The Dynamic Interaction between Engagement, Friendship, and Collaboration in Robot Children Triads

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Abstract: Grounded in child/robot interaction and inclusive education, this research has designed a small socio-technical community of a robot and two children where children play and learn equitably together while they help the robot learn. This designed community was implemented in a school media lab twice a week over three weeks, each session taking about 20 minutes. We ethnographically observed and video recorded children's participation in the triadic interaction naturally. The phenomena of interest include friendship development, collaborative communication, and engagement with the community. Data collection is still ongoing, and analysis will occur over this summer. This paper presents the theoretical frameworks and data analytic scheme. We expect to report the findings at the ICQE conference in October.

Keywords: Child-Robot Interaction, Collaboration, Engagement, Friendship

1 Research Problem

As the demographics of classrooms in public schools both in the U.S. and worldwide becomes increasingly diverse, public education faces the urgent challenge of finding ways to promote effective learning environments in which all children develop and learn equitably. We propose that supporting equitable friendships and collaboration at an early age can be an effective way to address this challenge. Also, recent research on humanoid sociable robots indicates that children develop social and affectionate relations with the robots, voluntarily engage in the interactions with the robots, and mimic the robots' behaviors [1, 2, 3]. This research project titled Inclusive Design for Engaging All Learners (IDEAL) aims to design a socio-technical learning community in which a social robot fosters friendship building and collaboration among kindergarten-aged children who come from diverse backgrounds. The research also examines the efficacy of this design by observing children's engagement, friendships, and collaboration as they interact with the robot and with their peer in a natural setting.

There has been a dearth of research on systematically assessing young children's verbal and nonverbal behaviors in learning contexts. Examining the efficacy of our design whose evidence is gleaned from children's interactive behaviors poses us a great challenge. We will use ENA (Epistemic Network Analysis), a statistical modelling tool which identifies,

quantifies and represents (visualizes) connections among three phenomena of interest: friendship, collaboration, and engagement [4]. ENA is designed to analyze a large number of segments (snapshots of an ongoing activity), and may therefore allow us to systematically analyze and interpret the patterns and evolution of children's engagement in the triadic learning community and their friendship building and collaborative behaviors while they engage in the community.

2 Theoretical Frameworks

The design of a robotic learning community is grounded in playful learning theory [30] and culturally-sustaining pedagogy [29]. While they play with peers, children develop intellectually and socially; therefore, learning and play could be integrated fluidly when designing for children. Also, in their learning processes, children as cultural beings should be encouraged to share their personal experiences grounded in home language and culture. The learning community of a robot and children can offer a kind of third space where children can develop a sense of agency and comradery as they play and learn together. The robot verbally invites the children to tell their stories, providing opportunities for participation and demonstrating empathy and appreciation for children's contribution. In this type of community, children's diverse experiences are positioned as assets rather than deficits; children become fully engaged participants rather than marginalized. This way the robot acts as a cultural broker that mediates equitable interactions among children regardless of their cultural and linguistic backgrounds.

Data collection and analysis are grounded in a few theoretical traditions (e.g., ethnography, phenomenology, and symbolic interactionism). We ethnographically observe children's natural participation in the socio-technical community. As children are immersed in the triadic interaction with the peer and with the robot, we will pay attention to what new patterns and protocols of engagement, friendships, and collaboration as *lived experience* will emerge, what existing theories and practices of those phenomena will be replicated, and/or what new shared meanings and experiences come out of their interactions. Two main research questions involve 1) in what way and to what extent aspects of children's experiences in the robotic community (engagement, friendship, and collaboration) evolve over time and 2) in what way such experiences of children interact with each other.

1.1 Friendship

Friendships are characterized by companionship (seeking proximity and spending time together), intimacy (closeness and self-disclosure), and affection in which reciprocity and mutuality plays a core role [5]. It is well established that mutual friendship has a crucial influence on the cognitive, social, and emotional development and well-being of children [6]. Five-year-olds with a mutual friend significantly outperformed their friendless peers on a comprehensive social and cognitive development battery, after controlling for socio-economic status, group popularity, and language skill [31]. Friendship at early age also has a lasting impact on individuals' well-being in that negative friendship experience affects

individuals' mental health adversely throughout life [7]. In recent decades, developmental psychologists and clinicians have implemented friendship training programs to coach young children to develop socially valid behaviors, the core of which include cooperation with peers, active listening, and having fun together equally (Frankel & Myatt, 2003). In our robotic community, children are asked to collaborate with each other to help the robot learn while they play together. The robot models active listening to children and solicits equal participation.

