INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED'09
24 - 27 AUGUST 2009, STANFORD UNIVERSITY, STANFORD, CA, USA

CREATIVE ENVIRONMENTS FOR INNOVATIVE LEARNING PROCESSES

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ABSTRACT
Identity, skills and creativity are created in interaction with the environment and are therefore influenced by the tools individuals have access too. Since working memory is flexible, we will investigate to what extent creative environment and problem solving tasks suited for girls and boys alike will affect working memory, thereby producing knowledge on how to design creative environments in order to achieve optimal and innovative learning processes. Visual artifacts, such as toys, pictures in schoolbooks and advertisements affect children emotionally, and are crucial as role models when forming identity. Identity and self-confidence are vital in learning processes. This paper elucidates the consequences of gender-segregated toys, advertisement of toys with gender specified target groups in relation to working memory, further interest and later choice of higher education and profession. It is common that children are forced into gender stereotypical games. We suggest that interest in engineering will rise if young children are stimulated to play and create their identity individually. This is a multidisciplinary research project and a unique collaboration in which we focus on different aspects of learning processes from a visual and gender study perspective, using a neurobiological point of departure.

Keywords: visual perception, design, toys, gender, working memory, image, interest, learning process.

1 INTRODUCTION
The exceptional thing about images is that they can look like the object they represent. The mimetic quality of visual representations has effects on how they can be used as role models in different ways — both deliberately and more or less unconsciously. It is well known that pictures can be imitated and that young people take photographers' models as examples for creating their identity in respect to performativity [1,2]; that is how to dress and behave. For young people of today lifestyle, created by them, is an important part of their identity, an identity that has its origin in clothes and tools such as cell phones, computers etc. The market forces and industrial designers have stimulated a demand for differentiated design, not only for different uses but also for different target groups based on gender and age since the late 19th century [3]. In a recent study [4] we have found that advertised toys are highly gender specific and that producers of toys often depict boys and girls in play situations. As a consequence, gender plays a role regarding what kinds of toys boys and girls are expected to play with. That means, for example, dolls for girls and cars and action toys for boys. The activities that are suggested for girls are mainly dressing up dolls, decorating dollhouses and playing with pets, while boys are supposed to build airplanes from assembly instructions, load and unload ships, drive fast cars and carry out chemistry and physics experiments.
Children's play often mirrors adult behavior but it is also a reflection of the future, since the children of today are the adults of tomorrow. The decreasing interest in engineering among young people in general is a growing problem in industrial countries [5, 6, 7, 8]. The interest among girls is even less, resulting in hardly any female technicians in contemporary industries. The tendency in industrial countries is that teenagers choose education and future jobs with regard to what kind of lifestyle they require. Research that focuses on how to create an interest in engineering and technical subjects is needed. To make engineering attractive for boys and girls, it is necessary to present an alternative to a rational and less glamorous picture of the profession. This does not mean that one has to be ingratiating, but the role model has to be changed to stimulate and attract youngsters.
One solution to attract girls to engineering professions has been to broaden the education and include soft values and contextual perspectives on engineering, such as social relations in production systems,

environmental aspects and sustainability. To take social relations into consideration is admirable in many ways, but it preserves gender expectations. What we suggest is a less deterministic discussion and treatment of those questions. Instead we want to discuss more creative ways to stimulate children to feel free to play and learn without presupposed gender labels.
The purpose of this paper is from a theoretical perspective to discuss the relation between toy advertisements and children's play in relation to their interest in school subjects, and later choice of education and profession. We consider working memory as crucial to study in order to provide optimal conditions for learning. This paper summarizes the state of the art in different areas as well as offering a starting point for further research in the area.

