Explanation-Giving in a Collaborative Tangible Tabletop Game: Initiation, Positionality, Valence, and Action-Orientation

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Abstract: Explanations given to each other by 20 pairs of 5th grade children while playing a tangible tabletop sustainability game were analyzed inductively for key themes relating to their use of language, gesture and system tools. Half the pairs had been assigned roles (human development or natural resources manager) with associated system controls. Findings showed that explanations by pairs in both conditions often employed collectivist language ("we") in conjunction with positive reflections on the game-world state using the provided Impact Tool which gave feedback while system was paused. Pairs in the roles condition also gave explanations in response to partner actions and more frequently included negative and action-oriented prospective language about what should be changed moving forward. Roles pairs additionally used questions to seek confirmation or action from their partner and made comments from the perspective of the inhabitants of the fictional world. Implications for the research and design of collaborative tabletop learning systems are discussed.

Keywords: Tangible systems, discourse, student roles, positive interdependence

Collaborative learning with interactive tabletops and tangibles

Interactive tabletops and tangibles are technologies that allow for physical interaction by users directly with the digital surface (Higgins et al., 2011) and/or via digitally augmented objects that are recognized by the system (Ullmer & Ishii, 2000). They are particularly exciting for supporting face-to-face collaborative learning for multiple reasons (Fernaeus & Tholander, 2006; Dillenbourg & Evans, 2011; Speelpenning et al, 2011) such as the ability to have multiple simultaneous users and create a shared transaction space for reference, negotiation, and action. Of particular interest in this work is the ability to facilitate joint attention through the visibility of action, the possibility to engage multiple modes of communication (e.g. speech, gesture, system action), and the opportunity to generate positive interdependence through the physical embodiment of distributed control. Despite these affordances, opportunities for collaboration aren't always taken up by children. In addition to such obvious problems as domination by one child, independent parallel play, and competition (Fleck et al., 2009; Marshall et al., 2009), children can also work together to complete tasks successfully but without deep engagement around the issues involved. For example, in our prior work studying children's' collaboration using a tangible tabletop sustainability game, we found that pairs worked together for the entire duration of system use, but only talked in depth about their sustainability choices 5% of the time (Wise et al., 2015). For the remaining 95%, the children engaged in other forms of interaction in which they made game-based decisions, but without substantive explanation of their thinking. This mode of operation is parallel to quick consensus building in the context of argumentation, in which learners are simply "accepting the contributions of the learning partners in order to move on with the task" (Weinberger & Fischer, 2007, p. 77). This stands in contrast to richer forms of consensus building which are integration-oriented or conflict-oriented in nature. Fundamental to both of these activities is the opportunity for students to experience a change in perspective based on hearing the ideas and reasoning of their peers (Teasley, 1997). Thus getting children to share their thinking may have benefits for reflective processes, collaboration, and learning (Price et al., 2003), and a greater understanding of what leads children to explain their ideas in a tangible tabletop learning environment and the characteristics of this language that might lead to it be accepted by their partner is of central concern to the CSCL community.

Giving explanations, positive interdependence and the Youtopia system

One way to encourage children to share their thinking is by setting up a situation which requires their complementary participation for success. Tangible systems can be used to create such situations through the technological interdependence of different objects' use (i.e. more than one input action must be taken sequentially in order to create a successful system response) (Ullmer & Ishii, 2000; Antle, 2015). This can be

further layered with social interdependence in which the objects are assigned to children along with a set of duties, rights and responsibilities (Wise et al., 2015). When multiple actions are needed to produce a certain outcome and children require the assistance of their partner to enact these actions, it should encourage them to articulate and explain their thinking to each other. Previously we have described a system designed to enact these ideas: Youtopia is a tangible and multi-touch tabletop activity about sustainable land-use planning that includes co-dependent access points and the option to add scripted roles (with associated tools) to the existing contingencies of tangible use (Antle et al., 2013; Fan et al., 2014). In a prior study we measured the degree of explanation-giving by 20 pairs of 5th grade children using Youtopia in an authentic school environment with and without roles (Wise et al., 2015). Results showed pairs in the assigned roles/controls condition gave a greater number of explanations to their partners about what they wanted to do in the game. In this follow-up study we use inductive qualitative methods to unpack this finding and probe the reasons why this occurred.

