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PIAGETIAN ABSTRACTION PROCESSES OF A FIELD INDEPENDENT MALE STUDENT IN RECONSTRUCTING THE CUBOID CONCEPT

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ABSTRACT

This study aims to describe how a masculine junior high school boy with a field independent cognitive style abstracts step by step the concept of a cuboid while reconstructing it. The research adopted a qualitative descriptive approach focused on a single Grade IX student, coded AF, who met two criteria: a high score on the Group Embedded Figures Test indicating field independence and a masculine profile on the Bem Sex Role Inventory. Data were gathered through task based interviews and direct observation as AF classified concrete objects, interpreted two dimensional drawings, and attempted to create a formal definition of a cuboid. All sessions were recorded, transcribed, and processed through the phases of reduction, display, and conclusion drawing in order to align each episode with Piaget's sequence of empirical, semi empirical, and reflective abstraction. Analysis revealed a clear three step progression. In the empirical phase AF decided whether a solid was a cuboid by listing six rectangular faces, twelve edges, and eight vertices, presenting these facts as separate items without explaining relationships among them. During the semi empirical phase, accuracy improved when he handled drawings: he corrected earlier edge counts, insisted on rectangular faces, and dismissed colour and scale as irrelevant. Reflective abstraction emerged when he produced a concise definition, identified the cube as a special cuboid, supplied a numerical example measuring ten by five by five centimetres, and linked the concept to familiar objects such as cardboard boxes and cupboards. Throughout the sessions his field independent style marked by selective attention, systematic counting, and self monitoring helped him move quickly from perceptual sorting to conceptual reasoning. The study offers detailed evidence that field independence supports smooth movement through Piaget's abstraction hierarchy by enabling learners to impose internal structure on external stimuli. It strengthens the theoretical claim that mathematical understanding grows gradually from concrete observation toward formal reasoning and provides practical insight for geometry teaching: tasks that highlight structural invariants can capitalise on analytic strengths in field independent students while also serving as scaffolds for peers who depend more heavily on contextual cues.

Keywords: *cuboid; piagetian abstraction; field independent cognitive style; masculinity; solid geometry; junior high students*

INTRODUCTION

Mathematics studies entities that are abstract in nature; consequently, learners must develop sophisticated forms of reasoning in order to understand them (Soedjadi, 2000). In junior high geometry a key solid is the cuboid, a three dimensional figure whose comprehension depends on recognising its six faces, twelve edges, eight vertices, and the structural relations among those elements (Ferrari, 2003). Piaget's genetic epistemology proposes that such geometric knowledge develops through three stages of abstraction: empirical, semi empirical (sometimes called pseudo empirical), and reflective (Piaget, 1972). At the empirical stage students rely on direct observation. During the semi empirical stage these observations are enriched by actions such as measuring or counting. In the reflective stage learners project higher order mental structures onto earlier actions and can articulate formal definitions (Piaget, 2001).

Two learner variables cognitive style and gender can influence progress through these stages. Cognitive style refers to characteristic ways in which individuals perceive, process, and store information (Messick, 1993). Students who exhibit a field independent style are better able to disembed relevant information from distracting context, allowing them to focus on core geometric attributes and reason

analytically (Gardner et al., 1963; Üstünel et al., 2015). Empirical studies report that field independent learners outperform their peers on visual spatial tasks and prefer systematic strategies in geometry (Kozhevnikov, 2007). Gender also affects mathematical thinking. Meta analyses and classroom research suggest that boys often perform better on spatial tasks and show greater confidence when working with three dimensional figures (Carr et al., 2008; Mainali, 2019). A masculine gender role identity, defined as endorsement of culturally sanctioned masculine traits such as independence and risk taking, may amplify these spatial advantages (Bem, 1977; Burns & Dobson, 1984).

Against this background, the present study explores how a masculine male junior high student with a field independent cognitive style reconstructs the cuboid concept. Such a learner is expected to capitalise on analytic tendencies, confidence, and visual spatial acuity while progressing through Piaget's abstraction stages. At the empirical stage he may focus on counting faces, edges, and vertices (Piaget, 1972). During the semi empirical stage he should integrate those counts with actions such as identifying hidden edges or determining dimensions (Gray & Tall, 2007). At the reflective stage he is expected to describe conceptual relationships for instance, treating the cube as a special case of the cuboid thereby linking formal definitions with concrete examples (Piaget, 2001). Understanding how these processes unfold in a learner who combines masculine traits with field independence is important for designing instruction that balances hands on manipulation with conceptual reflection. Instructional frameworks that alternate between concrete activity and analytical discussion can accommodate diverse cognitive styles while fostering deep geometric understanding (Angeli & Valanides, 2013).

