FIRST® LEGO® League: an exploratory inductive inquiry - impact and interaction
About the research

The FIRST® LEGO® League is a science, technology, engineering and maths (STEM) programme designed by the international organisations FIRST® and LEGO® Education for children aged 4-16 years. The Institute of Engineering and Technology (IET), based in the UK, delivers the FIRST® LEGO® League (FLL) programmes in the United Kingdom. The FIRST® LEGO® League programme is designed to be used for three different age/ability groups using various LEGO® Education kits:

- FLL Discover (4-6) uses LEGO® Steam.
- FLL Explore (6-9) uses LEGO® WeDo or LEGO® Spike Essential.
- FLL Challenge (9-16) uses LEGO® Mindstorm Ev3 or LEGO® Spike Prime.

More information on the FLL programme can be found here: https://education.theiet.org/first-lego-league-programmes/

Each year the programmes have a common theme. This year’s theme is CARGO CONNECT℠, focussing on finding solutions for the transportation of goods. The programme is designed to be delivered in 12 two-hour sessions but can be adapted by the coach depending on the time available.

Children who participate in FLL can be in different settings, eg, schools, after-school clubs, community groups, or home educating clubs. One of the researchers is a LEGO Coach and took part for the third time this season with three teams of children and young people aged 4-16.

This research was conducted qualitatively to explore and understand the impact of FLL on how young people interact and take part in the programme.
About the researchers

Fadoua Govaerts
Primary Investigator (PI) – Project Lead

In her final year of PhD, Fadoua specialises in alternative education with over 20 years of experience in the field of education (primary, secondary and further education). She is a FIRST® LEGO® League coach, LEGO® Serious Play facilitator and Home educator for over 14 years. Finally, Fadoua is also convenor for the Alternative Education Special interest Group (AltEd SIG) for BERA (British Educational Research Association).

Sarra Boukhari - Research Assistant

Sarra is a PhD candidate and a teaching assistant at the University of Bath. She is also a co-creator at the Skills Centre- University of Bath. She is taking part in other projects that explore different aspects of education. Her main research interests include refugee studies and children’s education.

Fatma Kormaz - Research Assistant

Fatma is a former teacher and a current PhD student at the University of Bath. She did MA in Special and Inclusive Education and her doctoral research is focusing on dyslexia and bilingualism. Her main research interests include special educational needs, social justice in education and inclusivity.

Rui Yan - Research Assistant.

Rui started her PhD in October 2021 in the University of Bath, with research focusing on gamification in EFL classrooms. With a personal interest in LEGO® and her research area, Rui was glad to observe how children engage with LEGO® robotics throughout the whole programme.

Dan Zhao - Research Assistant

Dan is a PhD student in applied linguistics and a teaching/research assistant at the University of Bath, after working as a language teacher and translator globally. She is also the chair of the Graduate Students SIG of EuroCALL. Her research interest includes technology assisted language learning and visual methods.
Context to the research

The FIRST® LEGO® League programme (with the theme Cargo Connect) was delivered during the period of January – May 2022 to home educating LEGO® Club in Swindon, Wiltshire, England. The following three programmes took place:

Discover:
A total of seven children aged between four and five years old registered for the FLL programme. Out of the seven children, six gave consent to participate in the research project. None of the children had ever experienced the FLL programme and not all children knew each other prior to attending the LEGO® club.

Explore:
The explore group was very popular amongst home educators and was full to capacity. There was a big demand for a programme like this but unfortunately, we were not able to meet this demand. A maximum of 15 children could be accommodated in this group. Out of the 15 children, one dropped out after two weeks, and 14 gave us consent through their parents to participate in the research project. The group was split into three teams, according to their preference. Not all children knew each other and it was preferred that those that did know others remained in the same team. This caused one team to only have three children, a team of six and a team of five. There were four children who had experienced the FLL twice before, the remaining children did not have prior experience of FLL.

Challenge:
The challenge group consisted of six young people aged between 10 and 13 years old. None of the young people knew each other and none of them had any experience with the FLL programme or LEGO® robotics. Out of the six children, four gave us consent to participate in this research project.

