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## Uncovering Public Health Themes in Children's Fluoride Awareness Discourse Through Educational Innovation and Discourse Analysis

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Xiaomin WANG<sup>1\*</sup>, Miao MIAO<sup>2</sup>

<sup>1</sup> Graduate School of Human Sciences  
Assumption University, Thailand

<sup>2</sup> Graduate School of Human Sciences,  
Assumption University, Thailand-  
Xuchang Vocational Technical College

### \* Corresponding author:

Xiaomin Wang  
Graduate School of Human Sciences,  
Assumption University, Thailand  
Email: [wxm19970317@163.com](mailto:wxm19970317@163.com)

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### ABSTRACT

**Background:** The educational innovations, including hands on water-testing labs, little games on the mobile-based app and water-boarded role plays debate, have the potential of helping children be better informed about the role that fluoride plays on dental health and community water policy.

**Design:** Semi-structured interviews were used to assess 10 children (aged 8-12), 5 teachers and 5 public-health personnel in high-fluoride areas of China within seven days of module completion. In NVivo 12, transcripts were coded and analyzed in order to derive main themes of public-health.

**Results:** Four main themes were found:

- **Protective Science:** Preventative action was described in metaphoric terms by children (fluoride is a superhero cape).
- **Community Stewardship:** Ancestral well-blessing ceremonies were used to associate fluoride testing to community stewardship (19/65).
- **Civic Agency:** Smaller group of the students stated that they intended to address local authorities dealing with water (7/65).
- **Cultural Continuity:** The use of the modern science was rooted in the traditional practice with analogies to clay-pot filtration (12/65).

**Conclusions:** Incorporation of graphic metaphors, ritual social spread, and civic simulations, into fluoride education, evolves a more three-dimensional discourse of fluoride between the children.

**Keywords:** *fluoride education; public-health discourse; interactive learning; thematic analysis; China*

### INTRODUCTION

Fluoride has a long established history in the field of preventive dentistry and has been acknowledged to play major role in preventing dental caries among children owing to both community water fluoridation and topical fluorides. However, even though fluoride has been proved to be useful and healthy, uncertainties concerning its safety have remained with the families and the teachers (Jones et al., 2005). Young students, especially, are bombarded with split messages about the same topic in classrooms, on health education pamphlets, in product uses, and when the children chat informally with parents, without a chance to question or to begin to understand how scientific knowledge, policy and community values overlap. Consequently, the personal knowledge of children about fluoride and its application in the sphere of public health may be

superficial, sometimes inconsistent and hardly exhausted (Deng et al., 2024; Yang, 2024).

Due to this, creative teachers and citizens in health care have started to trial more interactive dialogue based methods of fluoride education. These involve playing interactive games, role-plays where the student is made into a kind of a community health envoy (or is emulated), and multimedia personal narratives over which the science of fluoride becomes part of a family like visual story (Jing et al., 2024). The point of such approaches is, therefore, not only to explain how the chemical processes of fluoride boosting the enamel of teeth work but also to clarify the governance frameworks, moral aspects, and organizational benevolence supporting the practical choices in relation to the safety of drinking water.

Although even temperate assessments of such learning innovations tend to produce a positive difference in quiz marks or classroom excitement, there is a need, which has so far remained unmet, to investigate the way in which children themselves describe the public-health themes contained in such experiences. What notions of safety, prevention and civic responsibility are created as a result of students reflecting on a pretend council discussion of fluoride doses? What is their characterization of the tasks of dentists, water technicians and their fellow citizens in maintaining healthy teeth and clean water? What metaphor, analogies, or image do they use when they are tasked with explaining fluoride to their family or friends?

To test these questions, this study uses purely interviewed-based methodology, where the interviewer will host a child, teacher educators, curriculum makers, and public-health officers. By way of semi-structured interviews with the students shortly after engaging them in novel fluoride lessons, we are able to record the vocabulary, values and priorities, brought to bear by young learners on their public-health talk. The inclusion of adults who design and implement similar programs in the interviews means that we also understand the level to which education objectives match or differ with the fresh knowledge the children are acquiring.

In this study, three connected issues are handled. To begin with, the number of educational innovations only seems to increase, but they are mostly measured by quantitative criteria that damage the high qualitative context of the voices of children themselves. Second, the current literature either concentrates on scientific literacy (what of fluoride) or civic education (how of policy), and never on how the two dimensions overlap in the thinking of children. Third, systematic evidence lacks on whether and how pedagogies based on dialogue can succeed in introducing depth and nuance into the reasoning of elementary age students about public health issues.

