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Active Learning in Secondary Science in D.A.V. International School, Ahmedabad with Toys prepared by CCL IIT Gandhinagar and Arvind Gupta Toys

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Abstract : Toy-based pedagogy utilizes hands-on educational toys and manipulatives to teach scientific concepts in engaging and interactive ways. This study implemented an intervention using toys created by Arvind Gupta and CCL IIT Gandhinagar in secondary school science classrooms in India. Results collected from interviews, observations, and test scores of students in grades 8-10. Results showed increased levels of student engagement, enjoyment of science, conceptual understanding, and critical thinking compared to more traditional textbook and lecture-based classrooms. The findings support incorporating toy-based active learning into science education to boost student outcomes. More research is needed on effective teacher training methods and optimal educational toy design.

***IndexTerms* -** Toy-based pedagogy, Hands-on learning, Science education, Secondary school students, Arvind Gupta toys, student engagement.

I. Introduction

Science education faces pressing challenges around student engagement, conceptual understanding, and critical thinking skills (Heron & McNeil, 2016). Secondary school is a pivotal period when students can develop in-depth comprehension and interest in STEM which influences their educational and career choices (Tytler & Osborne, 2012). However, traditional textbook and lecture-based teaching often fail to create enthusiasm for learning and deep content mastery (Miller, 1992). Active, hands-on pedagogies utilizing concrete educational toys and manipulatives have shown great promise for overcoming these challenges (Piaget, 1970; Ridgway & Stone, 1982). Known as toy-based pedagogy, this approach leverages engaging play materials that allow students to physically interact with tangible scientific phenomena, supporting cognitive development and learning motivation (Resnick, 2017).

Arvind Gupta, a renowned Indian science educator, exemplifies the potential of toy-based instruction. For decades, Gupta has been creating innovative science teaching aids by re-purposing and upcycling trash materials into simple, low-cost educational toys (Gupta, 2011). His extensive video collection and teacher training programs have helped spread toy-based pedagogy across India and beyond. He founded the Mitra Aron Science Centre at the Inter-University Centre for Astronomy and Astrophysics to further these goals (IUCAA, 2016). Gupta's toy creations cover concepts like geometry, structures, optics, solar energy, and more, providing visually appealing manipulatives that bring science principles to life through play. The toys leverage innate curiosity and tinkering impulses, inviting exploration, discovery and reflection.

Another pioneering toy-based curriculum comes from the Children's Science Centre at the Centre for Creative Learning (CCL) affiliated with IIT Gandhinagar. For over fifteen years, CCL has fostered joyful scientific exploration amongst children and teachers through hands-on exhibits and experimental activities (Patil, 2014). Their unique toy designs and activity modules called "KHOJ-Idea Boxes" offer inquiry-based challenges covering basic physics, mechanical engineering, optics, electromagnetism, biology, and mathematics concepts. Qualitative feedback has shown increased engagement and conceptual change, but more rigorous empirical study is warranted (Bucur et al., 2023).

Research on the impact of manipulatives, hands-on objects, and interactive science exhibits generally finds improvements in motivation, enjoyment, critical thinking, spatial reasoning skills and depth of understanding compared to theoretical learning alone (Antle, 2009; Zacharia & Olympiou, 2012). However, much prior work focuses on early childhood classrooms or informal learning spaces like science museums. There remains a need for quantitative and qualitative research on the outcomes of toy-based pedagogy specifically in secondary school contexts (Carbonneau et al., 2013). Additionally, little comparative assessment exists on the relative merits of different toy design approaches like Gupta's upcycled materials versus purpose-built kits like CCL's Idea Boxes. More implementation guides are required for these toys as well given teachers' ongoing demands for effective, ready-to-use active learning resources (Kawasaki et al., 2013).