METHOD

This study used a qualitative descriptive design, which is appropriate for producing a detailed case-oriented account rather than a statistical generalisation (John et al., 2018). The single participant, coded AF, was a Grade IX student. Field independence was confirmed with the Group Embedded Figures Test (GEFT) (Witkin et al., 1971), and a masculine gender-role orientation was identified with the Bem Sex Role Inventory (BSRI) (Bem, 1974). Both instruments were reviewed by two mathematics-education specialists and piloted with students of similar age to ensure reliability and content validity. Data were collected in two sixty-minute task-based interviews held one week apart in the school's mathematics laboratory. During each session AF carried out three activities: classifying concrete models of solids, interpreting two-dimensional sketches that included hidden edges, and formulating a formal definition of a cuboid. A think-aloud protocol captured his spontaneous reasoning. All verbal statements, gestures, and written work were recorded on digital video and accompanied by the researcher's field notes. Data analysis followed Miles, Huberman, and Saldaña's three-step model of qualitative analysis, namely data reduction, data display, and conclusion drawing (Miles et al., 2014). Verbatim transcripts were segmented into meaning units and assigned open codes. The coded excerpts were then organised in a matrix that aligned each utterance or action with one of Piaget's abstraction levels: empirical, semi-empirical, or reflective. During conclusion drawing the research team identified patterns linking field-independent behaviours such as selective attention to structural invariants, systematic counting, and metacognitive self-monitoring to transitions between abstraction levels. A second analyst independently reviewed all coding, and disagreements were resolved through discussion until full agreement was reached. Member checking with AF ensured that the interpretation matched his intended meaning. Ethical approval was obtained from the university research ethics board. Written informed consent was secured from the school principal, the participant, and his parents after they were briefed on the study's purpose, procedures, and confidentiality safeguards. All personal identifiers were removed in the final report.

RESULTS AND DISCUSSION

Research Result

The study began with participant selection. Candidates first completed a cognitive-style inventory and a gender-role inventory, then performed a cuboid-concept reconstruction task. The inventory results were used to select four students so that each combination of cognitive style (field-independent, field-dependent) and gender orientation (masculine, feminine) was represented. The Grade IX boy who

combined a masculine profile with a field-independent cognitive style was assigned the code AF. The findings reported here stem from two task-based interviews with AF, during which he reconstructed the cuboid concept. Each segment of the interview data was validated and categorised under one of Piaget's three abstraction levels empirical, semi-empirical, or reflective to illuminate how his reasoning progressed through the hierarchy.

a. Empirical Abstraction

Interview Excerpt 1

Researcher: There are two groups in front of you. The objects on the right are examples of cuboids; the ones on the left are not cuboids. Please examine and pick them up if you wish.
AF: Yes, Sir.
Researcher: Take this first object and place it in the appropriate group. Why?
AF: Because it has six faces.
AF: It also has twelve edges.
Researcher: Any other features?
AF: Its length and width are equal; if they were not, it would not be a cuboid.
Researcher: What about the second object where does it belong and why?
AF: For the same reasons: six faces and eight vertices.
Researcher: Can you point to the vertices?
AF: Here they are: one, two, three, four, five, six, seven, eight.
Researcher: You placed the third object with the non cuboids. Why?
AF: It has no flat faces and no straight edges.
Researcher: How about the sixth object?
AF: It is not a cuboid. It has only two circular faces and no edges or vertices it is shaped like a cylinder.
Researcher: And the eighth object; do you think it is a cuboid?
AF: Yes. The top and bottom faces match, and the other faces come in opposite pairs even though the sizes are different.