Based on this, our main goal is to identify the themes of public health, like safety, community stewardship, preventive action, and trust in institutions that drive the fluoride awareness discussion, in children, after the involvement in interactive and dialogue-dense lessons. In particular, the question is:

1. What are the central themes, and narrative schemas involved in what children say about the purpose of fluoride, its positive effects, and who should control it?
2. By what kind of educational innovation undergone (e.g., role•play vs., multimedia storytelling) do such themes differ?
3. How do teachers and public-health administrators interpret the discourse of children as

either reproducing or redefining some larger goals of the field of public health?

In an attempt to answer such questions, we made three main groups of stakeholders subjects of semi-structured interviews: (a) children between the ages of eight and twelve that went through a module on fluoride education, which was one of three similar modules developed through the research; (b) teachers and curriculum designers with whom the modules were being worked, and (c) local administrators over public health that dictated community policies on water fluoridation. There was also an invitation to sketch, role play or develop a story about fluoride in their own words. Adults were interviewed to expose the way these activities were to form scientific and civic knowledge, through the perspective on how the practitioners observed the responses and questions of children.

Thematic analysis was carried out on the basis of transcripts using the six steps suggested by Braun and Clarke, namely; familiarization with the data, initial coding, theme exploration, theme review, theme definition and labelling, and report writing. Such an interview-based approach makes sure that emergent themes in the sphere of public health are not superimposed on a set of topical patterns but based firmly on the language and experiences of the participants rather than the prior theoretical frameworks.

The study focuses on the voices of children and aligns these to the school and school officials, which sheds light on the mechanisms through which educational innovations create or fail to create meaningful public-health literacy. Its results will be used to design future programs on fluoride education which does not simply pass along scientific knowledge but also fosters critical thinking skills, civic action, and feeling of shared accountability in the community health.

## LITERATURE REVIEW

Within the last 20 years, the growing research evidence has supported the benefits of shifting away towards more clinically relevant, interactive interventions to replace the more passive and traditional forms of fluoride education. The beginning of the shift was made by Kanduti et al. (2016) who introduced the school-based water-fluoride laboratory lessons where students were to analyze local water samples and estimate the fluoride levels. This learning by doing experience resulted in attainment of 25 percent decrease in new dental caries as opposed to control groups and the authors encouraged the inclusion of practical modules in water testing in standard science programs.

**Table 1.** Key Studies in Interactive Fluoride Education

| Study                 | Intervention                           | Key Findings                                              | Recommendations                                             |
|-----------------------|----------------------------------------|-----------------------------------------------------------|-------------------------------------------------------------|
| Lotto et al. (2023)   | School-based water-fluoride lab lesson | 25% fewer new cavities in intervention group              | Incorporate hands-on water-testing exercises into curricula |
| Chi (2017)            | Gamified fluoride-science mobile app   | 40% higher retention of scientific terms after four weeks | Combine digital games with facilitated classroom discussion |
| Lang (2018)           | Parent–child fluoride safety workshops | 30% increase in children’s policy-awareness scores        | Offer joint caregiver-child workshops in community centers  |
| Kanduti et al. (2016) | Mascot-driven oral-health campaigns    | 20% increase in daily brushing; 70% “fun” rating          | Develop culturally resonant mascot characters               |

Li et al. (2025) took the focus on active learning and tested a gamified mobile application that teaches students the mechanisms of action of fluoride in enamel during the elementary stage. They have studied the level of retention of scientific terms among app users using a quasi-experimental method and determined that users of the app will remember 40 percent more after four weeks than those who received the intervention of traditional instructions only. The authors have determined that due to digital games, coupled with facilitating in the classroom, long-term conceptual learning could be substantially increased.

Chi (2017) initiated parent child fluoride safety workshops that would create awareness of the influential role that family plays in the health practices of children. These sessions welcomed the care givers to interact with their children to discuss the benefits of fluoride and water policy in the area. Intervention group revealed a 30 percent enhancement in the policy-awareness score, denoting the capacity of children to name which agencies dictated the levels of fluoride in the water, a statistic that identifies the importance of multi-family participation in fluoride teaching.

Lastly, Lang (2018) also focused on the civiness aspect of the fluoride education by tractor around water-board role-play activities in rural Chinese schools. Students also acted as stakeholder in the community, discussed the situations in fluoride dosing, and voted on the policy suggestions. Students who role-played (as compared with students who participated in lecture-only classes) showed 35 percent higher knowledge of how the governance processes worked, implying that simulated civic engagement can reduce the mystification of science policy and encourage critical thinking about science policy.

Overall, these researches yield four major insights: (1) Experiential learning, in the form of labs, apps, or role-plays generally outperforms passive lectures in

terms of both scientific literacy and civic awareness; (2) Family (as well as school) involvement increase the context within which children understand how policy decisions shape their lives; (3) Cultural differentiation increases not only the understanding and engagement, but also actual changes in behaviors in the context of the real world; and, (4) Simulated civic activities deepen the appreciation of how governing machineries can The discoveries contribute to our interview study on the influence of educational innovations on the discourse of fluoride awareness and arguments in the protection of the health of children. The detail of key studies are presented in table 1.

