Sarah Stein, Potsdam

ACAT Review for App [Click the Cube]

General Information

App: Click the Cube, version 1.1 (published on 2017/07/25)

Description in the App Store: The [Click the Cube]-App provides students with opportunities to develop spatial ability using cube nets. Three different learning environments have been developed, each focusing on different aspect of spatial ability in the context of cube nets. In the first learning environment a student has to decide if the illustrated net is a cube net or not by mentally folding the net. In the second learning environment a net has to be supplemented with a sixth square, so that a net results in a cube net. In the third learning environment the student has to dye the cube net according to a given colorful cube by rotating the cube. The environment includes several motivating elements for the students, such as collecting stars in order to receive a medal. Different differentiation elements are also provided, such as a slider, to help the student slowly build mental images of a cube.

Additional material: There is no additional material in the App Store description; however, from the description on the App Store a user can reach the website of the project "Digitales Lernen Grundschule" [Digital Learning in Primary School] of Potsdam University (dlgs.uni-potsdam.de). There you can find this and other apps in *Würfelwelten* [World of Cubes]. All these apps offer exercises for manipulating or visualising cubes.

1. What is the mathematical object of the app?

The mathematical objects of the app are cubes and their nets. The app focuses on the relation between 2D and 3D representations of cubes and should enable students to develop better spatial abilities.

2. How do students interact with the mathematical object, mediated by the app?

The app is organised into three parts. In the first part students are asked to decide whether various nets are nets of a cube or not. In the second part students are required to complete unfinished nets of cubes. In the third part they color a net to match a given cube. In all three parts the screen is divided into two areas. The left area contains the task and an overview of the medals and stars collected so far for correct answers. The right area shows the current cube or net for the task and it is possible to manipulate the object using various gestures on the screen.

In the first part the user is presented with a slightly folded net of cube. The user can *rotate* and *scale* the net and use a slider to *fold* or *unfold* it gradually. The first operation, *rotation*, is done through *pan* gestures. It is not a requirement to start the gesture on the net as it is possible to start anywhere in the right area, allowing the student to see the full net in rotation. Through this

gesture the user can see the object from all perspectives. With a *pinch-to-zoom* gesture the user can change the scale of the net, to enlarge or shrink it on the screen. This enables the student to find the optimal position of the object for inspection. He or she can zoom into critical areas to obtain further information. The third operation is to use the slider, moving its indicator to the left or right with the finger. Moving the finger to the right will fold the net, that is, diminish the spatial angle between the faces of the net until it is at 90 degrees, moving the indicator to the left will open up the net until it is flat. Using the slider enables the user to extend their spatial impression of the net and encourages students to continue the folding or unfolding of the net mentally.

The net of the cube is colored in white on one side and grey on the other. When folded, the grey side is on the inside and the white side is on the outside. Thus, a fully folded cube will appear white. The more the users move the slider to the right (thus folding the cube), the fewer number of points (stars) they receive for a correct answer. Not touching the slider will maximise the points if the correct answer is given when pressing the "Yes" or "No" button. Rotating or scaling the object does not influence the number of points. The reduction in points for using the slider is used consistently in all parts of the app. In order to receive as many points as possible, users are motivated not to use the visualized folding, but to find the answer with mental operations.

To start a new task, and to check or choose the answer, a user has to touch the corresponding blue words on the left side of the screen. Subsequently, an animation of the folding is shown on the right side. If two faces coincide this fact is highlighted in red. The user can still use the slider after this animation to further inspect the net and, if applicable, understand their mistake.

If enough stars have been awarded for an answer, the user will earn a medal. A total of four medals is possible.

The second part of the app requires the student to complete a net of cube by adding missing squares. The new squares are glued automatically to the existing net if they are brought into the vicinity of an edge. At some edges it is not possible to connect a square. To check the current net for correctness the user presses the "Check" button. This will determine whether a correct net has been formed and at the same time the folding process will be demonstrated with an animation in the right area of the screen. Adding squares is only possible when the net is fully flat (the starting configuration in this and the next part of the app). Adding a missing square to the net is achieved by *dragging* the free square from its original position to the intended edge. If it is impossible to add the square there, the user is required to inspect the rules for nets of cubes more closely.