Methods

Research question

What kinds of talk, gesture and tool use characterize explanation-giving in pairs of children playing a tangible tabletop sustainability game with and without assigned roles/controls?

Youtopia design

Youtopia is a hybrid tangible and multi-touch tabletop application about sustainable land-use planning in which children have the opportunity to design their own world, exploring how different land-use decisions affect the amount of food, housing and energy provided to the population, and the impact these decisions have on the level of pollution in the environment. Following the principles of Emergent Design (Antle et al., 2014), our interaction goals were for children to explore the relationships between different land-use decisions, see their effects on the world, discuss with their partner the inherent tradeoffs between meeting human needs and causing pollution, and through this make informed decisions to create a world they would want to live in. Children begin with an undeveloped map of mountains, grasslands, forest and a river. They interact with the tabletop through two kinds of physical stamps that designate different land-use types (see Figure 1a): natural resource stamps (tree icon); and human development stamps (wrench icon) [see Table 1]. Each stamp also has a picture and a label describing the land-use type, and color is used to indicate land-uses that relate to the same human need.

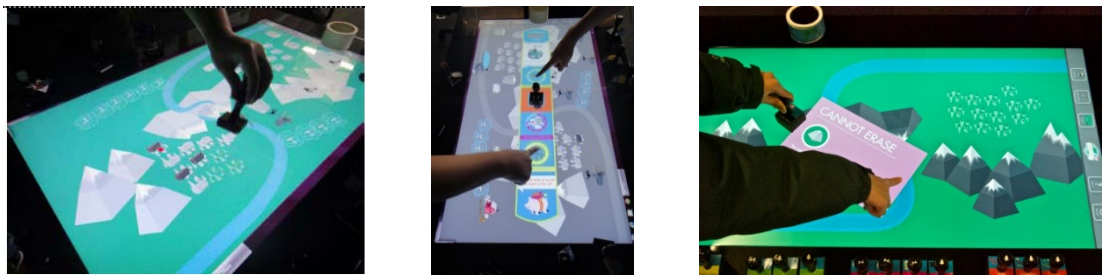

Figure 1. (a) Stamping a land-use (b) Assessing world-state from Impact Tool (c) Attempting to erase a land-use.

Land-use types have predefined relationships to each other and to the terrain designed to reflect real world relations (see Table 1). For example, a farm can only be built on grasslands and requires irrigation connecting it to the river. Thus, while each stamp is used individually, system interdependencies require multiple stamps to be used together to build the Youtopia world. Children can learn about these relationships and their effects on the world through trial and error with educative error explanation tabs, using the open circular tangible "info ring," and by assessing the state of the world with the Impact Tool that provides visual information about pollution levels and the proportion of the population that has shelter, food and energy (see Figure 1b). The Impact Tool freezes the map (so no other interactions with the system can take place while it is in use) and includes a diagnostic touch functionality: children can touch any of the four rings indicating levels of food, shelter, housing and pollution to highlight the elements in the world contributing to it. The Impact Tool also contains an image of a pig that asks children "Is this a world you want to live in?" with the goal of eliciting a discussion of tradeoffs. An Eraser Tool (see Figure 1c) is available to remove land uses children want to eliminate or replace without penalty, allowing for experimentation and incremental building. A full description of the system design is given in Antle et al. (2013) and a short video of functionality is available at tinyurl.com/youtopiagameplay.

Table 1: Types of Youtopia Land-use Stamps

Area of Human Need	Natural Resource Stamps (tree)	Human Development Stamps (wrench)
Food (green labels)	Garden, Farm ←	Irrigation***
Shelter (pink labels)	Harvest Lumber →	Houses, Town Houses, Apartments
Energy (yellow labels)*	Coal Mine →	Coal Plant Hydro Plant***
Environment (orange labels)**	Forest, River & Mountain Reserves	

Arrows indicate land-uses required for other land-uses. * Energy land-uses *increase* pollution. ** Environment land-uses *reduce* pollution *** Irrigation and hydro plants use-up river water; this is reflected in a visual display of the water level

