DISHA: Multiple Mice in Narrative Content-based Computer Aided Learning for Children

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In this paper we evaluate immediate learning and retention among primary school children aged 10-12 across four separate instruction mediums - multiple-user-multiple-mice PC, multiple-user-single-mouse PC, video and narration. The work thus far addresses the usage scenarios and design interfaces for MultiMouse. Here, we do a real world proof of concept using a MultiMouse application tailored for a standard school setting in developing regions. The experiment was conducted on 68 primary school children on malaria learning. Overall, immediate learning was found to be relatively same in both the PC scenarios and the video. However, the retention level after a week dropped considerably for the video case. This suggests the value of interactive games while employing multiple-input shared designs. In addition, seating position effects were found where, in contrast to previous studies the leftmost child performed better.

Single Display Groupware, Shared Computers, Education, Multiple Mice, Developing Nations.

1. INTRODUCTION

MultiPoint technology [23] enables multiple mice connected to a single machine to interact on a single screen. The initial motivation behind this arose from the observation that in resource-constrained environments, multiple users share a single machine, particularly in school education environments in developing regions. Such shared usage generally skews the learning and interaction benefits to a single child. MultiPoint allows equal opportunity of engagement for multiple children sitting on a single computer. The immediate next step was to explore its learning benefits through impact on engagement and collaboration [19,24] over shared mouse scenarios. This entailed studying the design of user interfaces for MultiPoint applications [19,21,22].

Through these studies, we have some evidence of what multiple input modes are good for, and potentially how to best design interfaces for these. What has been lacking thus far is a study on a real world replacement of a single-input computer aided learning module design with a multiple-input option to understand what potential if any such technologies actually hold within learning, and accordingly where we need to focus on design hereafter. Our research goal aimed at finding out whether employing multiple mouse applications in schools yield significantly successful learning outcomes, which would warrant the use of this technology on a mass scale. Consequently, it was required to find out if such applications yielded significantly better learning outcomes (immediate learning and retention) in comparison to other instruction mediums prevalent in the developing regions. This is different from the previous quantitative study [24] which looked at comparisons of collaborative and competitive immediate learning in multiple-user-multiple-mice mode and multiple-user-single-mouse mode using a simple test application.

On the basis of proven design principles we designed a MultiPoint application named DISHA and conducted an experiment on 68 primary school children comparing their learning and retention across four different instruction mediums and found results which give a perspective into the approach to be taken when deploying such learning applications. The next sections describe the related work, experiment methodology, experiment and the results.

2. RELATED WORK

Work on shared computers and input for education is rooted in design and collaboration work in a range of areas from shared editing on single screens [4], on single-display groupware [26], and on turn-taking using multiple input devices on a single machine [12]. Till the early 2000s, the work in this space was primarily oriented towards exploring the benefits of collaboration, both in how children could use computer sharing and in creative data representation and co-editing techniques [25,27,7]. A more recent increase in research on multiple concurrently active input devices for single machines [23,8,10,14] has been driven by the documented ubiquity of computer-sharing in schools due to resource shortages in much of the developing world [22]. This recent work in the multiple input space has shown evidence of learning gains over single keyboard or mouse use in shared scenarios [24] as

Proceedings of IDID 2010

well as changed patterns of engagement in such scenarios that require designers to account for collaboration in the design of such applications [19].

In the space of Computer-Aided Learning (CAL) applications for children in developing regions, the work is quite limited. Azim Premji Foundation (APF), an NGO dedicated to the cause of universal education has created CAL applications [2] for primary school children on various subjects. These applications enable the children to learn while playing games and are widely used across various schools in India.

3. EXPERIMENT METHODOLOGY

As described by Katsioloudis [15], the learning outcomes of a visual-based learning material depend on multiple factors. Our goal in this project was to design learning content that could be used in a controlled experiment to measure the effectiveness of multiple-input scenarios. Our constraints were:

- The learning content should be contextually relevant.
- The content should be relatively new, so as to avoid evaluation bias based on students' past knowledge.
- The experimental design should include as many relevant learning modes, both with and without a technological intervention.
- The learning content should be exactly the same across all instruction mediums.
- The Novelty Effect for initial improvement related to new technology should be minimal [17].
- The evaluation tests should test learning, independent of any instruction medium-dependency.