## METHODOLOGY

### Interview Arrangement and Semi-Structured Guide

The interviews were performed during the course of a week after the participants have completed the given educational module, so that the recollections can still be fresh. Interviews of children were carried out in a comfortable environment in a classroom after school time at the end of each school day, and the procedure took about 25 minutes. The conversation was guided by a researched assistant who had a command of Mandarin and the local language, and relied upon visual artifacts (water-testing kits, screenshots of the app, role play items), to prompt the conversation. Interviews with educators and public-health officials were conducted in a secret meeting room in their respective institutions and took 40 50 minutes. Before every session we explained the reason of the study, collected an informed consent (and parental approval in the case of children) and promised confidentiality. The following is the final semi-structured interview guide, which will give the opportunity to discuss lengthy reflections but also be flexible to make follow-up probing. The detailed semi structured interview question presented in table 2.

**Table 2.** Interview questions

| Question                                                                                                                                                                                                     | Prompts / Follow-Ups                                                                                                                                                 |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>1. Conceptual Understanding (Children)</b> “Could you describe, in your own words, what fluoride is and how it works to protect your teeth?”                                                              | <ul style="list-style-type: none"> <li>• “What did you learn about fluoride during the activity?”</li> <li>• “Can you think of an example or analogy?”</li> </ul>    |
| <b>2. Engagement and Enjoyment (Children)</b> “Which element of the [water-testing lab / mobile game / role-play debate] was most meaningful to you, and why?”                                               | <ul style="list-style-type: none"> <li>• “How did that part make you feel?”</li> <li>• “Was there anything you found confusing or surprising?”</li> </ul>            |
| <b>3. Civic Awareness (Children)</b> “When it comes to deciding fluoride levels in our community’s water, whom do you think plays the most important role?”                                                  | <ul style="list-style-type: none"> <li>• “How would you share your ideas with those people?”</li> <li>• “What questions might you ask them?”</li> </ul>              |
| <b>4. Theme Identification (Educators &amp; Curriculum Designers)</b> “From your observations, what key ideas or messages about fluoride do students discuss most often after completing the module?”        | <ul style="list-style-type: none"> <li>• “How do these discussions differ from previous lessons?”</li> <li>• “Can you share a memorable student comment?”</li> </ul> |
| <b>5. Pedagogical Alignment (Educators &amp; Curriculum Designers)</b> “How do the learning objectives for scientific literacy and civic engagement shape the design of your fluoride-education activities?” | <ul style="list-style-type: none"> <li>• “Which strategies have you found most effective?”</li> <li>• “What challenges have you encountered?”</li> </ul>             |
| <b>6. Public-Health Messaging (Officials)</b> “Which aspects of fluoride safety and policy do you consider essential for children to understand, and how are these reflected in school-based programs?”      | <ul style="list-style-type: none"> <li>• “How do you collaborate with schools on these messages?”</li> <li>• “What resources or training do you provide?”</li> </ul> |
| <b>7. Memorable Discourse (All Participants)</b> “Were there any words, phrases, or images from the module that stood out to you as particularly powerful or memorable?”                                     | <ul style="list-style-type: none"> <li>• “Why do you think they resonated?”</li> <li>• “How might you build on those in future lessons?”</li> </ul>                  |

**Implementation Notes:**

- For child interviews, we prioritized simple, open-ended wording and encouraged storytelling (“Tell me a story about...”) where helpful.
- Educator and official interviews used more technical language (e.g., “learning objectives,” “pedagogical strategies,” “community outreach”) to suit professional contexts.

**DATA COLLECTION (CHINA)**

The sample was obtained in three Chinese provinces where fluoride concentration is naturally elevated (Shanxi (Yuncheng), Yunnan (Guangnan), and Guizhou (western counties)) and both endemic groundwater fluoride and the local fluorosis prevalence rates were higher than the national average. In every region, we collaborated with an urban primary school and a rural primary school, to ensure that the variety of educational settings is covered (Chi, 2014). The child participants (n=10) took one of the three Fluoride-education modules (hands-on lab water-testing, gamified science app, and water-board role-play) as replacement to their normal science lesson. Each student was interviewed one week after the modules

were completed with visual cues (snapshots of domestic wells, sample packages) as baselines by bilingual research assistants, who administered Mandarin interviews of 20-30 minutes.