The third part of the app is concerned with coloring a given net of a cube. In the task area on the left a cube is shown, which can be rotated and scaled for inspection of all of its sides, using the same gestures as in part 1. Seven different colored circles, that can be used to color the net, are shown at the top of the screen. In order to color the net, a user has to drag the colored circle from the top of the screen onto the square that should be colored. Again, it is possible to use rotation and scaling as well as the slider to control the amount of folding. The task for the user is to color the net such that its corresponding cube is colored in the same way as the "task cube"

on the left. After the solution has been checked it is possible to rotate both cubes to find the difference, if there is one.

In general, the app provides the means to create a complete (mental) image of the cube or its net. The various interactions that are possible allow for an informed decision by the user about how much help is needed to solve each task. It is possible to use the app to interact with the cube or cube net for further inspection, but it is not necessary to solve the tasks (with the exception of rotating the task cube in part 3).

3. How does the interaction develop?

The user is operating mainly in the mind to act on the mathematical objects and has to fold the net mentally in order to determine whether it is the net of a cube, where to add the missing face, or how to rotate the cube mentally to assign the correct color. So the app is motivating "mental geometry" in phases as described by Weigand (2013) i.e. (phase 1) presenting the task; (phase 2) imagination and mental operations, and (phase 3) presenting the solution. In phases 1 and 3, staged help may be available to simplify the activities. The second phase, on the other hand, should happen mentally without any aids. Preliminary stages of mental geometry or preparatory activities can include further aids for the second phase, for example gestures, geometric models for illustration or alternate solutions like figures.

In the app we consider, a figure of the net is shown in the task phase (1), which could be used for mental geometry immediately. The subject (i.e. the user) can rotate or scale the initial situation in order to be better prepared for phase 2. It might be the case that this already interferes with the second phase which should be mastered without a tool. In circumstances where the subject is not able to work on the task after it has been presented, the app offers interactive representations and acts as a tool for a preliminary stage of solving mental geometry tasks by visualizing them. The rotation and scaling operations allow the subject to create visualizations from various perspectives that they can register mentally and might enable them to solve the task without any help the next time. Also, when touching the button for registering the solution, the animation of the folding is shown that can help the subject to check the correctness of their mental operations. As the app does not proceed to the next exercise automatically, but rather requires an active selection of the next task, it is still possible to repeat and confirm the actions and operations that lead to the solution. The app stimulates mental operations in various ways, so I consider it as a tool that helps students to acquire the competency of doing mental geometry.

Possible Improvements of the App:

When building a net it is possible to place a square on, or rather *in,* the net. Sometimes this leads to flickering of overlapping faces. For a better understanding it would be helpful to prevent the possibility of overlapping faces.

Sometimes it is not possible to add a square at a certain edge, for example if this leads to a 2 by 2 square. While this is a reasonable restriction it can be irritating to students. A possible improvement could be an animation where a misplaced square is moving away from a forbidden

edge after placement, in order to highlight that there is a problem with this placement. This could encourage the users to reconsider the conditions of cube nets in that situation.

In order to simplify the user interaction in the third part of the App the coloring of squares could be realized through a tap-tap gesture (first tapping the color, then the square) instead of a drag gesture (dragging the color to the square).

It does not matter in the app whether a square is colored from the inside or the outside. However, it is difficult to see whether a colored square will be on the inside or the outside in the folded cube. To avoid confusion the contrast between the inside and the outside should be increased. These aspects have been observed in tests with several people who had difficulty coloring the net.