3.1 Software Application Design

Previous work [21] has shown that children respond well to interactive visual content as opposed to explicit instructional content. Our application is based on the design methodology of the widely used computer aided learning content of Azim Premji Foundation (APF) [2]. Such content follows a standard narrative-interactive loop format of some material shown on screen followed by a multiple choice Q/A, which is possibly the most popular means of children's software. These games have a high tendency to fall prey to the random-lucky clicking by the students, where students not knowing the answers resort to random clicking and eventually get it right. We tried to minimize this problem by devising games which are closer to what we normally perceive as games rather than MCQs. Besides this, the games bear most of the effective CAL characteristics such as performance points, negative feedback ("Sorry! Try again"), positive reinforcement ("Congrats! It's right"). As previously noted [16], students in developing regions are more accustomed to reading than listening to English, so Same Language Subtitling (SLS) is included (Figure 1). Like previous works [21, 24], color coded mouse pointers are used to enable distinction among players. DISHA implements personalized scoring through *healthlines*, which displays the performance-based current health (score) of a user. The goal based progression thus achieved works towards building up and retaining student interest.

For the learning material, we sought content which came in the context of their learning, but was not so common that some children already know about it significantly. We decided on the disease Malaria – partly because the children have heard of the disease in day to day conversations, but there are many misconceptions floating around (especially for the students who have not yet studied it in their academic courses.) Also, no CAL application in our knowledge addressed the issue of diseases like malaria directly, though general health and hygiene issues were handled. The application was titled DISHA – **Dis**ease and **H**ealth **A**wareness.

As mentioned before, DISHA follows an approach where instruction on a part of the content is covered through a conversation based animation story on-screen called storyline. This is followed by an interactive game to reinforce the same content. Overall, there are 3 storylines followed by a multiple mice enabled game each; each of which covers the cause-spread, symptoms and preventive measures of malaria respectively. All the games support multiple mice, ranging from one to five at a time and hence support a single mouse configuration implicitly. These games are described below.

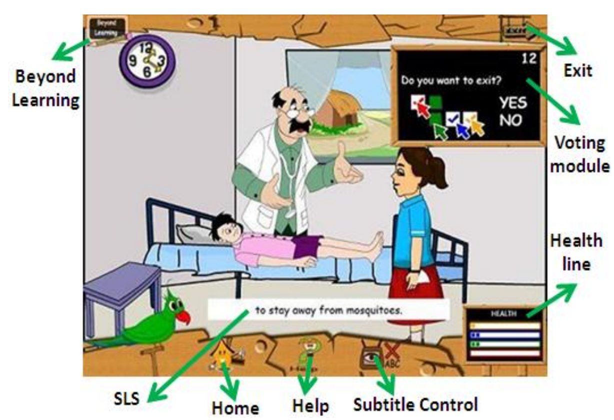

Figure 1: *The interface elements in DISHA during a storyline*

Game1 (Figure 2): This game follows after the symptom storyline to reinforce the concepts. For a multi-mouse scenario it implements the turn-taking model. The game play is based on the *card memory game*, with 12 cards appearing on the screen. Each card hides either a name or an image referring to a malaria symptom. In a round robin fashion (with a bulb showing whose chance it is), each player opens (clicks) two cards at a time, and needs to match a symptom's image with its corresponding name to get the correct answer.

Figure 2: *A Screenshot of Game1 in DISHA*

[21] emphasizes that turn-taking model suffers from a limitation of decreased engagement among the non-active students; but here these students need to remain active and see and retain the cards' position and content when the other players are playing. The game stresses on the fact that establishing connections between visual and verbal representations of a system results in meaningful learning [18]. Preliminary tests showed that children tend to help each other out during the game, though they were being individually scored.

Game2 (Figure 3): It follows after the prevention storyline and is based on a shared screen collaborative model. The students need to fill in the blank, by rearranging the letters and forming a word. The students have to drag the letters in the colored blanks provided; each color represents the corresponding player who has to fill it in. Collaboration is enforced as each child is given one or more blanks to fill; so they have to figure out collaboratively which letter goes into which blank. Even if one child gets his blank wrong everyone has to repeat the exercise, which forces them to work together.