2 STATE OF THE ART

2.1 Gender

While sex is a biological definition, gender is a social construction. According to Judith Butler, and many other scholars, gender is a performative activity; we play the role as a girl/woman or boy/man often after predestinated patterns [2, 9] Over a long history it is obvious what roles and behaviors belong to which sexes, and interpretation of animals' behavior frequently serves as an argument for preserving traditional sex roles. Within the academic field, feminist studies and gender studies go back to the late 1960s, and have now partly been replaced by queer studies. An early standpoint among feminists was based on an essentialist ideology; that is a belief that women's biological differences from men makes them unique in many ways that have effects on thoughts and behavior [10]. An essentialist attitude could lead to ideas about women as a peculiar makeup and thus inspire sex differentiated activities and interests. In the first women's liberation movement, during late 19th century and early 20th centuries, it was a common apprehension that women and men have different natures, and that women are more nonviolent than men. As a consequence, the women's liberation movement and the peace movement worked hand in hand [11]. In the second women's lib movement, the essential ideas were more connected to motherhood and women's close connection to nature and sustainability. However, the feminist movements and feminist scholars have systematically fought for equality between men and women, the right to equal education and professional treatment; and guaranteeing respect for women.
One's biological sex one often traps a person into predetermined expectations concerning abilities and interests. That is questioned in gender studies, in which attention is focused on individuals and how gender is created in a social context — both femininity and masculinity. Frequently, however, biological sex dominates in gender discussions and there is limited space, or no space at all, for negotiation about gender positions. It is still more accepted that girls are doing so-called boyish things, than for boys to be doing girlish things. This could be explained by the fact that girls and women are still the Other. In queer studies there is a focus on how gender is performed based on a theory about gender, above all that gender is separated from biological sex [2]. From that perspective it is not possible to argue whether there is some gender (read sex) related behavior or interest.
There are studies showing that the brains of newborn girls and boys are very similar, but that following socialization into different gender patterns the structure of the brain changes, and that adult brains reveal differences between the sexes [12, 13].
Both Hyde [14] and Spelke [15] have studied whether differences between sexes may explain the uneven sex distribution in mathematical and technical subjects, and the results showed that these skills originate in biological cognitive functions shared by both sexes. Weiss [16] has examined differences in verbal and visiospatial abilities among university students and showed that women perform somewhat better than men concerning verbal abilities, while the opposite was seen regarding visiospatial abilities. However, these differences were quite small, and the authors argue that they can be explained in terms of sociocultural, academic and training background. Regarding toy preferences, there are studies showing that boys show toy preference but girls do not [17, 18, 19]. However during socialization processes, girls are raised to choose female toys. Even if a toy is regarded as very attractive, a girl will not choose it if it has a boy label [20]. Altogether these results indicate that differences in interest in science and technology (S&T) can hardly be explained by biological causes, but the way we raise our children is mirrored in biological consequences.

2.2 Engineering design education

Design makes gender because design of all kinds is gender differentiated, from watches to cars designed for (and by) women. Design and engineering have long been intertwined. The border between industrial design and engineering design is blurred, and by closely examining the concepts we will find similarities. Design research is mainly applied science and contributes to improvements in industrial design and in engineering design. Engineering design focuses on problem solving, while industrial design emphasizes the interaction between the human being and the use of the artifact, and on aesthetic values. Therefore, industrial design traditionally attracts women more than does engineering design. Both industrial design and engineering design research focus on practice, and have a solid tradition based on educational systems and values; those are more or less explicitly expressed. Academic traditions are often based on regulations that are called canons; to be innovative, it is necessary to ignore those rules. Engineering design has a long male tradition, and to change that it is necessary to challenge the canon, and to train the engineers of tomorrow to be aware of the interaction between the objects in environments and the effect of that interaction on our cognitive development and thinking.

In The Design of Everyday Things Donald A. Norman points out that natural mapping leads to immediate understanding of how an object works [21]. However, we claim that natural mapping is not universal. Experience is required for the user to find a technical instruction logical. Boys are often stimulated from early childhood to build models, do physical experiments etc., while girls are not. To attract young people of today (boys and girls), engineering design education must be improved concerning how different backgrounds affect the individual learning processes. A creative environment in engineering design education will stimulate youngsters to apply for admission to engineering programs, and will stimulate teachers to initiate innovative processes in their classes.

2.3 Play – education - technology

Studies on gender related behavior in children's play have mainly focused on pre-school children [22]. As a result of those studies, there have been discussions about how to change boys' and girls' play to be less dissimilar, and some activities that compensate gender stereotypical play have been introduced in several daycare centers. There are examples where the teachers have initiated specific days when boys are promoted to play with girls' toys and vice versa. In addition, many daycare centers stimulate boys to engage in more tranquil activities, instead of restraining aggressive behavior.