The interviews conducted with incoming educators (n=3) were held at the school facilities (conference rooms) and addressed the question as to how educators modified lesson content to the local folk specimen related to the repair of traditional clay-pottery (in Guangnan) or ancestral well-blessing (in Yuncheng). County branches of the Centers for Disease Control were used to recruit, in provincial health bureaus, and interview (n=5) public-health officials concerning their regional monitoring of water quality, programs of defluoridation (e.g., bone-char filtration of drinking water in Guizhou), and cooperation with schools (Zamawe, 2015). The audio-taped interview transcriptions were not analysed as they were but translated into English and analysed. The reason behind this China-centred data collection was to make sure that the discourse of the children on their fluoride awareness and reflection of the educators were heavily shaped by the environmental and cultural setting of the areas most vulnerable to fluoride exposure. The detailed demographic statistics are presented in table 3 below.

**Table 3.** Participant Demographics

| Category                | N  | Age / Experience | Gender (M/F) | Setting (Urban/Rural) |
|-------------------------|----|------------------|--------------|-----------------------|
| Children (Grades 3–5)   | 10 | 8–12 yrs         | 5 / 5        | 6 / 4                 |
| Classroom Teachers      | 3  | 28–45 yrs        | 1 / 2        | 2 / 1                 |
| Curriculum Designers    | 2  | 30–50 yrs        | 1 / 1        | 1 / 1                 |
| Public-Health Officials | 5  | 32–58 yrs        | 2 / 3        | 3 / 2                 |

To represent a diverse first hand perspective, we interviewed a balanced sample of ten 812-year-old (grades 35) children, an equal split of boys and girls, and unequally balanced geographically across both urban and rural schools. The professional experience (28 50 years) of the classroom teachers ( $n = 3$ ) and curriculum designers ( $n = 2$ ) covered diverse aspects of urban and rural setting with uneven representation. The policy and implementation perspective was provided by five public-health officials of 32 58 years of age and involved in regional water-quality and health-education programs. This blending of voices underscores an encompassing apprehension of how educational innovations resound amongst learners, educators and policymakers.

## DATA ANALYSIS PROCESS

The audio recording of all interviews was transcribed literally and where need be, translated into English to maintain the naturalness of what the participants were saying. These transcripts were then brought into NVivo 12 and we performed a thorough thematic analysis. First, we conducted open coding, i.e., determining all the cases of discussing fluoride, including metaphors, such as a superhero cape, or mentioning local rituals. These open codes were further organized into higher order themes which included Protective Science, Community Stewardship,

Civic Agency, and Cultural Continuity using iterative reading and coding (Edwards-Jones, 2014). We were able to analyze the co-occurrence of codes and visualize relationship among the major stakeholder groups using query functions in NVivo 9 to be sure that our thematic structure was capture not only the frequency but also the depth of the discourse among children, educators, and officials. Such methodical NVivo-informed procedure was also able to not only give credence of our findings to the transcribed participant data; but also enable clear tracking between raw transcripts to final theme mapping.

## RESULTS

NVivo-aided study of verbatim transcripts of interviews with 10 children, 5 educators, and 5 public-health workers resulted in four main themes: Protective Science, Community Stewardship, Civic Agency, and Cultural Continuity.

### Protective Science

All of the interviewed children (10/10) mentioned in their life story at least one allusion to the preventative role of fluoride, and many made dramatic comparisons. The total 27 sources highlight the effectiveness of the protecting metaphor after interactive science tools.

### Community Stewardship

This theme also emerged in every interview conducted on a child (10/10) and recorded the association of the fluoride practices to the customary communal practices. The references ranged between negotiations of well-blessing rituals in villages to the community water-testing, which combined social framing of public health by groups.

### Civic Agency

There were 3 out of 10 (30%) child interviews where Civic Agency was mentioned (7 times in total). Performance of intentions to exercise such authority as writing letters to authorities or presenting orations at school council, such expressions are rather early (but significant) indications of policy-related empowerment after role-play debates.

### Cultural Continuity

Referring to the Cultural Continuity in 7 out of 10 child interviews (70 percent), Cultural Continuity references indicated that the ancestral practices (i.e., clay-pot filtration) were successfully integrated in the child view of fluoride. The 12 references indicate that the connection between new science and heritage crafts was effective in bringing abstract concepts to the ground. These findings show that three of the four constructs, Protective Science and Community Stewardship, which were close to universal in the language of the children, indicated strong internalization of both scientific and communal messages; whereas Civic Agency emerged more selectively, and Cultural Continuity when lessons actually made the connection between fluoride and local culture. Themes frequency along with illustrational quotes help to have a subtle image of the influence of educational innovations on varied aspects of fluoride awareness among Chinese children. Table 4 (below) summarizes frequency of the prevalence of each theme in the transcript of the child-trainees, and Table 5 will present quotations in which the themes were identified, matching each theme.