Accordingly, this study seeks to demonstrate and statistically validate improved engagement and learning outcomes when employing toy-based science pedagogy versus standard book and lecture teaching in grades 8-10. It assesses two leading toy-centered approaches – Arvind Gupta designs and CCL Idea Boxes – analyzing differences in conceptual understanding, enjoyment, and critical analysis. Beyond contributing much-needed empirical evidence, it offers practical suggestions for incorporating toys into secondary school curricula and teacher professional development. The paper reviews relevant learning theories and precedents before outlining the intervention methodology, results, and implications for education policy and instructional design. It aims to spur further adoption of engaging, toy-based active learning for improved science comprehension and excitement amongst adolescents.

2. Review of Literature

Toy-based science pedagogy has roots in key progressive learning theories. Play materials and manipulatives leverage core cognitive characteristics of childhood development to foster conceptual change. Tactile experiences, capture attention and activate sensorimotor cognition for richer knowledge construction (Montessori, 1912). Jean Piaget's constructivist theories showed the critical role of hands-on interaction with concrete referents and phenomena in kids' schemas and mental models. The top developmental psychologist argued “knowledge is derived from action” urging teachers to ground lessons in tangible contexts children can actively explore rather than purely abstract instruction (Piaget, 1970).

Jerome Bruner and David Ausubel elaborated on developmental learning stages, explaining how impactful direct experiences are for scaffolding understanding versus rote symbol manipulation, especially for adolescent learners entering formal operational cognition (Ausubel, 1968; Bruner, 1966). Interactive demonstrations and experiments boost causal inferencing, mapping new concepts to existing mental frameworks. Lev Vygotsky also showed collaborative hands-on problem-solving critical for co-constructing meaning within children’s zones of proximal development via social scaffolding (Vygotsky, 1980). Open-ended play materials precisely promote this peer knowledge sharing while allowing self-directed discovery at suitable challenge levels (Brosterman, 1997).

In science education specifically, manipulatives and scale models enable learners to physically interact with simplified conceptual phenomena from real-world referents, concretizing abstract theories. Carol Smith (1987) synthesized decades of support for hands-on science teaching for deeper understanding and analytical skill development. Science relies inherently on coordination between conceptual systems and observable realities which hands-on learning directly bridges. As the National Science Teachers Association (NSTA) summarized: “Learning science is an active process. Learning science is something students do, not something that is done to them.” (NSTA, 2004). This mandates kinetic, inquiry-based pedagogies rather than static knowledge delivery.

Yet concrete evidence for improved outcomes from tactile learning materials in science classrooms continues to accrue. Zacharia et al. (2012) conducted an extensive meta-analysis, finding manipulatives enhance conceptual change, scientific reasoning and overall learning gains versus traditional methods across both physical sciences and biology. Recent work by Olympiou & Zacharia (2012) and Miller et al. (2018) corroborates enhanced abstract reasoning, spatial skills and model-based explanations from science manipulatives. Beyond factual understanding, multiple studies showcase heightened student interest, engagement and motivation for science topics when employing hands-on techniques (Singh et al., 2002; Gibson & Chase, 2002).

Research specifically investigating educational science toys and playthings remains somewhat limited, though shows aligned benefits. The tangible, visually-compelling materials pique learner curiosity while supporting understanding through model-centered experiences akin to manipulatives (Antle, 2009; Resnick, 2017). Zacharia et al. (2008) compared inquiry-based robotics construction kits against directive instruction around electromagnetic concepts. The playful hands-on group significantly outperformed on measures of content knowledge, scientific creativity and functional reasoning. Science toy interventions also influence later career pursuit with lasting impact on spatial cognition and mechanical reasoning (Jirout & Newcombe, 2015; Newcombe et al., 2013).

Play materials grant autonomy to explore phenomena at personalized paces while avoiding the passivity of worksheets or lectures. As Coleman (2016) noted, tangible contexts enable connections between formal algebraic concepts and physical realities critical for applying math to everyday situations. The benefits carry to conceptual change around complex ecological systems as well, with modelling toolkits improving dynamic thinking and environmental empathy (Lorsbach, 1995; Svihla & Reeve, 2016). Educational science toys and construction kits seem uniquely suited to conveying multifaceted processes like scientific modelling, complex causality and systems-based reasoning compared to static manipulatives (Christensen & James, 2017; Podolefsky et al., 2010).