In recent decades, scholars from different disciplines have focused on computer games and gender. The results indicate that playing computer games is mostly a boy activity [23]. The computer games that have attracted girls are Barbie games. This has actually been explained by the content of the games, namely that they include social relations rather than competition and violence [24]. Many of the contemporary toy producers have imitated the Barbie concept and offer web based computer games on their homepages. Polly Pocket and Winx belong to that category. While the games aimed at girls stimulate aesthetic creativity, games for boys encourage excitement and problem solving. Producers of traditional boy toys display milieus from cities and harbors on their websites, populated by men in professions like policemen, firemen, and engineer or harbor worker. No shopping centers are displayed and no small city cars, only trucks, caterpillars, ambulances, police cars, trains and fire engines [4]. It is therefore relevant to ask what narration about the children's future and possible choices of profession is retailed in toy advertisements and computer games. And what consequences will that have on the society of the future?

In many countries several projects have been realized to motivate children´s interest in engineering design. Professor Allison Druin writes on her website: "We have a chance to change technology, but more importantly we have a chance to change the life of a child. Every time a new technology enables a child to do something they never dreamed of, there are new possibilities for the future" [25]. Since 1998 Druin has been working in different collaborative projects together with children to design software for children. Dr. Mary Flanagan has created a computer game for children, The Adventure of Josie True, to encourage girl's interest in math and science [26]. She made the games between 1997-2002. Josie is visualized as a boyish girl, and thus the character preserves gender expectations, i.e. to be interested in science and math you should either be a boy or a boyish girl. But how to represent a girl who breaks a long tradition of visual representations of girls? This is a great problem with which feminist artists and illustrators of schoolbooks have been struggling.

2.4 Working memory

Working memory, earlier referred to as short-term memory or primary memory, is crucial in learning situations and learning processes; and it is flexible. Working memory retains, processes and consults earlier knowledge and experiences at the same time. Working memory is used when dealing with situations and information of which we have little or no experience, in contrast to situations or information where we have a great deal of experience and knowledge and use our long-term memory. Different models have been presented regarding the function of working memory, both anatomically and cognitively; among them some models have received greater acceptance [27, 28, 29, 30, 31]. The multi-component working memory model suggests two separated systems that process information independently of each other, the visiospatial sketchpad and the phonological loop, which are further integrated by a central executive system and linked to the long term memory via the episodic buffer [32, 33]

The capacity of working memory is generally considered to be limited; in 1956 Miller [34] introduced the magical number seven as the maximum number of different units that can be kept in mind at the same time. However, later studies have proven that this number varies between individuals, and also depends on the character of the unit (digits, letters, pictures, words etc).

Moreover, the working memory can be blocked by emotions. A study of schoolchildren with dyscalculia showed that the math problem by itself caused blockage of the working memory [35]. In addition, Krawczyk [36] has shown that working memory correlates with motivation. Finally, there is also a strong correlation between the capacity of working memory and the ability of problem solving [37]. Thorell et al.[38] have recently studied the effects of executive functions in preschool children, and concluded that the visospatial working memory is easily trained, compared to the inhibitory control system where no results of training could be seen. This indicates that the different processes involved in working memory have different psychological and neural design.

Altogether this research indicates the importance of working memory in facilitating learning and raises the question whether it is possible to train or develop working memory capacity.

Today there are numerous ways to test working memory capacity, and quite recently numbers of commercial tools have been released for training the working memory [39, 40, 41]. By using these tools, children have improved their working memory not only regarding the specific game but also in general, and the effect is long lasting. Until recently the general belief was that human brain is unable to repair itself; nerve cells present at birth only decreased during life. However, studies on songbirds showed the presence of newly formed neurons in the birds' brains, and when exploring the human brain these findings could be confirmed: so-called adult neurogenesis (in comparison to embryonic neurogenesis). The mechanisms behind adult neurogenesis are well studied in the peripheral nervous system [see e.g. 42], but more studies on the central nervous system are required.