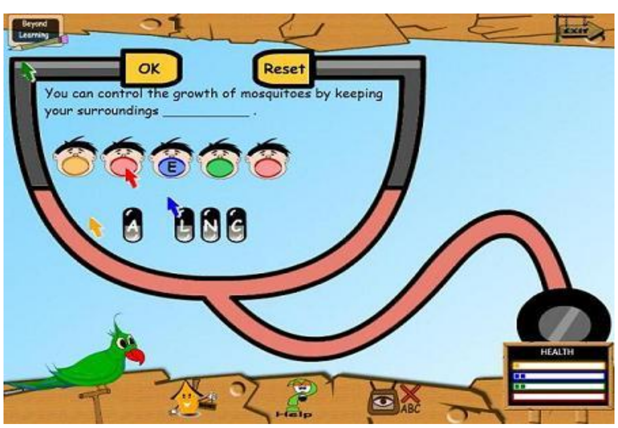

Figure 3: *A Screenshot of Game2 in DISHA*

Game3 (Figure 4): It is the last game which revises the concepts learnt through a shared screen brick falling game. Labeled and colored bricks keep falling and each player has to collect their corresponding bricks into a basket which conforms to the label. Players use arrow buttons to move the bricks around. If a player drops a brick into the wrong basket, the brick falls again and again until the player gets it right.

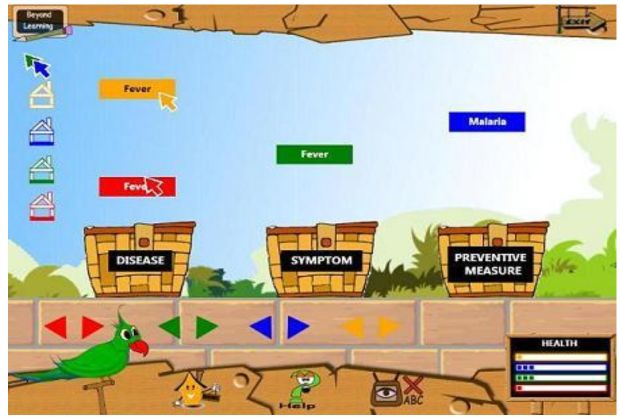

Figure 4: *A Screenshot of Game3 in DISHA*

It is clear that the games differ in their design models – turn taking/collaboration/racing. This was primarily done so as to remove any sort of monotony that might arise while playing the same kind of game repeatedly. Also, it was conjectured that this would boost retention as different games will lead the children to remember each aspect of the disease differently and hence later, they would be able to distinguish among them.

3.2 Evaluation Method Design

The primary goal was to evaluate the students' learning through a MultiMouse instruction medium and compare it across other instruction mediums. The aim was to see how the interactive learning games affected a student's learning. We decided upon three separate mediums on account of their comparative value against MultiMouse and the frequency and ubiquity with which they were being employed in schools (in the context of developing regions) – SingleMouse (Multiple children sharing a mouse and playing the game); Video (A group of children watching a video on a big screen.); No-Visual Narration (A group of children was narrated the learning material.) And finally, we kept a no intervention to group to validate if the children had any significant external factors affecting their learning outcomes while the experiment was being conducted.

To ensure that the learning material to which the students were being exposed was semantically equivalent, the content for all the instruction mediums was derived from DISHA. For SingleMouse, DISHA itself was used, albeit with only a single connected mouse. For the Video, a film of the storylines in DISHA was created. Since the games simply reinforced the content of the storylines, the video content was equivalent to that of DISHA. For the No-Visual Classroom, a narration of the same content was given. In this case, it was particularly essential that while someone was narrating the content the resultant effect of a human intervention remains minimal to keep the results meaningful; consequently the instructor did not indulge in any interactive activities with the students.

Learning outcomes in our case refer to the factual learning that occurred during the intervention. Though, it would be interesting to observe if affective learning [5] took place wherein students actually take the necessary steps to keep away from malaria after the instruction such as asking their parents to get a mosquito net, not allowing dirty water to collect etc. Affective learning is when the learning leads to a growth in attitudes and feelings; when the learning exerts an influence over the behaviour of the student. Quantifiably, learning refers to the difference in knowledge before and after a certain treatment and therefore a paper based Pre-Post test methodology was adopted to ascertain the factual learning outcomes of each of the mediums.