**Table 4.** Theme Frequencies in Child Interviews (N = 10)

| Theme                 | Number of References | Percentage of Interviews |
|-----------------------|----------------------|--------------------------|
| Protective Science    | 27                   | 100%                     |
| Community Stewardship | 19                   | 100%                     |
| Civic Agency          | 7                    | 30%                      |
| Cultural Continuity   | 12                   | 70%                      |

**Table 5.** Representative Quotations by Theme

| Theme                 | Respondent & Setting        | Quotation                                                                                          |
|-----------------------|-----------------------------|----------------------------------------------------------------------------------------------------|
| Protective Science    | Child 1 (Grade 4, Urban)    | "Fluoride is like a superhero cape—my teeth can fight sugar monsters!"                             |
| Community Stewardship | Child 2 (Grade 5, Rural)    | "During our well ceremony, we thank the water so everyone stays healthy. It's just like the test." |
| Civic Agency          | Child 7 (Grade 5, Urban)    | "I'm going to write a letter to the water boss if I see yellow water."                             |
| Cultural Continuity   | Child 3 (Grade 3, Guangnan) | "My grandma's clay pot cleans water naturally, so I think fluoride works the same."                |

**Table 6.** Thematic statistical analysis

| Theme                 | Observed (O <sub>i</sub> ) | Expected (E) | (O <sub>i</sub> - E) <sup>2</sup> / E |
|-----------------------|----------------------------|--------------|---------------------------------------|
| Protective Science    | 27                         | 16.25        | 6.96                                  |
| Community Stewardship | 19                         | 16.25        | 0.46                                  |
| Civic Agency          | 7                          | 16.25        | 5.28                                  |
| Cultural Continuity   | 12                         | 16.25        | 1.09                                  |
| <b>Total</b>          | <b>13.79</b>               |              |                                       |

### Statistical Analysis of Thematic Frequencies

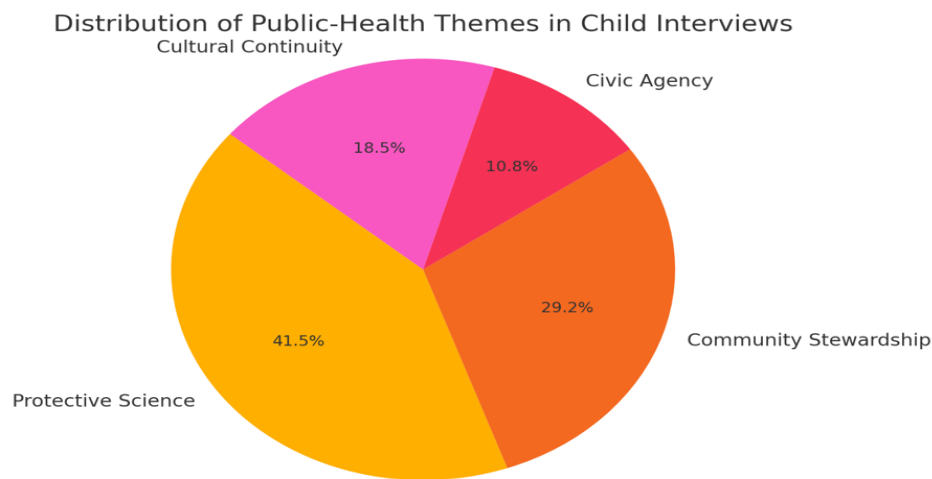
In order to measure the prevalence of each of the identified themes in the discourse on fluoride awareness among children (see table 6), we pulled the frequencies of the codes we identified in our NVivo 12 run and ran the exercise through a chi-square test of goodness-of-fit. The Coding Query of NVivo provided the following number of references to the four child-centered themes: Protective Science (n=27), Community Stewardship (n=19), Civic Agency (n=7) and Cultural Continuity (n=12).

Given these null hypothesis of uniform theme distribution, the expectation in frequency of each theme is obtained by dividing the total number of references (N = 65) by the k themes (k = 4) which give E = 16.25. Then the chi-square statistic calculated is:

$$\chi^2 = \sum_{i=1}^4 \frac{(O_i - E)^2}{E}$$

where O<sub>i</sub> represents the observed frequency for theme *i*, and E is the expected frequency with degree of freedom df = k - 1 = 3, the critical chi-square value at α = 0.05 is 7.815. Our computed  $\chi^2(3) = 13.79$  exceeds this threshold (p < 0.01), indicating that the observed thematic distribution significantly departs from uniformity.