Regarding working memory and gender it is reasonable to expect that boys and girls raised in stereotypical environments differ in their earlier knowledge and experiences, and thereby having different basic conditions when it comes to new learning situations. The newborn child is given role models and social influence to a large extent by its parents [43], and these models are confirmed by non-parents, thereby strengthening the expectations on the child's behavior and preferences when it comes to e.g. toys. Stereotypical toys also promote different types of abilities; playing with masculine toys may be linked with higher visiospatial ability while playing with feminine toys may be related to higher vocabulary ability [44]. This indicates that different parts of the working memory are active in playing in a stereotypical manner thanks to the different working memory components (visiospatial and verbal) [45]

In conclusion, the working memory is necessary in learning. It is possible to train the working memory and thereby form new nerve cells. The characteristics of training are important regarding which abilities are about to be developed, and therefore a careful individual perspective needs to be considered in learning processes.

3 AREA OF RESEARCH

This is a multidisciplinary study in which we combine visual studies and neurobiology with gender studies and relate those perspectives to learning processes. From visual and gender studies we know that visual representations have effects on people's emotions and behaviors. We also know that emotions and behavior have an effect on the capacity of the working memory, hence visual

representation is extremely important for the ability to learn. Pictures externalize mental images, and thus relieve the pressure on memory. We use visual representations for communication, and therefore their appearance has an effect on how they are understood. There is a constant interaction between mental images and input from pictures, text, language and the environment as such. In schoolbooks there are mainly two kinds of pictures, those that portray things and those that are visiospatial. The first category depicts things like form, appearance etc., while the second group represents relations, maps and flow diagrams. Many pictures contain both categories: anatomical illustrations both map the body and depict is appearance, or rather the idea of how it looks. All illustrations are an interpretation of an object, an idea or a phenomenon; a re-presentation and not a blueprint. Schoolbook illustrations have an influence on the pupil, but also on the teacher and the learning situation. That goes back to a long pedagogical tradition in which teachers used pictures, wall charts and models in demonstrations in the classroom [46, 47, 48]. Many gender stereotypical pictures are to be found in contemporary schoolbooks [4].

The Swedish publisher Natur & Kultur collaborates with a leading author in their publishing of schoolbooks in physics and technology for grades one to six. The author, the publisher and the illustrator have tried hard not to be trapped in traditional gender perspectives concerning how phenomena and experiments are presented. The schoolbooks and the accompanying teacher handbooks have a gender-neutral approach and content. It is more remarkable, however, that there is no discussion at all in the teachers' handbook from a gender perspective. We will here discuss some examples from a textbook in technology for grades 4-6. One chapter is about different ways of travelling. In the introduction the author writes that we travel more than ever today, and that our cars, ships and airplanes are faster, bigger and safer than ever before. The illustrations in opening of the chapter show two cartoon figures looking at the sky, where they see a photograph from Pompeii, a painting representing wheels from Mesopotamia and the front of a high speed train. The text is about different ways of traveling on roads and on railways. It describes car industries like Ford, and traffic regulations. The following chapter opening discusses travelling by ships and boats; it is richly illustrated with water and different kinds of boats and ships operated by men; see Figure 1. In the teacher's handbook for this chapter, the teachers are encouraged to refer to history, such as the Stone Age and episodes from songs about a sailor's life. Lave & Wenger [49] emphasize, "As an aspect of social practice, learning involves the whole person; it implies not only a relation to specific activities, but a relation to social communities – it implies becoming a full participant, a member, a kind of person. To ignore this aspect of learning is to overlook the fact that learning involves the construction of identities" [49]. How has the author tried to involve the children's experience in this chapter? It provides a lot of details about different parts of the ship and the sailing boat, and the function of the steamboat.