Youtopia use

Forty 5th grade children (ages 10-11, 18 boys / 22 girls) from two classrooms used Youtopia in pairs (N=20). All children had extensive experience collaborating and participated in a class unit on sustainability issues four months earlier. Use of Youtopia was introduced as a review of the sustainability unit in which children would get to spend up to 25 minutes building a world they wanted to live in to share with the class. Half of the pairs were randomly chosen to be given assigned roles/controls with role types balanced across gender in the overall sample. For these pairs, one child was randomly assigned to be the "natural resource manager" with all the "tree" stamps (lumber; garden; farm; coal mine; nature, river, mountain reserves) placed in front of them on one side of the table; the other child was randomly assigned to be the "human development manager" with all the "wrench" stamps (irrigation; (town)house; apartment; coal plant; hydro dam) placed in front of them on the other side of the table. Use of assigned tools was not explicitly enforced; the design relied on social norms around ownership of items on tables (e.g. you use the cutlery placed in front of you) and the explicit labeling of the tools with the wrench/tree icons that identified them as associated with a particular role. Tools not associated with a role (Impact Tool; info ring; eraser) were placed at the end of table between the children. For pairs who were not given assigned roles/controls, all of the stamps were placed at the end of table between the children.

Data collection and explanation identification

Videos of all twenty pairs' sessions were collected. Youtopia use (using one of two identical installations) was conducted in separate rooms apart from the classroom to minimize distraction and extraneous noise. A high-definition digital video camera captured a landscape view of the children and oblique view of the tabletop.

One (roles) pair's data was removed from analysis as an outlier due to a lack of substantial talk or engagement throughout the session. Time-periods in which children explained their thinking or reasoning related to decisions about what resources and developments to use were identified in the remaining video data. For example "Let's build houses, not apartments-they use less lumber so we can make more nature reserves" would be coded as an explanation but "I think we should have houses not trees" would not. Three researchers achieved acceptable inter-rater reliability ($\kappa > .63$) with all differences reconciled. A total of 58 explanations were identified across the 10 non-roles pairs while 80 explanations were found for the 9 roles pairs.

Analysis

Data analysis was conducted inductively following the constant comparative method (Gibson & Brown, 2009) with particular attention to the concerns of video-based data (Derry et al., 2010).

Phase 1: Transcription

All 138 explanations were transcribed into a text file. With the goal of understanding collaborative processes, the time-span of an explanation included events that led up to the explanation as well as any response or reaction expressed by the partner. Transcripts thus captured (a) all verbalizations during the coded time period and two to four related turns of talk before and after; (b) indication of the physical actions taking place during / between turns of talk including (i) body position, (ii) tool use, (iii) gestures, (iv) facial expressions, and (v) child location around the table. In addition, the transcriber provided a global overview of each event that indicated what aspect of the Youtopia world the explanation was about, what occurred leading up to the comment, and any response or reaction expressed by the partner. An example for one explanation is shown in Figure 2.

Phase 2: Open and confirmatory coding of non-roles explanation transcripts

Three researchers individually read all the transcripts for the non-roles pairs and using constant comparison generated a list of potential themes seen in the data. The goal at this stage was to be as inclusive as possible in

retaining themes. The researchers then shared and discussed proto-themes, condensing and combining similar ideas to create a master list of 11 possible themes. Each potential theme was then subject to individual scrutiny with a search through the transcripts for confirming or disconfirming evidence. Each of the three researchers took primary responsibility for a theme, but work was conducted collaboratively with extensive consultation. Importantly, attention was paid not only to how frequently evidence of a theme was found across the whole corpus, but also its existence across multiple episodes and groups. In this round of coding, two similar themes relating to use of the Impact Tool and the initiation of explanations were combined and two related to the expression of emotion were dropped due to lack of evidence. This left a total of 8 themes.

C1 (f) Human Devel.	C2 (m) Natural Resour.	Verbalizations and Physical Actions Surrounding C2 Explanation in R3@10:15
	X	And then what should we do? [*puts Impact Tool on screen*]
X		[*reading from Impact Tool*] Is this the kind of world…? [*pointing to the text*] No. We need more power.
	X	I don't know about using coal because we don't want to make it too polluted.
X		A dam.
	X	Sure, you have it.
X		Hydro dam [*picks up stamp and places it on river*] there.