According to classical intergroup contact theory [8], interacting with other ethnic groups may help reduce cognitive biases against outgroups. A volume of subsequent research confirms this theory, reporting that intergroup interactions enhances socio-cognitive skills of children. Having cross-ethnic friendships in childhood has also been associated with positive intergroup attitudes in adolescence and adulthood [9, 10]. Particularly in ethnically heterogeneous contexts, cross-ethnic friendship is considered powerful in developing positive intergroup attitudes, such as equal status and cooperation [8, 11]. Children show less cognitive biases when they have more cross-ethnic companions and high-quality cross-ethnic friendships than when they do not have such relationships. Cross-ethnic friendship is also related to positive change in trust and sympathy toward other ethnic groups. These growing trust and sympathy in turn predict adolescents' inclusive attitudes [12]. In the context of inclusive schooling, direct dyadic friendship is more effective in changing intergroup attitudes than extended friendship – i.e., being aware of others' friendship [13]. Especially for young children, cross-ethnic friendships seem to be associated with other positive developmental outcomes of children judged by teachers [14] such as improved social adjustment, inclusive relationships, prosocial behaviors, and leadership skills. In this research, the robotic learning community sets physical space for direct friendship of two children coming from different backgrounds, where the robot model constant positive regard and appreciation for the information and help contributed by each child.

One important challenge is that some characteristics of friendships can be subtle and are difficult to identify particularly among young children whose thoughts, language, and emotions are still developing. For young children, therefore, friendship characteristics are typically inferred from their behaviors during interactions and play [15].

2.2 Collaboration

With solid curricular efforts, kindergartens can be the context where young children not only learn early academic skills but also develop such social skills that are necessary to be successful in school [16]. Studies on kindergartners' social skills – defined as the ability to resolve conflicts, to collaborate and to understand social cues – and academic development in the first years of school suggest a positive association (e.g. [17]). Mirroring this finding, Welsh, Parke, Widaman, & O'Neil [18] report that children rated at high risk of failure in school demonstrate less than average social competence already in kindergarten. Activities and task designs which foster collaboration are essential to help develop social skills. Through joint play, for example, children learn to share objects, how to resolve peer conflicts, and what it means to work together with others. Indeed, programs designed to

help young children learn social skills are found to yield significant positive effects in the targeted competencies [19].

A promising means to foster collaboration among children is digital technology although the design and development of advanced technology to support collaborative interaction among young children are rare. Given the early stage of social and intellectual development of children, design can be focused on fostering effective collaborative communication, rather than collaborative problem solving. Our design of robotic triads seeks to elicit forms of collaborative communication which occur with increasing frequency in the real world. Referring to intercultural communication theory [20], we identify three core constructs of collaborative communication particularly for inclusion and diversity: common ground, equitable partnership, and co-cultural schemas. While two children and a robot play and engage in learning together, the robot can act as a mediator to draw both children to achieving the three communication goals.

2.2 Engagement

There is broad agreement that being engaged in learning means learners are participating actively in learning, persist when facing difficulties, and maintain a strong interest in resources available in the learning environment [21]. Renninger [22] emphasizes that strongly engaged learners appropriate resources for the purpose of learning, including to answer questions they themselves developed, in contrast to less engaged learners who simply carry out an assigned task or follow prescribed rules. Similar to the characterisation of engagement in older children and teens, engagement in younger children is described as demonstrating curiosity, enthusiasm, initiative and effort [23]. For many scholars, engagement is a description of learners' relation to the environment, not a psychological construct [24]. Psychological constructs such as motivation and interest however are directly related to engagement. It is presumed to be malleable, responsive to contextual features, and amenable to environmental change, making it an important measure to evaluate learning design.