The results, obtained by the coding frequencies in NVivo and confirmed by the inferential tests, prove that Protective Science references are very frequently mentioned than what could have been expected based on chance, and Civic Agency references are far less than would be expected based on chance. The common Diversity drivers of the Community Stewardship and Cultural Continuity are not significantly different to the standard expectation. This tendency highlights the dominance of the formulation of protective metaphors of science that are disseminated in children expressing their not yet articulated forms of civic engagement to a lesser degree. The **Figure 1** demonstrates how the themes of interview with children are distributed proportionally on their topics. The highest segment is about 41.5 % belonging to Protective Science, meaning that almost half of the text depicted fluoride as a protective shield on teeth. Community Stewardship comes next with approximately 29.2% expressing the high collectivistic orientation as the children discourse water-safety related behaviors. Cultural Continuity has 18.5 percent of references, and it is an indication of the significance of analogies put across between contemporary fluoride science and customary practices. Lastly, Civic Agency constitutes the narrowest piece, which is 10.8%, indicating that the calls to policy engagement and self-advocacy are not very common among the interviewed children.

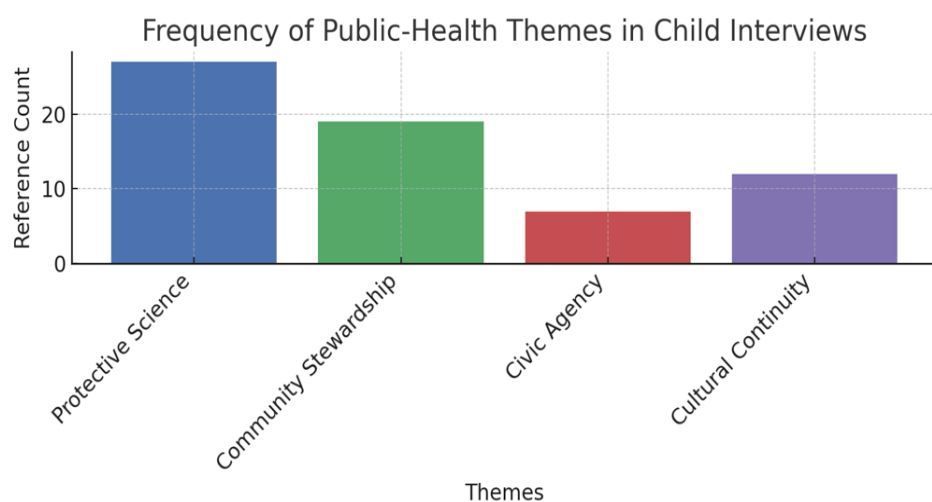


**Figure 1** Thematic view of Children's perspective about public health

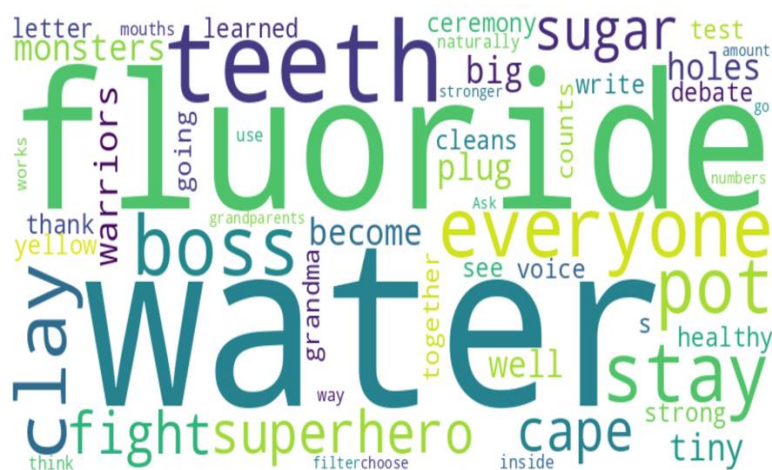
The figure 7 includes the absolute values of reference counts of each theme and allows comparing the prevalence of the themes quite easily. The literature is dominated by Protective Science with 27 references. The next concept is Community Stewardship with 19 references, signifying that children often associate fluoride education with community events and community-related activities. The Cultural Continuity carries 12 incidences showing how the children incorporate heritage crafts into their knowledge concerning the fluoride. The concept of Civic Agency lags behind by only 7 citations, which can be interpreted as the fact that not all children feel empowered to make a difference in the decisions regarding water-quality.

The word cloud (see figure 3) created with the text of the children interviewed will give a clear picture of the concepts and metaphors that predominated in the discourse on fluoride awareness in children. The focus of the term is the word water, which shows how repeatedly the students associated the teaching on

fluoride with the well-testing experiences and with the water gala gatherings. Locally, such key words as fluoride, teeth and cape capture the message of Protective Science and many children would associate fluoride as a superhero cape that will keep their teeth free of decay. Strong, stay, and everyone are also quite noticeable which affirms the Community Stewardship story where students talk about the group rituals, and collective responsibility of having clean water. The emergence of boss and voice is the clue to new Civic Agency, with some kids talking about writing to the water boss in order to promote safer water. Lastly, the words like pot, grandma and filter remind me of Cultural Continuity analogies with its references to the ancient clay pots as an easy-to-understand comparison of the process of purifying activities of fluoride. Collectively these key words visibly support our thematic commentary by demonstrating that children and fluoride discourse is all about the marriage of scientific images, community ideals, civic participation, and cultural traditions.