Figure 2. Sample transcript of an explanation by child C2 in Roles Pair R3 at 10 min 15 sec into the session.

Phase 3: Open and confirmatory coding of roles explanation transcripts

The above process was repeated with the roles transcripts while carrying forward the 8 already identified themes. In the open coding, 4 additional potential themes were identified. Thus, a total of 12 possible themes were examined in the confirmatory coding. As the data was examined, two of the newly identified potential themes were incorporated into an existing theme due to similarity in content, and one theme related to the use of the Eraser Tool was dropped due a lack of evidence. In addition, the final new theme and three existing themes which all related to aspects of articulation of arguments and tradeoffs were combined into a single theme. The existing themes whose scope was altered or expanded during analysis of the roles condition were taken back for follow-up examination with the non-role pairs' transcripts. This resulted in a total of 6 themes relating to explanation-giving whose presence or absence and characterization are reported across roles and non-roles pairs.

Findings

The six themes described below speak to how explanation-giving was initiated as well as the perspectives the explanations represented and the temporality, valence and positionality expressed within them.

Theme 1: World-state- versus partner-initiated comments

Explanation-giving often occurred as a response to the world-state; in the roles condition explanations also commonly occurred in response to a partner action or comment

In ***Non-Roles*** pairs, explanations were most often made in response to the state of the world. This was commonly prompted by use of the Impact Tool which provided feedback on pollution levels and the meeting of human needs (e.g. "So how are we turning out? [*puts Impact Tool on screen*] Food is pretty good. I think it is really good because there is no pollution." C1 in N8@15:58). Children also gave explanations of their thinking about the world state as depicted on the map (e.g. "I don't like how we took up all the trees but *[rubs hands on face*]…like…I think it's good." C1 in N1@18:03). In a more limited number of cases, non-roles children gave explanations in response to something said or done by their partner (e.g. "But we don't want to put it near a mountain, it will kill the goats and stuff. That's sad." C1 in N9@11:42 responding to their partner's suggestion about where to put a coal plant). In ***Roles*** pairs the same kinds of situations initiated explanations with one notable difference: there were a substantial number of both world-state *and* partner-initiated explanations. In many cases these explanations appeared to be related to stamp ownership by the two roles (e.g. "Yea, because then most people will have food." C2 in R6@18:54 responding to their partner, who had the garden stamp but had not yet used it, making a hesitating statement that only "maybe" stamping it was a good idea). Similar initiation of explanations occurred even when the action in question would be taken with the Eraser Tool which both children had access to. This indicates a tacit acknowledgement of the ownership of decisions related to particular land use types in roles pairs (e.g. "These ones? [*motioning to some apartments on the map*] maybe we *should* lose some apartments. They're too cramped up in that area." C2 in R5@16:19, who was responsible for human development, responding to their partner's idea that they should remove some of the apartments).

Theme 2: Retrospective versus prospective temporality

Most explanations were retrospective reflections on the state of the world, but in the roles condition there were also action-oriented prospective explanations about what should be done to change it

Explanations in ***Non-Roles*** pairs were mostly retrospective reflections on the existing state of the world (e.g. "Wait, if you look at our pollution. See now our pollution is fine." C1 in N3@18:55). At times these also included a call to action about what should be done (e.g. "There's little pollution! We're in the good zone! Let's just put one more." C2 in N6@16:28). In addition, there were a small number of statements of a timeless nature describing what children valued in the world (e.g. "There should be at least many [people who have food]." C2 in N2@8:57) and ones which described an anticipated future (e.g. "Yeah, it will be nice to have some animals." C2 in N6@3:21). In ***Roles*** pairs the temporality of explanations distributed into the same four categories; however, there was a much greater presence of prospective calls-to-action about what should be done. These occurred both in combination with reflections on the existing state (as was seen for non-roles pairs, e.g. "Oh man, a lot of the water's gone [*looking at the brown river*], do you think we need to kill the hydro dam? C1 in R8@12:56") but also on their own as stand-alone comments (which was seen less frequently non-roles pairs, e.g. "I don't know about using coal because we don't want to make it too polluted." C2 in R3@10:20).