While the positive correlation between high levels of engagement and learning achievements is well established for school grades 6-12 (e.g. [25]), much less is known on the impact of engagement on learning for young children. McClelland, Morrison, & Holmes [26] found that children demonstrating high task engagement (including with playful tasks) during kindergarten outperform their peers in academic tasks when in first and second grade. Brock, Rimm-Kaufman, Nathanson & Grimm [27] obtained a similar result for cognitive (task) engagement of kindergartners, but additionally found that high emotional engagement does not affect their academic achievement in the first school years. Blair, Denham, Kochanoff & Whipple [28] argue that social competence affects positively children's level of emotional engagement but may negatively influence their on-task behavior. Overall, there is agreement that different types of engagement affect children's learning differently, but very few studies have examined all components of engagement concurrently to identify the unique contribution of each to children's learning. Furthermore, there are additional challenges in examining the efficacy of this new type of robotic

interaction community where children's engagement is multi-layered (i.e., engagement with the robot, with the peer, and with the task).

2. Method

2.2 Participants and Context

Participants were ten kindergarten-aged children (six girls and four boys) in a rural elementary school neighboring Northern Illinois University. Five groups were formed with two children per group (one child with the native-English speaking background and the other child from the Spanish speaking background). Four groups were mixed genders and one group was girls only. Each group participated in six interaction sessions (each taking 15 to 20 minutes). The interaction activities were implemented during an afterschool program run by the school two days per week over three weeks. The activities were video recorded and transcribed for analysis.

2.2 Intervention: Robotic Interaction Triads

In an interaction triad of robot and children, we personified the robot, *Skusie,* as a new friend who just arrived from another planet and did not know much about life on earth. In this learning community, Skusie needed children's help in order to learn about animal, birthday, school, and family. Skusie spoke both Spanish and English but its speech was not always perfect. Children were asked to work together to teach Skusie. We adopted a Wizard of Oz method to control Skusie, where a hidden researcher remotely controlled its pre-scripted utterances and bodily movement while children interacted with it. Skusie asked open-ended questions as prompts to initiate and then extend engaging conversations between pairs of children, e.g., *what are animals? What do you do on your birthday? Why do you come to school?*

4. Plan for Data Analysis and Interpretation

We will analyze three sets of data: video recording, transcripts, and ethnographic observation notes. Table 1 presents our initial analytic scheme. To examine friendship development, we will assess children's behaviors in terms of three core constructs of friendship (sharing, togetherness, and parity). Friendship in essence involves sharing physical space, tasks, ideas, and experiences. Friendship is inferred by proximity as friends sit together, draw together, and play together. Parity involves being equal while children exchange views, negotiate, and agree/disagree with each other. For our observation of children's engagement, we will start with the widely accepted categories of engagement (behavioral, emotional and cognitive) [21] as a tentative conceptual guide.

Although we start with theory-based categories for each phenomenon of interest, we fundamentally will take a grounded approach to analyzing children's experiences while they

are working on tasks and interacting with the robot and each other. In this grounded analysis, observation data will be evaluated qualitatively to determine the presence or absence of potentially meaningful behaviors. We expect that these data from children's natural interactions will enable us to produce genuine elements of each phenomena.

Table 1. Data Analytic Scheme

Phenomenon	**Core Categories**	**Behavioral Indicators (BI)**
Engagement	Cognitive engagement	Taking the initiative at task, voluntary elaboration
	Behavioral engagement	Immediate responses to events, initiating new actions without being prompted
	Emotional engagement	Strong emotional expressions (verbal, facial, and bodily)
Friendship	Sharing	Whispering, helping, being nice
	Togetherness	Mutual gaze, leaning toward
	Parity	Taking turns, agreeing
Collaboration	Common grounds	Talking about personal experiences, mindful listening, understanding the other's stories and symbols
	Equitable partnerships	Yielding turns, allowing autonomy, being nice
	Co-cultural schema	Agreeing, co-construction of experiences and artifacts

4. Significance of This Work

Being able to work collaboratively and equitably in diverse groups is an essential skill to succeed in schooling and career development. We view some urgent challenges that public education faces currently (e.g., high dropout rates of minority youths) through the lenses of

equitable collaboration, friendships, and engagement. The provision of constructive contexts assisted by humanoid robots might offer a solution, where all students engage in collaborative learning of STEM topics and develop positive relationships. Importantly, the way in which collaboration, engagement and friendship interact and potentially strengthen each other has not yet been studied before. In our designed interaction setting, the three phenomena can be studied systematically. Using ENA will allow us to gain a deeper understanding of how the phenomena co-occur and evolve over time.

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