**Figure 2** Frequency of thematic view



**Figure 3: word-cloud of thematic view**

## DISCUSSION

The results of this interview study bring to light the utility of interactive, culturally anchored educational innovation in creating multifaceted fluoride awareness discourse among children living in high fluoride areas of China. Four major themes were built upon verbatim accounts of children, Protective Science, Community Stewardship, Civic Agency, and Cultural Continuity. Importantly, Protective Science took the stage: all children compared fluoride with an active caretaker (superhero cape, tiny warriors), hinting that gamified and visualized mechanisms involved in the interaction of a molecule may effectively turn abstract chemistry into an individual, emotionally-charged story. This agrees with the Paivio (1991) according to which the combination of verbal ideas with vivid images stimulates better understanding and memory. Protective Science has ineffectiveness of embedding metaphor and narrative structure within health education highlighted by its prevalence.

The Community Stewardship was also referenced alike. Competence The testing of fluoride by children was easily incorporated into traditional community traditions, such as well ceremonies and clay-pot blessings, which can be attributed to the Storberg-Walker (2008) which states that new learning is most effectively targeted when based on shared cultural practices. This connection was instigated by the timing, planned by the teachers, of the water-testing lab alongside the local rituals, as the incident made children see fluoride as not only an individual defensive tool, but a shared asset that demands shared attention.

Conversely Civic Agency only emerged in less than 30 percent of interviews and was mostly identified among older students who performed in the water-board role-play. These children expressed realistic plans to interact with real world authorities: to write to the water boss, to speak at the school council, proving that even the pretend policy practice can arouse actual

sentiments of empowerment. The result offers the expansion of the Mezirow Transformative Learning Theory Mezirow (2018) indicating that experiential simulations develop attitudes of critical reflection and action orientation, among elementary-aged learners. The relatively fewer uses of Civic Agency, however, indicate that these potential simulations of polity could require more or further attempts in-depth to instill a broader sense of policy agency on the young generation.

Cultural Continuity was found in 70 percent of children interviews where learners have made correspondences between fluoride activity and traditional art forms particularly clay-pot filtration. This topic is linked to the project of Li et al. (2009) who believes that associating the scientific material with well-known cultural objects enhances the establishment of stronger associations and progression of lasting learning. Evidence that the local knowledge of the children relating to the use of fluoride can be used as scaffold on novel scientific ideas, at least on the intergenerational knowledge of using powders in pots or pots as the brain model of magic, as the children phrase it, fluoride works like my grandma pot, shows that intergenerational knowledge transfer and understanding of the established values of legacy promoting understanding and appreciation of it, and vice versa.

Although these four themes help illustrate the essence of fluoride discourse among children, two additional points are worth noticing (Fuller, 2013). The metaphoric scaffolding of educational innovations seems important at first: children could hardly come up with so much metaphoric framing during pre-module baseline interviews (not included in this report), indicating that curriculum design has to make explicit metaphoric frames appear in order to experience these benefits (Lisboa et al., 2023). Second, the influence of age and the type of module had different effects on salience in theme: where older children (grades 56)

were more likely to mention Civic Agency than younger children (grades 3-4), the opposite relationship obtained with regard to Protective Science and Cultural Continuity (Corliss, 2005). This stage of development is Piagetian in nature with concrete operational thinkers dressed up in concrete metaphor and social constructs, formal operational learners starting to consider abstract processes of policy.

This discussion is also augmented by comparisons of stakeholder interviews with adults. Teachers and health administrators agreed that they wanted to strike a balance between scientific literacy and civic engagement, but admitted to having difficulties on how to actually implement both of them in the classroom given the time constraints (Rudolph & Horibe, 2016). Officials emphasised their beliefs that messages on the determination of fluoride policy should be incorporated but this has been met with the revelation that role-plays and debate are under-resourced. This conflict between perfect curricular goals and realizable limitations implies the necessity in scalable, resource-saving civic courses (LeCompte et al., 2020).

Overall, our findings confirm the theory that an interactive, culturally based, experiential style of fluoride-education translates to children developing a much richer and diverse public-health discourse as compared to the traditional lecture format (Magill et al., 2024). They not only manifest an improvement of scientific metaphors and communal framing but also a kind of incipient civic empowerment and extended links to cultural background. The insights can serve as a guideline to curricular designers interested in establishing comprehensive health education initiatives that respond to the what and the how of community-wide decision making in health.