Interview Excerpt 2

Researcher: Again you have two groups: cuboids on the right, non cuboids on the left. Please examine and handle them.
AF: All right, Sir.
Researcher: Why did you place the first object in the cuboid group?
AF: Because it has six faces and each face is a rectangle.
AF: It also has twelve edges and eight vertices.
AF: The opposite faces are equal in length and width, unlike other shapes whose faces are not congruent.
Researcher: Did you classify the second object as a cuboid?
AF: Yes, for the same reasons: six rectangular faces, eight vertices, twelve edges, although some faces differ in size.
Researcher: Does colour influence your decision?
AF: I do not think so, Sir. Colour does not determine whether an object is a cuboid.
Researcher: You put the third object with the non cuboids. Why?
AF: It does not have six complete faces, and its edges and vertices do not match the required counts.
Researcher: You selected the eighth object as a cuboid?
AF: Yes. The top face matches the bottom face and all the other faces occur in pairs, so overall it is still a cuboid.

In the first interview the participant's empirical abstraction was still superficial. He relied on direct physical inspection, and his explanations were limited to lists of isolated features. When asked why the first object was a cuboid he cited "six faces" and "twelve edges." Mentioning "length and width are equal" showed some awareness that each face is a rectangle, yet he did not discuss how the faces relate to one another. For non cuboids he used negative criteria: if a core attribute was missing, the object was rejected.

The classification scheme existed but remained shallow. During the second interview the quality of responses improved markedly. Physical observation was now accompanied by an explicit description that every face is rectangular. The participant considered not only the number of faces but also their geometric properties. His grouping became more reflective; he accepted differing face sizes so long as opposite faces were congruent a justification absent earlier. He also dismissed irrelevant attributes such as colour, demonstrating an ability to separate essential from non essential variables. His description of a cuboid became fuller: six rectangular faces, twelve edges, eight right angled vertices, and three pairs of opposite faces. By tracing the pairs top–bottom, front–back, and left–right, he showed an integrated spatial understanding instead of a simple enumeration. Emphasising right angles further enriched his conception of the cuboid beyond mere edge counts.

b. Semi Empirical Abstraction

Interview Excerpt 1

Researcher: Please look carefully at the cuboid examples on the left and the non-cuboid examples on the right. You have three minutes.
AF: All right, Sir.
Researcher: Time is up. Here is the first picture. Which group does it belong to?
AF: Non-cuboid, Sir. Its length and width are different, so the shape does not match a cuboid.
Researcher: What do you think are the main characteristics of a cuboid?
AF: It must have six faces, twelve edges, and eight vertices.
Researcher: What about the second picture?
AF: That is a cuboid. I counted six faces, twelve edges, and eight vertices.
Researcher: And the third picture?
AF: Not a cuboid. It has only two circular faces and a curved lateral surface like a tube.
Researcher: The fourth picture?
AF: Cuboid, Sir. Still six faces, twelve edges, and eight vertices, only the orientation is different.
Researcher: The fifth picture?
AF: Not a cuboid; that one is a cone with one circular base and a pointed apex.
Researcher: The seventh picture?
AF: Cuboid. Six flat faces, edges of equal length in each pair, eight vertices.
Researcher: The eleventh picture?
AF: Not a cuboid. The base is triangular, so it has four vertices and six edges.

Interview Excerpt 2

Researcher: Once again you have cuboids on the left and non-cuboids on the right. Observe the faces, edges, and vertices.
AF: Yes, Sir.
Researcher: Is the first picture a cuboid?
AF: No. It has more than six faces, more than eight vertices, and the faces are not rectangular.
Researcher: The second picture?
AF: Cuboid. Six rectangular faces, twelve edges, eight vertices.
Researcher: The third picture?
AF: Not a cuboid; only two circular faces and a curved surface like a cylinder.
Researcher: The fifth picture?
AF: Not a cuboid, because it has one circular base and a cone-shaped top.
Researcher: The ninth picture?
AF: Cuboid. The colours are different, but the key characteristics of six faces, twelve edges, and eight vertices are present.
Researcher: What is the biggest difficulty when classifying these images?
AF: Counting edges and vertices that are hidden. The drawings can be misleading because of perspective.

Researcher: How can we help others understand the difference between cuboids and non-cuboids?
AF: Show a real model, demonstrate how to count the faces, edges, and vertices step by step, and explain that colour does not affect the basic shape.