Theme 3: Collectivist versus partner-directed language

There was a strong use of collectivist language ("we") in both conditions; in the roles condition language referring to the learning partner ("you") was also commonly seen

Within ***Non-Roles*** pairs there was a much greater use of first person plural language (e.g. "Okay so that means we need [to use] more trees which is kind of sad." C1 in N1@3:30) than first person singular (e.g. "I think it is really good because there is no pollution." C1 in N8@13:05). When employed, use of the first person singular was almost always followed by an opinion verb such as think or feel (as in the example above) and often also connected with a reference to the collective (e.g. "I feel like we're using up too much of the trees." C2 in N4@9:55). A similar pattern was seen for ***Roles*** pairs with the addition of a greater use of the second person singular ("you") in combination with a reference to the collective (e.g. "Do you want to try another irrigation to get more food 'cause that's the only way big problem we have?" C2 in R1@25:00).

Theme 4: Positive versus negative language

Non-roles pairs primarily used positive language in giving explanations while roles-pairs also used negative language to oppose things their partner had said or done, and used questions to seek confirmation, agreement or action from their partner

Children in ***Non-Roles*** pairs gave explanations largely using positive terms. Typically a child made a statement about the state of the world, followed by a positive comment (e.g. "Only a little [pollution]. That's good." C2 in N4@4:54). Other positive statements referred to the state of the world directly (e.g. "We have a pretty darn good world here." C2 in N6@17:10). Non-roles children less frequently used negative terms in their explanations or opposed something their partner had said. When they did, these tended to be tied to action-oriented phrases about what should be changed (e.g. "There's not enough water though, maybe we need to erase the fish." C1 in N5@11:53). In contrast, children in ***Roles*** pairs expressed their explanations using a variety of neutral, positive and negative statements as well as questions. Notably, there were many more explanations in that had a negative valence; children often offered an explanation as they opposed something their partner had just said or done (e.g. "But this like pollutes though, remember?" C2 in R2@12:43 responding to their partner stamping a coal plant on the map). Often these opposing statements involved negative terms and/or suggested undoing what the other learner had just done (e.g. "Maybe, ugh … Water brown?"[*erases the irrigation they have just stamped in response to their partner's suggestion that they build more gardens and a farm*] "I don't want to do that 'cause then the fish don't have much water." C2 in R5 15:02). Opposition was also enacted at times in the form of a question which opened up a space for the partner to share their thoughts in response to the difference in opinion (e.g. "Why is the garden so far from the houses?" C2 in R2@3:14 in response to C1 placing an apartment stamp)." Directing questions to the learner partner was also a frequently occurrence in roles pairs' explanations, even when opposition was not present. For example children often sought confirmation, agreement or action from their partner either directly (e.g. [*placing Impact Tool*] "Not everyone has shelter…Do you want to take out some parks?" C1 in R8@8:48 [C2 who is responsible for natural resources responds by erasing three nature reserves]) or indirectly (e.g. "Energy would be coal plant and hydro dam [*points at both stamps which belong to their human developer role*]. Both cause pollution. This is less [*waves hand above hydro stamp*]. Maybe hydro dam? Where can it fit?" C1 in R9@18:59).

Theme 5: Holistic versus positioned perspective

Children in non-roles pairs gave explanations when the environment was healthy or human needs were met, often shifting to focus on the balance between these towards the end of a session; in contrast children in roles pairs gave explanations when pollution was high or human needs were not met and many of the pairs aligned their comments with their roles for the majority of the session.