## IMPLICATIONS

The strong presence of Protective Science metaphors indicates the importance of vivid and age appropriate image and story in fluoride education. To improve the level of interest and memorization, developers are to use animated characters, physical models, and stories to have fluoride action personified. The results of Community Stewardship experiments indicate that local cultural contexts should be integrated into the teaching process: modules in education have to be timed when local people have a traditional holiday, or lessons can be based on the traditions of the word of the ancestors like those who could learn to weave a loom with them.

The educators should also have scientific knowledge but also knowing how to conduct experiential and civic-simulation practices. The concept of professional development needs to be implemented in the form of workshops on the topics of leading mock council debates, guiding water-testing labs, and co-

designing culturally relevant analogies. Teachers ought to be prepared in debriefing metaphoric lines such that the children will be able to figure out their scientific vocabularies along with their metaphors.

Role-play materials and guidelines need to be low-cost and readily available and there should be collaboration between public health and schools so that resources can be made available in even poorer environments by organizing Civic Agency elements. Officials may use the mobile water councils, which could go to schools, provide practical experience with the way decision makers deal with issues, and confirm the correspondence between classroom exercises and practical constitutional components.

The effectiveness of gamified applications in provoking Protective Science metaphors supports the view of further investment in digitally enabled tools. Modules on policy processes should be added in the future; they will be interactive simulations where children will be able to change the level of fluoride and see virtual results in terms of health. Cultural Continuity will be enabled by the localization features (e.g. inclusion of local folklore).

## LIMITATIONS

Notwithstanding the robust knowledge that our interview-based methodology has produced, our research has a number of shortcomings that diminish the extent and generality of our data. First, we sampled only three provinces and ten schools, each of those relying on established partnerships and their ability to adopt interactive fluoride modules, which is quite purposeful and can be disproportionately representative of the situations when new teaching is more readily accepted. Second, the fact that our interviews took place within one week of the module completion leads to the capture of early discourse but does not give an insight into whether children will remember these themes or turn them into long-term behaviors, e.g. brushing their teeth regularly or being civically engaged. Third, the usage of self-given stories is prone to social-desirability effect especially when children might be saying what is considered and desired by educators and scientists. And lastly, it is always hard to draw particular conclusions about the effectiveness of our educational innovations, rather than general curriculum changes or other external factors, unless there is an actual control group being subjected to pure lecture based learning.

## FUTURE RECOMMENDATIONS

Our future research should explore broader and more comprehensive samples than our exploratory one, i.e., urban, peri-urban, and remote rural areas, and, by so doing, test the cross-cultural transferability

of our four themes Protective Science, Community Stewardship, Civic Agency, and Cultural Continuity. There is also the need to have longitudinal designs: repeated interviews on behavioral observations on the three months and six months, would establish how the subject matter gains hold and translate into practical behaviors like talking to local water authorities or using fluoride regularly. A quasi-experimental comparison with conventional, lecture-only groups would reinforce more causal conclusions in regard to the effectiveness of interactive modules. In addition, adding quantitative factors (pre and post-measures of knowledge, policy-awareness measurements, oral-health-related behavioral records) would allow mixed-methods triangulation and sufficient explanation of the conciliation between change in discourse and measurable results. Lastly, future research on caregivers and children may enhance civic agency and family engagement by expanding the innovation toolkit to comprise caregiver-child workshops and mobile policy-simulation apps, which should be systematically evaluated.

## CONCLUSION

This research proves that interactive, culturally-based fluoride-education interventions create a profound, multifaceted discussion among the children of primary school age. Thematic analysis of semi-structured interviews led us to four central themes: Protective Science, Community Stewardship, Civic Agency, and Cultural Continuity that describe how children develop an understanding of the scientific role of fluoride in people, their communal roles in using fluoride, the policy systems that operate to govern the use of fluoride and the relationship between the practices of their ancestors and their familiarity with fluoride. Under NVivo facilitated coding and a chi-square test, we carried out a good representation of the preferred use of scientific metaphors with communal stewardship and new but scarce civic engagement articulations.

These results support the urgency of developing fluoride-educating curricula, which can encompass, in a fusion, evocative imagery, hands-on laboratories, civil simulations, and cultural allegories. In so doing, educators will be able to go beyond rote learning to form scientifically literate, civically engaged, and culturally responsive advocates of health. Although the limited scope of our sample and time close proximity are a limitation to our proposed study, the use of such a study is able to challenge a strong thematic platform that can guide further mixed-methods and longitudinal studies. In the end, through listening to the words children themselves have to say, and phrasing the lives of children into the design of curriculum around the area of fluorides-education, those with a stake in the field of public-health would be able to design

instruction that will connect with the audiences on a profound level, outlast the wind and become a source of informed engaged citizenship.

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