Figure 5: *Students giving a Post-Test. Notice, a student hiding his sheet using the notebook.*

An immediate Post-test was scheduled to test and compare *immediate learning*. A surprise retention test was scheduled one week after the intervention to test and compare the *retention* amongst students across mediums.

Evaluation tests were decided to consist of MCQs based on the content to yield empirical, verifiable statistics. All the three evaluation tests namely Pre-test, Post-test and Surprise test consisted of the same MCQs with the same options, to effectively compare the three results against each other. Notably, the options in the Surprise test were jumbled up after the Post test, so as to prevent the results from getting influenced by students getting the answer correct not because they remember the answer, but because they remember the corresponding option number.

For the experiment to yield results usable in the real world scenario, we specified a set of criteria for selecting the right student population:

- The students should have a basic understanding of English as the application supported English.
- The students should be such that they have not been introduced to malaria in their academic curriculum to avoid conflicting content, if any.
- The students should be reasonably sensitized to the usage of computers and mice, so as to keep the novelty effect of the intervention low.

The set of students we selected were 4th grade students, aged 10-12 years from an English medium school, which conducted two computer classes weekly.

3.2 Preliminary Test Run

Before the final experiment was conducted, we conducted a test run, which helped us define several parameters for the final experiment and pointed us towards variables that need to be controlled to get the most accurate results. Following are some of the observations –

- We noted that all the students were able to complete the tests within a duration of 10 minutes.
- The single-gender groups were collaborating the most effectively.
- While the tests were taking place, the teacher left the class for a minute and the students started shifting from their seats, trying to look into others' sheets. This prompted us to have a mandatory teacher presence during our intervention.

Besides this, significant changes were made in the questionnaires to remove ambiguity from the questions and make the language simple and understandable.

4. EXPERIMENT

The experiment was conducted over a span of two days in the school. The computer classes in school sometimes consisted of CAL applications previously mentioned [2] which helped reduce the novelty effect among students. 68 students from the two sections of 4th grade – 4A and 4B were selected to be part of the experiment. 4th grade was selected as in the school's academic curriculum the introduction to diseases such as malaria is covered in the 5th standard syllabus. Collectively, the two classes were divided into five groups, each pertaining to a different instruction medium.

We asked the class teachers of the respective grades to randomly divide the students into groups so as to ensure that every group is balanced mix of high- and low-achiever students. This was done to remove the possibility of any discrepancies in the results due to imbalanced allocation of students, if a complete random selection was made. Importantly, the teachers were *not* told which group will be exposed to which form of instruction, to remain free of any biases.

Figure 6: *DSM Mode - Notice the proximity between the mouse and the hands of right and centre kids as the left one watches*

The number of students in each of the groups could not be made uniform because of practical constraints such as the lab and video room capacity. Moreover, it would have created an unnecessary disturbance in the school's regular studies if other measures would have been tried. Also, the duration of each of the instruction sessions could not be made the same as it depended on how much time the students take to play a game. But the learning content for all the sessions was kept strictly the same.

A paper based pre-test and a post-test were administered in the classrooms immediately before and after the instruction session respectively. Surprise test was administered one week after the intervention. A person to oversee the test sessions was present at all times, in addition to the teacher. The teacher's presence was important so as to maintain seriousness amongst the students and ensuring that no cheating takes place. The tests consisted of 10 MCQs, for which a time of 10 minutes was given, based on the previous test run. We shall now describe each instruction session individually:-

DISHA–MultiMouse (DMM): The session was conducted in the school computer lab with 18 children, where the equipment and the software were setup and a person was present to get the children started and monitor the session. The setup was tried and tested once before to prevent any malfunction during the instruction session. Six groups each with 3 children sat on six computers with every child having a mouse of his/her own and played DISHA. All groups were single-gender groups, which have been evidenced to be more effective in earlier works [1,11] and which was also an observation in our prior test run. Each group was randomly assigned 3 boys or 3 girls considering that 3 has been shown to be a good grouping criterion [28] and the fact that with more than 3 children on a single screen, it is difficult for the kids at the edges to sit and see the screen comfortably.

DISHA–Video (DV): 15 children sat in front (but at a distance) of a large LCD screen and watched the video in a video room. A person to initiate and monitor the session was present.

