International Journal of Scientific & Technology Research*, *8*(9).

Tasni, N., Nusantara, T., & Hidayanto, E. (2019b). Anticipating failure of students' productive connective thinking transformation in solving mathematical problems. *International Journal of Scientific & Technology Research*, *8*(09), 392–400.

Vale, C., Widjaja, W., Doig, B., & Groves, S. (2019). Anticipating students' reasoning and planning prompts in structured problem-solving lessons. *Mathematics Education Research Journal*, *31*(1), 1–25. https://doi.org/10.1007/s13394-018-0239-5

Yudianto, E. (2015). Profil antisipasi siswa SMA dalam memecahkan masalah integral [Profile of high school students' anticipation in solving integral problems]. *Kreano, Jurnal Matematika Kreatif-Inovatif*, *6*(1), 21. https://doi.org/10.15294/kreano.v6i1.4472

Yudianto, E. (2017). Antisipasi ide kreatif mahasiswa level rigor dalam menentukan algoritma benda ruang menggunakan maple [Anticipation of rigor level students' creative ideas in determining the space object algorithm using maple]. *Jurnal Didaktik Matematika*, *4*(2), 98–106. https://doi.org/10.24815/jdm.v4i2.8369

Yudianto, E. (2021). Anticipation of student ideas in designing Sierpinsky square batik using maple. *Journal of Medives*, *5*(1), 189–200. https://doi.org/10.31331/MEDIVESVETERAN.V5I1.1563

Yudianto, E., Sunardi, S., Sugiarti, T., & Fiantika, F. R. (2021). Student's anticipation profile at rigor level in determining papaya tree root dimensions. *Jurnal Didaktik Matematika*, *8*(1), 59–74. https://doi.org/10.24815/jdm.v8i1.19954

Yudianto, E., Suwarsono, S., & Juniati, D. (2017). The anticipation: How to solve problem in integral? *Journal of Physics: Conference Series*, *824*(1), 012055. https://doi.org/10.1088/1742-6596/824/1/012055

Zulnaidi, H., Mafarja, N., Rahim, S. S. A., & Salleh, U. K. M. (2024). Effect of identity as a mediator: The relationship between mathematics teacher cooperation and readiness in facing the era of industrial revolution. *Nurture*, *18*(2), 288–301. https://doi.org/10.55951/nurture.v18i2.610