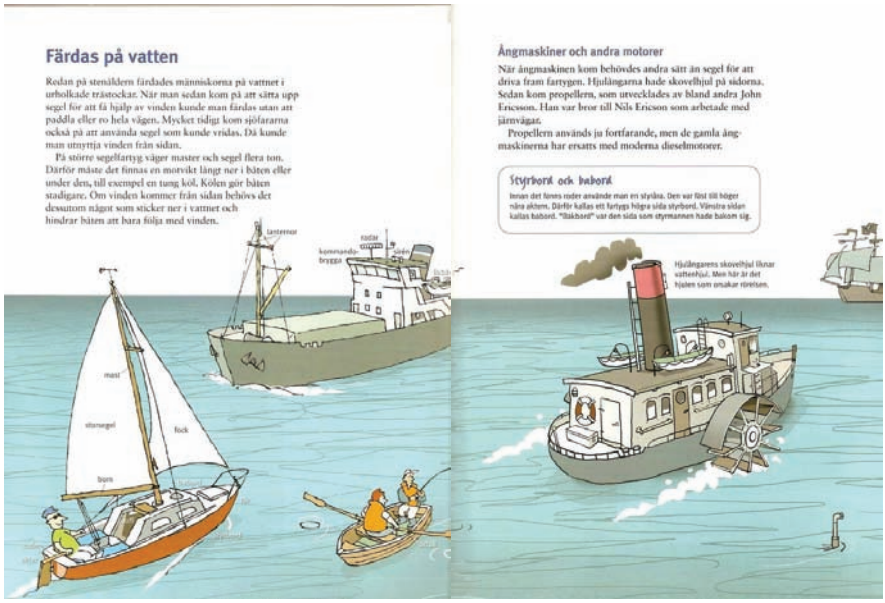

Figure 1. From Grundbok, Teknik (Textbook in Technology), grades 4 – 6, 2006

Further on in the book there is a chapter called "A day in the factory", describing the Ford factory, but what about the contemporary industry? And as Brickhouse put it: "The idea of learning as transformation of identity-in-practice provides a way of thinking about learning that is gendered, but does not regard gender as a stable, uniform, single attribute" [50]. Looking at the illustration, Figure 2, we see male workers from the beginning of last century. A production system that is no longer desirable or present.

Figure 2. From Grundbok, Teknik (Textbook in Technology), grades 4 – 6, 2006

Gender relations are important in learning processes, and equality within the student group supports the learning process. But it is important that the schoolbooks stimulate children and make them curious. To interest children it is necessary to get them involved in the subject at hand, in this case technology. Here the author, editor and illustrator have been so occupied with being gender neutral that it seems that they have forgotten all about the children. In addition, it is more about the history of technology than contemporary engineering design. What kind of ideas will they absorb about engineering design? Especially if we regard pictures as something that affect children's understanding and elucidate the text and give comprehension, and have consequences for the mental images. Contemporary scholars make a distinction between working memory and short-time memory. As mentioned before, Alan Baddeley introduced the term working memory, and he suggests that it consists of three parts: the visiospatial sketch pad that stores visual information; the phonological loop taking care of verbal information; and the central executive coordinating the two [32]. Working memory is involved in interpreting pictures. Picture interpretation is a complex process that involves long-term memory too, since earlier experience influences our understanding of a representation. On the other hand, visual representations have consequences for our memory, and hence our interpretation. There is a complex relation between mental image and visual perception. Our perceptions are influenced by our mental image, and our mental image by the environment. Therefore the illustrations discussed will have an impact on how the children will perceive information about the engineering profession in the future.

Working memory is flexible, and we suggest that by stimulating children to solve problems they will develop their creativity. To inspire the pupils it is essential that they can identify themselves and situations in textbooks. This applies to boys and girls alike. We know from research that boys and girls behave differently in many learning situations in connection with S&T [51]. Interestingly, a general trend is that the more developed the country, the less interested are young people in S&T and the larger the differences between sexes [8]. Several explanations have been given, including variation in experience and discrepancy in self-confidence caused by gender. Girls have the premonition and the expectation that they should not be interested in physics and technology, and therefore they have to be equipped with lots of courage to be active in elaborations and discussions in the classroom. The crucial question is however: how do we equip girls with necessary tools to have a chance to be interested in S&T? Is it by changing the name from technology or engineering to design? By including so-called soft values within the field of science? We suggest that children's play is a great part of their early learning process.

The history of S&T is consistently masculine, but as Lond Schiebinger puts it, "mind has no sex" [52]. It is the treatments and expectations of boys and girls that make gender; therefore it is necessary to create gender schemata in classrooms and day-care centers. Through a gender schema it is possible to systematically observe boys' and girls' behavior, and in addition the teacher becomes aware of her or his behavior. Does the teacher pay more attention to boys? Is the expectation of what girls can mange different from what is expected from boys? What kind of attention is given from the teachers in the classroom? It is important to formulate questions so they stimulate further questions and discussions; but it is equally important to formulate the questions so all children (boys and girls) have references to them. Boys are often directed how to solve problems themselves, while girls get help. This circumvents girls' focusing on problem solving as such in their own learning process.