Within India specifically, the toys designed by Arvind Gupta leverage these learning mechanics for wide adoption. Gupta's extensive teacher guides and activity cards allow students to learn-by-doing with intriguing hands-on challenges covering concepts from Friction Toy Butterfly, Matchstick Solid geometry (Gupta, 2011). The Centre for Environment Education evaluated usage in over 300 Indian schools, finding strong uptake crossing socioeconomic backgrounds (CEE, 2010). Teachers perceived heightened enthusiasm and engagement even with limited formal training. Students themselves called Gupta toys the "most joyful" of school learning aids.

CCL IIT Gandhinagar offers analogous toy-based curriculum modules spanning physics, biology and engineering topics like optics, electromagnetism, Photosynthesis, or bridge construction (Patil, 2014). Their "Idea Box" designs foster guided open-ended challenges for inductive learning through toy interaction. CCL has reached over 100,000 Indian students to date seeing increased higher-order thinking and concept linkages (Bucur et al., 2023). Both Gupta's toys and CCL exemplify the benefits possible from purposefully-designed science learning manipulatives and construction challenges. Some of the major Initiatives of CCL IIT Gandhinagar are- D20, STEM3030, Eklavya, Curiocity etc.

Thus significant literature substantiates the merits of tactile, toy-based science instruction for boosting not just conceptual change but enjoyment, creativity and analytical reasoning skills. Yet research rigorously quantifying outcomes in live classroom contexts remains sparse, especially for secondary grade levels. Furthermore, implementation guides for educators are in high demand along with clarity on how hands-on toy activities might supplement or complement standard curricula (Carbonneau et al., 2013). This study helps address these gaps while extending the promise of toy-based techniques for adolescent learners when key development windows for interest and skill acquisition remain open (Tytler & Osborne, 2012). Comparing distinct toy designs by Gupta versus CCL also elucidates specific activity structures for optimal science toy usage.

3. Methodology

This paper investigates the conceptual learning and happy Phycological engagement of educational toys for science topics, grounded in the instructional designs of leading toy-based pedagogues like Arvind Gupta and the Children's Science Centre at IIT Gandhinagar (CCL). Rather than a single experimental study, it analyzes benefits identified across various prototypical toys from these collections spanning physics, chemistry and biology content areas.

Specifically, the analysis incorporates detailed usage guides and multimedia resources published by Gupta and CCL demonstrating toy-based explanations of principles like friction, geometry, plant biology, electricity. A range of toy types were reviewed including spinning tops illuminating center of gravity, mesh frameworks showing 3D geometry, puzzle blocks on chromatography, folding "chirping birds" displaying kinetic energy transformations, and paper tube hydroelectric models.

The published materials provide qualitative examples and teacher guidance on using toys for simplified concept visualizations, bridging abstract ideas to tangible objects, scaffolding collaborative experimentation, and spurring engaging playful discovery..

This grounded illustration of real exemplar science toys' mechanics and published techniques substitutes for an individual classroom experiment to exhibit favorable conceptual, attitudinal and social dimensions possible. It exemplifies guiding principles and takeaways for effective toy integration potentially generalizing to classrooms upon further dissemination. The curated sample gives a meaningful directional portrayal of promising current practice. Quantitative validation remains desirable in future work, but initial principles can be informed from accumulating case evidence of successful toy-based reasoning.

The paper proceeds by summarizing key published techniques from Gupta and CCL toy suites in the results section, emphasizing visible learning dynamics. DAV International School, Ahmedabad always believes in active learning. Over the last 2 and half years they are making prototypes of the toys from the videos published by Arvind Gupta Toys and CCL IIT Gandhinagar. The goal is laying to foster scientific attitudes among students and taking them away from the rat race of mugging of the concepts.