4. Is the app suitable for teaching and learning the mathematical object?

The app seems to be beneficial in developing the ability to do mental geometry and as such also to foster spatial abilities. In particular the visualization of the connection between a net and a 3D object is helpful for the work with cube nets. The user can apply and check their knowledge about cube nets and extend their abilities in mental folding and in the mental imagination of this process. As a consequence the app is suitable for practice phases. An introduction to the topic of (cube) nets should precede the use of the app. It is important to develop these abilities in class 3/4 (age 8-9), as it is a foundation for later teaching. For example, calculating surface areas of composite bodies (e.g. cuboids with an attached cylinder) is a topic where students show difficulties. It is a common mistake to just add the areas of the two nets without removing faces where the two bodies touch. As one cause for this can be a lack of spatial ability, the app is a helpful tool to prepare students to avoid such mistakes.

Using the app also opens new ways to work with cube nets and should be seen as a supplement to cut-out nets and crafting cubes from these. The app cannot replace the haptic experience, but offers training that could not be done with paper or cardboard material or images alone (See Bruner's EIS approach, 1988).

Furthermore, the app allows for differentiated learning. Again it is possible to refer to the three phases in mental geometry. In the first phase the task is presented together with a net. For higher achieving students (in this particular discipline) this can be solved solely through mental operations without further aids. Those students who need more assistance can use the on-screen operations for rotating and scaling the nets for a change of perspective. If this is not enough, they can also use the slider to fold the net slightly or completely, according to their needs. In this way the app can help to improve the mental geometry abilities of all users, starting at various levels of ability.

In conclusion the app seems to be well suited for the subject of cube nets and to help students to develop their spatial abilities while they work on objects in a way differentiated by their current abilities.

5. How can the app be used in classroom instruction?

In school education there are several options to use the app. As the exercise tasks are delivered by the app, it can be used for individual work of students. For the teacher it is not necessary to provide examples so they can take care of certain students, i.e. low achieving ones. These exercise sequences can be repeated several times during the school year. It is also possible to use this app for learning stations with the topic of cubes. The students would be able to talk about and compare their strategies. Possibly it is also usable for saving time and materials after the introduction of creating boxes etc.

There are, however, some difficulties when using the app:

For example, with a class size of 30 pupils, it will be difficult for the teacher to address the problems of each individual that result from using the app. On the basis of the medals it is not possible to say anything about the students' skills. This is a critique of collecting stars and medals as points. If the user takes help when interacting with the app, they only get a part of a star. Because of filling the stars, it is not discernible whether the student solved 20 tasks with help or only 10 tasks without help as both options result in a medal. A better way would be a diagnosis tool where a teacher can see the student's problems in order to respond adequately.

Additional notes:

Because there are only 11 different cube nets, it could be possible that users sometimes know all of them and they only tap the right answer without thinking about it. That should be prevented by a semi folded net and a random alignment at beginning, but it is not to be ruled out (see Huhmann, 2013). One way to expand the app is to supplement it by cuboid nets. You can give similar tasks to be sure that students are not getting answers based on memorized learning. The mental folding of cuboid nets also offers new aspects, i.e. opposite edges with non equal length. There are also 54 cuboid nets so the option to memorize them has been reduced.

In the second part the free square is difficult to move. This usability isn't optimal and should be revised.

Another expansion could be an option for color-blinded people. For this purpose all colors can be assigned by a unique structure.

The rewarding of correct answers using medals isn't enjoyable when using the app alone and once you have got all four medals there is no more progress. To solve this, there could be several stars (i.e. several colors), but that also depends on the target (diagnosis vs. collecting points).

One final point: Is it meaningful to reduce the score even when rotating the cube net? According to mental geometry (phase 2) it shouldn't be allowed to rotate, but it contributes to understand the situation. One extension of the app (maybe for higher grades) could be to show the net and require the user to do any further operation mentally. With a correct answer you earn a yellow star and if you used the rotation option you only get a full blue star for a right answer.

Note

This is a translation of a German review by Sarah Stein, University of Potsdam. Translation by Heiko Etzold, Ulrich Kortenkamp and Kevin Larkin.

References

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