Since self-confidence dominates in problem solving with regard to the results, it is well known that boys often overestimate their own capacity while girls underestimate their capacities. Working memory is flexible, and therefore it might be fruitful to stimulate girls, as well as boys, in early childhood. To acquire creative designers and engineers it is necessary to stimulate both boys and girls in problem solving, to assemble and build from instructions, as well as obtain training in social relations and aesthetic values. It is remarkable that the toy industry and school still promote gender-segregated behavior, which holds back both boys and girls.

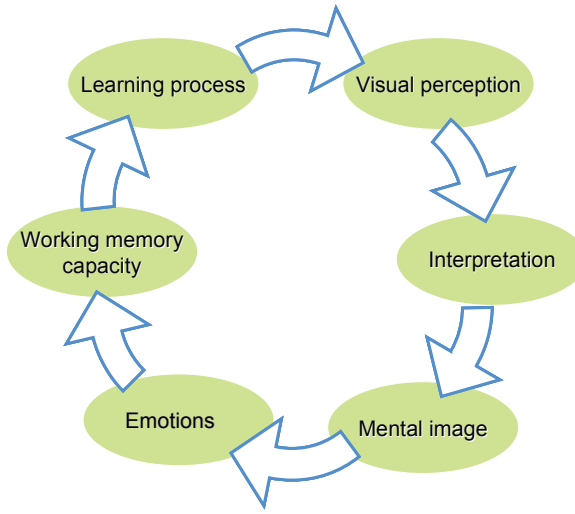

Figure 3. The important relationship of visual perception, working memory and learning processes.

We suggest that there is a strong correlation between visual perception and learning processes via the capacity of working memory as illustrated in Figure 3. All visual perceptions are interpreted in the brain in relation to earlier experiences and knowledge, and result in individual mental images. These mental images evoke different emotions that affect the capacity of the working memory, which in turn affects the individual learning process. The learning process creates new experience and knowledge important for future interpretations and so on. Our idea is to discover methods to optimize playing and learning in a gender-neutral way. The tools for doing this are to give the children motivation and interest, which are created through different activities depending on individual dispositions.
Our aim is to find the answer to how an interest in S&T can be achieved on an individual level. As pointed out earlier, the working memory is most needed when acquiring new knowledge, and we will therefore study how creative environments with different games and experiments affect the power of working memory. Our hypothesis is that by designing the environment as optimally as possible for the individual person, the learning process becomes optimized. Experimental design is of uttermost importance, and also the character of the milieu where learning takes place, what will happen if the children work in groups of one or both sexes, what will happen when the toys are changed etc. This will be coupled to studies of the brains of the children in order to create models for individual cognitive development and optimal interest, closely linked to the feeling of understanding. Methods that are to be used are working memory tests, methods of studying brain activity such as p positron emission tomography, functional radio imaging and diffusion tensor imaging.

4 CONCLUDING REMARKS

Many scholars have emphasized the dominance of visual culture in contemporary society. We communicate via pictures on the Internet and cell phones, and look at the news on television and in newspapers, magazines, non-fiction books and textbooks that are to a great extent illustrated. Pictures often complement text or speech, and they give life to ideas and explanations. In addition, illustrations elucidate conservative values about gender. It is not acceptable to write explicitly that girls shall play only with dolls and decorating dollhouses, but that can easily be found visualized in advertisements. We often identify ourselves with successful people or with those we think have an attractive life or lifestyle. It could be either a person in our environment, or someone we do not know or even a fictive person. Identification helps us to create our identity. Therefore it is important to not dissuade girls and boys from ignoring traditional expectations, but to encourage them to make individual choices concerning games. There is a close relation between identification, identity, treatment and

expectations. A person's self-apprehension is based on her identity and identification. One's identity and self-confidence have an influence on a person's behavior and actions. Since the working memory is flexible, a child's activities have an impact on the working memory's development. Playing with gender-stereotypical toys during childhood affects the capacity of the working memory in such a way that further learning in a stereotypical manner is strengthened and learning in a non-stereotypical manner is curtailed. The intricate relationship between identity and self-confidence impacts on girls' (and boys') interest in general, and in science and technology in particular. A creative and innovative environment is required to improve girls' and boys' interest in science and technology equally — a milieu that excludes all deterministic gender expectations from the very beginning and stimulates young children to develop their curiosity.

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