DISHA–SingleMouse (DSM): This session was again conducted in the computer lab with 14 children with a setting similar to DMM; the difference being that here there were four groups of 3 and one group of 2 children. The 3 children in a group shared a single mouse amongst themselves while playing DISHA. The mouse was kept in the central-right position with respect to the screen, which is normally the case in such labs. Note that, the children came in the lab randomly, but one by one and hence did not get to choose their seat. This was done purposely so as to prevent a high achiever (and usually dominating) child from taking the centre seat on a computer, as was shown to be the trend previously [22].

No–Visual Narration (NVN): 12 children sat in a classroom and were narrated the content about Malaria which was taken from the application. The narration was performed by a person from our team, so as to ensure a slow and steady flow and have no interactions with the children to minimize human impact.

No-Interaction (NI): This group was the smallest one with 9 children and was sent to play games, while the other instruction sessions were going on. It was necessary that the results are not affected by any external factors (such as the teacher telling the students about malaria) during the intervention period from the pre tests to the retention tests. The NI group was kept so that if the students' performance would have been found to be escalated in the later tests, it will clearly indicate the involvement of an external factor and the results would not have been empirically sound.

Immediate learning is measured by the percentage difference in the pre and post-test scores. Retention is measured by the percentage difference in the post-test and surprise test scores. While going through the surprise test scores, we noticed some questions where the students had responded wrongly to it in the post-test, but correctly in the surprise test. We inferred two reasons for it: a) These were lucky guesses or b) The students gained the knowledge from external elements (home/teacher/peers). Since our focused objective was to test only the recall value of the instruction mediums, we eliminated the points of such responses from our analysis to get as exact results as possible.

5. RESULTS

5.1 Immediate Learning

We determined that the type of instruction session given to the students did have a significant effect on the immediate learning outcomes (Figure 7(a) of the students (χ^2(4, N= 68) =0.00078, p<0.05). T-tests with alpha 0.05 were used to determine if the immediate learning of each group was statistically significant. We observed significant learning in the groups DV (t(28)=2.04, p=0.02<0.05), DMM (t(34) =2.03, p=0.02<0.05) and DSM (t(26)=2.05, p=0.04 < 0.05); while the NVN and NI groups do not reflect significant change. The poor performance of NI group assured the non-existence of any external factor affecting learning. The difference between the learning in DV and DMM is noticeable, but its significance is not reflected in the statistics. This finding is somewhat contrary to the belief that interactive games serve as better learning tools than plain visuals. A possible rationalization to this can be that though student involvement is very high while playing interactive games (from [22] and our own qualitative observations), their focus of attention gets consumed by the play element in the games rather than the content – a case of medium obscuring the message. It would be interesting to see if similar results are obtained for MCQ based games in a similar setting.

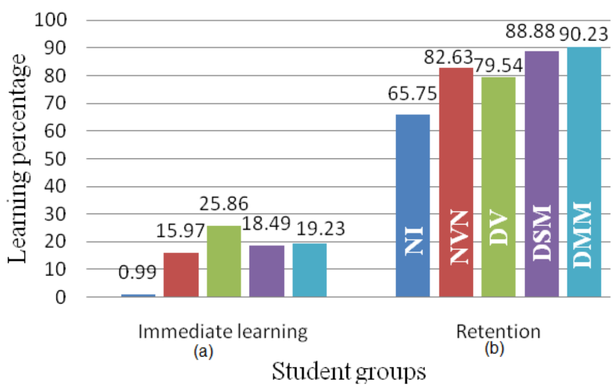

Figure 7: *(a) Immediate Learning (b) Retention across groups*

Learning in DSM comes out to be similar to DMM, which at the first glance can be attributed to the fact that children work well in single-gender groups of 3, even in the shared mouse scenario. But looking closely into the DSM case, we found that this outcome was entirely due to the high performance of students sitting on the left among the 3. (Figure 8(a)). We found a moderate correlation (r(10)=0.42, p=0.17) between the immediate learning and the sitting position of the students which indicates that as we go from a student seated left to a student seated right, there is a drop in learning. The unusual thing here was that in every computer setup in the DSM group, the mouse was at the central-right position and as a result the left child was the least actively involved in the game-play. To some extent, the situation of the left child mirrored the situation of a student watching the video which we suspect is the reason for their high performance. The learning of the central and right positioned children is even below the NVN group, showing that in the single mouse shared scenario even if two children are sharing a mouse, the learning is considerably affected.