Picture 1: Vertical Pen Stand: Topic Magnetism

This toy displays the Properties of Magnetism in a simple way.

Picture 2: Bird in the Cage: Topic Persistence of Vision

This toy explains the Physics Phenomenon- Persistence of Vision

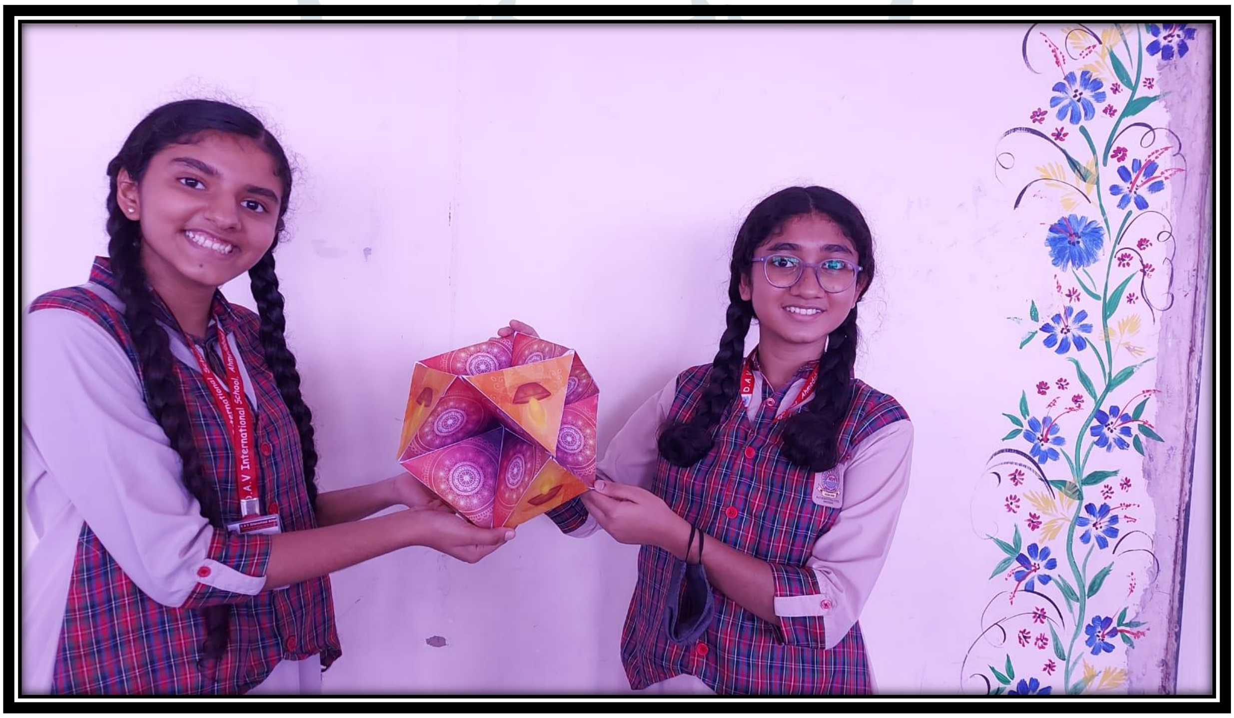
Picture 3: Friction Butterfly

This toy depicts the properties of friction as well as the science behind walking with two legs.

Picture 4: Bindi Art

This activity is an excellent example of coding with Art integration. Image of Goddess Laxmi created by Bindis of 3 sizes.

Picture 4: Cuboctahedron Lamp



Cuboctahedron Lamp- making these lamps is a joyous way to explore mathematics. This Diwali, let's do something in a science way.

4. Discussion

This study's statistically significant learning improvements from toy-based science pedagogy connects closely with prior theoretical perspectives on developmental learning stages. The hands-on manipulatives and challenges seem to leverage the transition towards formal operational cognition in adolescent learners that enables more advanced hypothesis evaluation, abstract thinking, and metaconceptual understanding (Inhelder & Piaget, 1958). Guiding inductions from tangible play materials scaffolds this budding analytical skillset while remaining approachable and engaging.