Children in ***Non-Roles*** pairs gave explanations about three main aspects of the Youtopia world. First, when the environment was relatively healthy (e.g. "Okay there's little pollution. That's way better." C2 in N1@7:25). Second, when human needs were met (e.g. "Oh wow… [*pointing to full shelter indicator on impact display*] …that's good!" C1 in N7@8:14). Third, about the balance or trade-offs balance between a healthy state of the environment and human needs being met (e.g. "Well I want everyone to have energy but then we might have more pollution." C2 in N2@16:42). More often than not, these comments were positive in nature as noted in the previous theme (e.g. [*looking at impact display rings*] "There's lots of pollution but everyone has energy now." C1 in N3 @23:06) though at times children also recognized the difficulty of the choices that needed to be made (e.g. "This is really hard trying to keep the water full and having stuff as well." C1 in N10@13:06). In some non-roles pairs children talked about trade-offs and advocated for a balanced world from the beginning; however in others they initially advocated for either people's needs or the environment, only shifting to consider balance later in the session (e.g. "I want everyone to have energy." C2 in N2@16:45 versus "All I wanna do is add more energy but then that's gonna add more pollution." C2 in N2@20:08). In contrast, children in five of the Roles pairs advocated according to their assigned role for most of the session. As described in the two prior themes, these explanations were often phrased in the negative and oriented towards taking action. For example, the natural resources manager gave explanations when pollution was high or water levels were low (e.g. "Oh no no no no, we don't need that happening [*erases irrigation*] we need to preserve some water [*tries a river reserve, water turns brown again, erases it the reserve*] that's not good." C2 in R5@15:31) while the human development manager gave explanations when human needs were not met (e.g. [*looking at Impact Tool*] "Not everyone has shelter…do you want to take out some parks?" C1 in R8@18:54). In the other four pairs, children gave explanations that were both aligned and in contrast with their assigned role. Near the end of their session, they shifted away from the roles to address questions of balance, making comments that showed a recognition of the trade-offs involved (e.g. "Now there's a little pollution but I think we're almost at full energy." C2 [natural resource manager] in R7@16:14).

Theme 6: Connected versus detached language

Children in roles pairs gave explanations that included the perspectives of the world's inhabitants

An additional theme found in the examination of explanations in ***Roles*** pairs was comments about the experiences or feelings of the inhabitants of the world. There were a substantial number of these statements relating to a variety of things such as: living conditions (e.g. [*smiles*] "Oh, they're neighbors." C1 in R5@5:17); the availability and proximity to food (e.g. "But should we do like houses around the garden? So they stay alive with food and stuff…" C2 In R2@4:28); the impact of pollution (e.g. "Do you want to put this over there so these people don't have like the pollution from that?" C1 in R1@20:51); and lifestyle concerns (e.g. "I think we should make a few because people like nature reserves don't they…" C1 in R7@5:08). What the comments all had in common was thinking about or from the perspective of the people living inside of the system. Such comments were seen much less frequently in the ***Non-Roles*** condition where the vast majority of explanations took a detached "gods-eye" view (e.g. "Okay there's little pollution. That's way better." C2 in N1@7:23).

Discussion

Explanations and interdependent roles/controls

The impact of positive interdependence induced via assigned roles with associated controls on explanation-giving was the core focus of this research. Prior work had found that the overall *amount* of explanation-giving was increased by this strategy (Wise et al., 2015). The present finding that, for roles pairs only, a substantial portion of explanations were given in response to a comment or action made by their partner, begins to offer some insight into why. Roles pairs asked questions of their partner to seek confirmation, opposed things their partner had said or done, and used "you" language to request (or direct) their partner to take a particular action. These behaviors appear to stem directly from the distributed ownership and interdependence of the system controls. For example, opposition was stimulated by the fact that actions taken by one child always had implications for the other (Antle, 2015). Similarly, questions or requests for action were necessitated by the fact that providing for human needs (food, shelter, energy) required using at least one stamp assigned to each

partner. Notably, while use of assigned tools was not enforced, no violations of the assignment occurred. Drawing on Rick et al.'s (2009) finding that children took more responsibility for the parts of the tabletop surface closer to their relative position, this may be in part due to the initial presentation of role stamps on opposite sides of the table. These norms of social ownership (Speelpenning et al, 2011) related to land-use were strong as they even extended to use of the shared Eraser Tool to remove elements associated with each role.