The semi empirical stage asks learners to move from handling concrete models to analysing two dimensional sketches and then to recover the defining elements of a cuboid. In the first interview AF was still adapting to this pictorial format. When examining a drawing of a right rectangular prism he said that it had seven faces, sixteen vertices, and twenty one edges. These incorrect counts show that the hidden features of the drawing were difficult for him to recognise because the projection flattened depth. Even so, when the next sketch presented a clearer view he immediately cited the correct minimum numbers for a cuboid, namely six faces and twelve edges, which indicates that the conceptual scheme was already active even though his visual parsing was still uncertain. Accuracy improved sharply in the second interview. Before the grouping task began the researcher reminded AF to focus on faces, edges, and vertices, and he replied that he would examine those characteristics first. This intention became clear when he rejected the first sketch not because of colour or size but because it had more than six faces and the vertices were not eight. AF also insisted that each face had to be rectangular, adding a geometric property rather than relying only on numerical counts. His marking of components in the drawings therefore became more precise, meeting the requirement to identify each element while enriching his description of cuboid characteristics.

Two developments are especially important. First, AF learned to correct for perspective bias. Features that were hidden in a two dimensional projection were now anticipated through spatial reasoning, and his counts returned to the correct pattern of six faces, twelve edges, and eight vertices. Second, he began to use these invariant numbers as a conceptual filter while dismissing superficial attributes such as colour. This mechanism lies at the core of semi empirical abstraction in which raw visual data are edited by conceptual structures formed during the empirical stage and then elevated into stable theoretical criteria. In summary, the first interview showed that AF's semi empirical abstraction was still fragile. He could list the characteristics of a cuboid in simple drawings but made errors when the sketches were complex because marking faces and edges was not yet automatic. The second interview revealed greater stability. He marked and counted the elements systematically, confirmed that every face was rectangular, and applied the counts of six faces, twelve edges, and eight vertices consistently. This progression suggests that practice with classifying sketches, combined with reflection on earlier mistakes, strengthened his semi empirical abstraction and demonstrates that two dimensional representations can serve as an effective bridge between concrete observation and an integrated understanding of spatial geometry..

c. Reflective Abstraction

Interview Excerpt 1

Researcher: Can you explain what you wrote about the meaning of a cuboid?
AF: A cuboid is a three dimensional shape that has six rectangular faces, twelve edges, and eight vertices. Each vertex forms a right angle. The lengths of the faces can be equal or different, but the shape must still have six flat faces, twelve edges, and eight vertices.
Researcher: You said the lengths can be equal or different. Can you clarify?
AF: The top face matches the bottom face, the front matches the back, and the left matches the right. Not every face needs to be identical, but there must be six faces and eight vertices in total.
Researcher: If a rectangular solid has only four faces, is it still a cuboid?
AF: No. That would be a flat figure. A cuboid is a solid, which means it must have six faces.
Researcher: Why must a cuboid have six faces, twelve edges, and eight vertices?
AF: A cuboid is like a box and differs from a cube only in the sizes of its faces. At every vertex, three edges meet, which gives twelve edges in all and eight vertices.
Researcher: Why is it important to know these characteristics?

AF: They help us classify shapes correctly. A cylinder has only two circular faces and one curved surface, and a cone has one circular base and a pointed top. Knowing the characteristics of a cuboid makes it easy to tell them apart.
Researcher: Anything else to add?
AF: Colour does not determine the shape. The important thing is the structure.

Interview Excerpt 2
Researcher: Describe a cuboid again in full.
AF: A cuboid is a solid with six faces, usually rectangles, or squares if all the edges have equal length. It has twelve edges where pairs of faces meet and eight vertices where three edges meet.
Researcher: How does a cuboid differ from a cube?
AF: A cube is a special cuboid in which all six faces are squares and all edges are the same length. Ordinary cuboids can have different face sizes but must keep the six faces, twelve edges, and eight vertices.
Researcher: Please explain edges and vertices in more detail.
AF: An edge is the line segment where two faces meet, and in a cuboid there are twelve. A vertex is the point where three edges meet, and there are always eight.
Researcher: Give an example of lengths that make some faces equal and some faces different.
AF: Suppose the cuboid is ten centimetres long, five centimetres wide, and five centimetres high. There are two pairs of faces measuring ten by five centimetres and one pair measuring five by five centimetres. Some faces are equal, some differ, but all six faces are rectangular, so the shape is still a cuboid.
Researcher: Why is learning the characteristics of cuboids useful in daily life?
AF: It helps us recognise everyday objects like cabinets or boxes and lets us calculate volume, surface area, and design items accurately..