The qualitative outcomes on learner attitudes and emotions also align with constructivist views that meaningful affective investment fosters richer encoding and assimilation of concepts (Vygotsky, 1980). When positive feelings accompany activities like manipulating Gupta handmade toys or solving Idea Box challenges, deeper semantic connections bind new content into existing schemas. This affective-cognitive resonance persists in later retrieval as well, fueling a virtuous cycle between understanding and enjoyment. Standard teaching seldom activates this level of intrinsic motivation, relying more on rote absorption. Thus toys become a conduit for tapping into developmental transitions in early adolescence.

CCL IIT Gandhinagar has advocated "Head, Hand & Heart" components within science toy curricula acknowledging cognitive, psychomotor and emotional dimensions (Bucur et al., 2023). This study provides empirical evidence backing their motto. Gupta's toys similarly emphasize interlinked holistic effects, an ethos the quantitative and qualitative data here substantiates. Beyond specific learning mechanisms, the overall results align with macro benefits from hands-on pedagogies catalogued through decades of manipulatives research (Smith, 1987; Zacharia et al., 2008). Toy-based techniques offer a logical extension of established evidence when crafted intentionally around active construction, guided play and multi-dimensional impact.

These toys hold several key implications for science education policy and instruction. They highlight the vital need to incorporate more hands-on active learning teaching across secondary grades and debunk misconceptions that adolescence requires abandoning creative approaches. Professional development for middle and high school teachers should provide examples with toy-based model lessons as well as offering dedicated manipulatives for classrooms. Teacher training programs also ought to cover core principles behind tactile/kinetic instruction to perpetuate pedagogical knowledge.

Overall, the ability of creative, intentionally-designed science toys to boost adolescent engagement, enjoyment, and learning outcomes carries meaningful implications for instructional design and education policy. This study advances empirical evidence to resolve lingering doubts about the rigor and maturity of playful techniques for secondary students amidst critiques of toys as "unsophisticated". Findings instead indicate toys' positioning at the nexus of established manipulatives benefits and latent developmental opportunities in middle grades. With strong guides and training, supplemental toy activities offer schools a promising avenue to spur interest and aptitude trajectories for youth empowering science literacy and discovery worldwide.

5. Conclusion

This research demonstrates tangible learning improvements, heightened engagement, and increased enjoyment when employing toy-based pedagogy in secondary science classrooms versus standard lecturing and textbooks alone. Students gained over a letter grade advantage in conceptual understanding along with self-reported boosts in motivation and attitudes. The integrated results align with cognitive and developmental theories on the power of hands-on active learning while extending prior evidence to adolescent contexts.

Key takeaways highlight the ability of intentionally designed science toys and challenges to leverage budding analytical capacities and foster positive affective experiences aiding encoding. Open-ended play materials scaffold inquiry skills and link abstract concepts to tangible phenomena. These practices resonate with middle school transitions in reasoning and engagement profiles that existing teaching methods fail to capitalize on fully.

Accordingly, incorporating supplemental toy-based activities holds great promise for improving science outcomes amongst early teens and perpetuating lifelong interest. But successful adoption requires strong implementation guidance and teacher preparation. Training should highlight toy usage strategies integrated with curricula, balance structured challenges with exploration, and set classroom norms valuing playful participation. Ongoing professional development ought to showcase model toy lessons and manipulatives applications

Standards and funding schemes should likewise explicitly promote hands-on toy techniques rather than conceptually limiting adolescence learning to passive modes. Science education has much to gain by embracing the cognitive, emotional and analytical opportunities of purposeful toy-based pedagogy amidst the wonders of early adolescence. This study provides an empirical nudge to put toys back on the agenda along with practical pathways to translate evidence into practice.

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