The extent to which the different character (and additional quantity) of roles pairs explanations has implications for the children being open to, or actually changing, their ideas is an important areas for future research. Children's efforts to seek confirmation or agreement from their partner about what to do in the game suggest some attempt towards the desired end of thinking beyond their own personal views (Teasley, 1997). This is also supported by the finding of comments considering the welfare of the world inhabitants by roles pairs. In addition, oppositional explanations are potentially valuable for stimulating learning since they push the children to reconsider their ideas about what an ideal world looks like in ways that positive evaluations do not (Weinberger & Fischer, 2007). Conversely, many children in the roles pairs stayed on "their" side of the issues (human needs or the environment) for the majority of the session, rather than progressing to a more balanced position acknowledging the tradeoffs between them. This suggests a design strategy first promoting an oppositional stance and then later switching to a togetherness stance. One approach to this could be via game phases where roles/controls are scripted/assigned at the beginning but deliberately released partway through.

Explanations and the impact tool

Across all pairs, the Impact Tool was commonly used in conjunction with explanation-giving. There are several design features that may have contributed to this. First, use of the Impact Tool paused interaction in the game. The ensuing talk during these pauses suggests the effectiveness of Antle's (2015) recommendations to help children "step-out" of the tangibles action and create space for them to explain their thinking. Second, the tool brought up a status screen that provided feedback on the world-state (levels food, energy, shelter and pollution) and was jointly available to both children with a prompting question ("Is this a world you want to live in?"). Previously we found that to be shared by group members, tabletop elements must be readable and reachable from multiple sides of the table (Antle et al., 2011). This appeared to be effective here in eliciting children to share their evaluations of the world and the reasons for them with each other. The visualization providing this feedback was intentionally value-neutral (see Emergent Design Principles, Antle et al., 2014): the pig's speech bubble asked "Is this a world you want to live in?" and the circular scales for pollution, shelter, food, energy could be viewed from either a "half-full" or "half-empty" perspective. While non-roles roles pairs tended to use this referential anchor to comment on what was (already) good in the world, roles pairs also used it to point out could be better. The root cause of this difference is not clear, but it is potentially related to a greater feeling of responsibility for the world imparted with the assignment of roles (Wise et al., 2012). There is evidence for this in the connected language used by roles pairs to talk about the experiences of people in the world (rather than the detached language used by non-roles pairs). Whether a heightened sense of responsibility and forward-oriented talk is advantageous for learning remains to be examined; we suspect there may be benefits for cognitive engagement from children feeling accountable for their activity and actively comparing the world-state with the one they would like to build, rather than simply admiring the current one (Chi & Menekse, 2015). This can be tested empirically with designs that intentionally lead children to take one perspective or the other (for example the pig could ask different questions: "What is good about this world?" versus "What can make this world better?") and evaluate the resultant talk and learning. The optimal situation may involve fluid flow between the two perspectives; this could be encouraged in various ways (e.g. the system rotates between different prompts or prompts whichever perspective is less represented). A third feature of the Impact Tool that may have been important specifically for roles pairs was the diagnostic touch functionality that showed the elements contributing to world's food, shelter, housing and pollution. This functionality was often used to identify and explain the causes of a dissatisfying situation leading to a suggestion for change. The presence of an Eraser Tool that allowed children to endlessly undo and redo actions also may have played an enabling role in supporting cycles of experimentation, evaluation, and change (Fleck et al., 2009). This follows Antle's et al. (2014) recommendation of multiple, bidirectional pathways through activities as a way to encourage emergent dialogue and the exploration of values. The proposition that diagnostic and undo functionalities play a role in supporting explanation-giving (when a prospective view is taken) can be tested via comparisons of children's system use with and without the relevant features available.

Conclusions and future work

This study investigated the character and differences in explanation-giving by pairs of children playing a tangible tabletop sustainability game with and without assigned roles/controls. Findings showed an important

role of the Impact Tool in provoking explanations related to its pausing, feedback and diagnostic features. The interdependency created in roles pairs led to greater opposition and question-asking as part of explanations. Improvement-oriented explanations that included references to Youtopia inhabitants' experience may be due to an increased sense of responsibility to the game-world. Enduring positionality among roles pairs needs to be addressed with future design iterations. An additional area for future inquiry is the use of the specific linguistic features identified as proxies to semi-automate the characterization of explanation-giving.

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