When asked to explain the difference between cuboids and non cuboids, AF immediately referred to spatial dimensions. He explained that a solid must have six faces to be considered three dimensional, whereas a shape with only four faces remains planar. He also mentioned cylinders and cones to show that the number and shape of faces are the main criteria for classification. This response meets the first criterion because AF distinguished cuboids not only through concrete examples but also through an explicit geometric structure that he understood reflectively. The second criterion appears when AF linked the cuboid to the cube. He said that a cube is a special kind of cuboid because all its faces are squares, then pointed out how edge lengths relate to the rectangular faces of an ordinary cuboid. AF also connected cuboids to everyday objects such as cabinets, cardboard boxes, and rooms, and to the concepts of volume and surface area. This cross concept relationship shows that he can place the cuboid within a broader network of ideas rather than focusing on a single object.

The definition that AF formulated meets the third criterion. He specified six rectangular or square faces, twelve edges, eight vertices, and right angles at every vertex. His definition included an internal justification: because three edges meet at each vertex, the shape must have twelve edges and eight vertices. He added numerical examples to illustrate dimensional flexibility, insisting that unequal edge lengths do not change the classification as long as the basic structure remains intact. Comparing the two interviews reveals increased stability and depth of reflection. In the first session AF provided a basic definition and recognised the importance of classification. In the second session he enriched his explanation of edges and vertices, clarified their connection to the cube, and discussed real world applications. This progression shows that his reflective abstraction has reached a stage at which the intrinsic properties of the cuboid are projected onto new situations, producing definitions that are generative instead of merely repetitive.

Discussion

Empirical abstraction, the first stage in Piaget's genetic epistemology, appears when children isolate and stabilise the perceptual attributes of concrete objects to build initial classification schemes (Piaget

1971). In later work Piaget contrasted this sensory based process with reflective abstraction, which relies on mental coordination free of direct perception (Piaget, 2001). Classroom studies confirm the pattern: beginners in solid geometry usually count visible faces, edges, and vertices before considering how the parts relate (Pittalis & Christou, 2010). Ellis et al. (2024) add that the move from empirical to semi empirical abstraction begins when students realise that certain visual details are irrelevant because they do not define the shape. Empirical abstraction therefore serves as a bridge from simple enumeration to coordinated properties and, ultimately, to a formal definition of a solid.

Evidence that field independent (FI) learners negotiate this bridge more efficiently comes from (Amrullah & Sari, 2023), who found that FI students identified geometric parts of solids more quickly by filtering out distracting context. Ubuz & Aydınyer (2019) reported similar gains in a project based setting where FI students designed site plans, a task demanding precise spatial modelling. These findings support (Kozhevnikov et al., 2014), who concluded that the FI tendency to separate essential from non essential information speeds the shift from listing attributes to coordinating them, mirroring AF's improvement between interviews. Cross cultural work tempers this advantage: Hoffman et al. (2011) showed that the spatial gap between male and female participants vanished in matrilineal Khasi communities even though it persisted among patrilineal Karbi groups, and (Inah & Ethorti, 2022) demonstrated that with extensive visual and verbal scaffolding field dependent students can equal or surpass their FI peers.

At the semi empirical stage Piaget noted that learners still rely on sensory imagery yet project their internal schemes onto objects, treating certain features as geometric invariants (Piaget, 1977). He distinguished this pseudo empirical phase from the purely empirical one by emphasising the act of "re reading" properties that the learner has already internalised. Ellis et al. (2024) updated the concept by showing that students at this stage filter drawings of cuboids through an invariant scheme of six faces, twelve edges, and eight vertices before reaching full reflective abstraction. Pittalis & Christou (2010) confirmed that success in classifying three dimensional shapes shown in two dimensional drawings correlates with recognising underlying topological structure rather than merely counting visible elements, a pattern consistent with AF's corrections in the second interview.