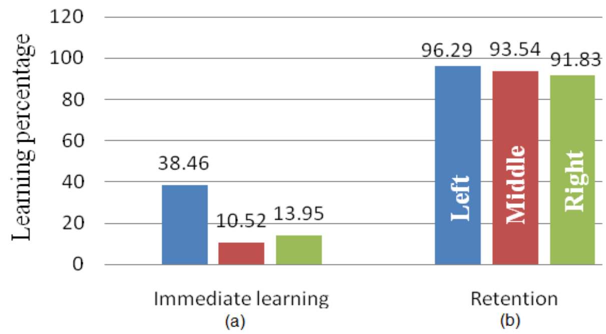

Figure 8: *(a) Immediate Learning and (b) Retention in the DSM group with respect to the student seating position*

Notably, no correlation has been observed in the seating position for the DMM group. The results for NVN conform to the existing idea that it is easier to process visual information more readily than auditory information [3]. Also, no significant variance was observed in the responses to questions based on different games.

5.2 Retention

Remarkably, the retention (Figure 7(b)) of the DV group came out to be significantly lower than the DMM and DSM groups. The t–tests between DV and DMM yielded (t (28)= 2.04, p=0.03< 0.05); between DV and DSM (t (23) = 2.06, p=0.04<0.05). This meant that even if the immediate learning with the interactive games was similar to the video (arguably less), the students retained most of what they learnt; while in the DV case the retention was considerably low. Even in DSM case, there was no difference in retention relative to the seating position (Figure 8(b)). This clearly indicates the effect of the games designed, on the recall value. We suspect this might be due to the different games helping build different contexts in a student's mind for remembering each concept. Hence designing such games might be an effective practice in such scenarios. This also conforms to Grabe's assertion that high levels of sensory simulation are associated with better retention [9].

Finally, on computing the overall learning of the groups, which is a difference between surprise and pre-test scores, DMM emerged as the group with the maximum learning gain, but these figures were not significant. This points towards the need to study the effect of multiple iterations of such instructions to see if they cumulate into a significant effect. More interestingly, the overall learning of the students seated left is significant at 33.33% (t(6)=2.44, p<0.06). So what we see here is that the left child in the DSM group has maximum learning, the maximum retention and the maximum overall learning. Thus to enhance learning, the instruction should try to produce an experience which is similar to that of the child seated left in the multiple-user-single-mouse scenario with similar settings.

6. CONCLUSION

Keeping in mind the fact that the content (in this case – malaria) could have a bearing upon these results, we can draw the following conclusions– (a) Student retention of concepts is highest in the multiple-user-multiple mice scenario, notably with single gender groups of three. (b) Students are not interested in plain verbal narration of concepts (refers to NVN), which closely resembles the case with many of the unskilled teachers in the developing regions. (c) Student retention is lowest when they are exposed to plain video without any active involvement, even when the immediate learning is high. (d) In the multiple-user-single-mouse scenario, the left child has the maximum retention and overall learning.

Conclusion (a) is fairly basic and reinforces the longstanding concept [13] of the powerful effects of collaborative learning. More importantly in this context, it gives an answer to our question that employing multiple mouse applications in schools yield significantly successful learning outcomes as opposed to prevalent instruction modes. However, it should be noted that the intervention that was carried out was of one week duration and a more longitudinal deployment might give a better perspective on this issue. (b) is another straight-forward outcome which reinforces the idea that it is easier to process visual more readily than auditory information [3]. The first part of (c) is understandable in reference to the idea that active learning [6] evokes a student to think more and hence retention is more while playing as opposed to simply viewing. The second part of (c), it is not as obvious as to why the immediate learning from video is same as in game playing. One explanation could be that since the post test was conducted immediately after the instruction, the concepts were fresh in the memory of the students and hence there were no significant variations.

The entire rationale behind the observation (d) is difficult to formulate. As said before, the children who are in close proximity to the mouse might be getting too involved in play element of the games rather than the content, while the left child has the right proportion of involvement in the game and the content. As the Dual Coding theory [20] suggests, that different individuals process information differently and hence respond to different instruction styles, what we need is an instruction mode which combines the verbal, visual and kinesthetic styles in the right way. The left child does shed some light on how this combination should be approached, but its perfect recipe is still open to research.

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