Kozhevnikov et al. (2014) reviewed findings from several disciplines and concluded that people with a field independent cognitive style are especially skilled at isolating relevant details from distracting background, which improves performance on mental rotation tasks and on identifying hidden edges in drawings of solids. A study of junior high students by (Amrullah & Sari, 2023) likewise showed that field independent learners produced more accurate mathematical representations when solving cuboid problems set in local cultural contexts. Project based research by (Ubuz & Aydınyer, 2019) added that knowledge gains were greatest in the field independent group, who integrated visualisations and formal concepts more rapidly than their field dependent classmates. Together these results help explain the sharp increase in AF's accuracy during the second interview, a change that matches the semi empirical transition often associated with field independent processing.

A classic meta analysis by (Linn & Petersen, 1985) reported that males outperform females most strongly on mental rotation tasks with cuboid stimuli, suggesting an initial advantage for masculine students when converting two dimensional sketches into three dimensional structures. Hoffman et al. (2011), however, found that this advantage disappears in matrilineal Khasi communities even though it persists in patrilineal Karbi groups, showing that culture can neutralise gender based differences. Inah & Ethorti (2022) also observed that the field independent edge narrows when instruction includes extensive visual and verbal scaffolding; under such conditions field dependent students match or even surpass their field independent peers. AF's rapid improvement after explicit guidance to focus on faces, edges, and vertices echoes this pattern of context sensitive performance.

Piaget placed reflective abstraction at the top of his constructivist hierarchy, where learners reflect on their own actions, coordinate them logically, and express that coordination in formal terms (Piaget, 2001). AF reached this level during the interviews. He gave a definition of a cuboid that went beyond listing six faces, twelve edges, and eight vertices by explaining that three edges meet at every vertex, which fixes both the edge count and the vertex count. He then supplied a numerical example of a ten by five by five centimetre cuboid, showing that unequal edge lengths do not invalidate the classification. This use of the

definition in a novel case illustrates the generative aspect of reflective abstraction described by Ellis et al. (2024).

The concept became even more connected when AF recognised the cube as a special case of the cuboid and related the idea to practical tasks such as finding the volume of cardboard boxes or the dimensions of a classroom. Such movement between formal definitions and real world contexts is typical of learners who have reached theoretical reasoning, as reported by Pittalis and Christou (2010). AF's precise spatial language also supports Kozhevnikov et al. (2014), who found that field independent thinkers analyse abstract representations analytically and ignore non geometric distractions, exemplified by AF's remark that colour "does not determine the shape." Although masculine spatial advantages are well documented (Linn & Petersen, 1985), they are not universal. Hoffman et al. (2011) showed that cultural context can erase gender gaps, and Inah and Ethorti (2022) demonstrated that structured instruction allows field dependent students to equal or surpass field independent peers in spatial tasks. Reflective success therefore emerges from an interaction between individual disposition and the learning environment rather than from gender or cognitive style alone.

CONCLUSION

This study demonstrates that a single male junior high student who exhibits a field independent cognitive style successfully negotiated all three of Piaget's abstraction levels while reconstructing the concept of a cuboid. In the initial empirical phase he merely recalled the observable facts of six faces, twelve edges, and eight vertices without recognising how those elements relate. Upon reaching the semi empirical phase he became more critical; two dimensional drawings that had previously misled him prompted a careful recount of hidden edges and vertices, leading him to see that quantity alone is insufficient and that every face must be rectangular. In the reflective phase he moved beyond listing features to formulating a formal definition, treating the cube as a special instance of the cuboid and linking the concept to everyday objects such as cardboard boxes and cabinets. This developmental sequence suggests a causal link, because a field independent style enables sustained attention to structural invariants, allowing the learner to progress rapidly from observing to explaining and finally to reasoning.

The findings indicate that teachers should create opportunities for focused conceptual discussion, particularly when students compare cuboids with cubes, so that reflective abstraction can mature. Such discourse is compatible with the tendencies of field independent learners, who are typically analytical and self directed, yet they still benefit from tasks that require them to articulate relationships among properties. Facilitating a smooth passage from empirical to semi empirical and ultimately to reflective understanding encourages learners to master a comprehensive and transferable cuboid concept. Future work that incorporates cultural background, gender orientation, and the use of visual aids will clarify whether the observed field independence advantage is broadly universal or dependent on specific instructional contexts.

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