Summary
All the children were home educated and the majority did not know each other. This has impacted the extent of collaboration and relationships within the teams, although it may not have impacted the delivery of the FLL programme, it is significant to take this into consideration.

The FLL programme took place over 12 weeks every Thursday for 1-1.5 hours. Although the FLL Discover programme is designed to take place over 10 weeks, we extended this for the team to finish at the same time as the Explore and Challenge teams and take part in the Swindon FLL festival.

The primary investigator (also the FLL coach) was responsible for the funding application from the IET, planning the research project, ethical application, overseeing the data collection, overseeing the analysis and writing the report. The PI met with the research assistants weekly to discuss the progress of the data collection, and initial analysis process.
The research assistants provided support during the initial planning period. This included assisting in applying for ethical approval and designing the research study. Moreover, their input during the analysis process was vital.

Research design
The research study adopted a qualitative exploratory design (Creswell, 2003; Denzin and Lincoln, 2017) with children/young people taking an active role in the research.

Our research design combined various observational data collection methods:
- Video recording
- Photographs
- Recorded conversations

Observations took place between 3 March – 5 May 2022, with the exception of school holidays.

**Video recording**
Researchers wore “spy cameras”, which are discreet small wearable cameras. The use of these cameras and video recordings helped capture some of the details of the interactions between children and the LEGO® kits. Cameras are an effective way of collecting rich data while eliciting children’s perspectives (Robson, 2011). Video recording also increases the reliability of the data as it has the advantage of enabling the researcher to review observational data as well as increasing the levels of observations, which cannot be replicated by real-time observations (Kopenhaver Haidet et al., 2009).

Whilst it may be argued that children may find a video recording intrusive or increase their consciousness of being recorded, researchers were very aware and sensitive in relation to this. At the beginning of each session, children were reminded of the purpose of the research project as well as the role of the assisting researchers. Also, they were constantly encouraged to communicate with the researchers about any concerns they have. Throughout all workshops, children were always reminded of the possibility of dropping out without the need to provide any reasons. There had been an occasion when a child clearly indicated the withdrawal of their consent, and the researcher did not take data of that child during that workshop. Traditional observations may result in researcher observation fatigue affecting the quality of data collected (Kopenhaver Haidet et al., 2009). Video recording is frequently used in research with children as it increases the opportunity in examining the details in the data such as facial expressions and language usage (Pálmadóttir and Einarsdóttir, 2016).

**Photographs**
Instead of using only traditional observations, research indicates that engaging during data collection with the children enriches the data. We considered the participants as agents actively participating in the creation of data. Therefore, specifically with children from the Explore team, we provided an instant camera for them to be able to take images of their models or progress and share that with the researcher, prompting conversations with the child/young person. This enforced the study to keep the voice of the child the focus of the study.
We considered providing the camera to the Discover team as well but decided against it in order to prevent distraction and focus more on the research than on the FLL programme. Similarly, in the Challenge team, the numbers attending were significantly less than Explore, and much more focus was needed on mastering coding skills.

Research with children has shifted in recent years from doing research “on” children to doing research “with” children (Luttrell, 2010). Traditionally children were seen as incompetent in making judgements or unreliable witnesses about their own lives (Fraser, Flewitt and Hammersley, 2014). When doing research “with” children it is more beneficial that researchers engage with the children and their activities. In order to gain a better understanding of children's experiences with LEGO®, researchers did not rely solely on observation notes. Instead, they interacted with the children and assisted when needed. The benefit of video recording and engaging with children’s activities are approaches supported by literature in the field of research with children and young people (Darbyshire, Macdougall and Schiller, 2005; Bucknall, 2014; Clark et al., 2014; Groundwater-Smith, Docket and Bottrell, 2015; Alderson and Morrow, 2011). It prompts conversations and dialogue between the participants and researchers. More importantly, it is seen as instrumental in allowing the data collection to help in bringing forward the children’s voice and perspective (Haggerty, 2020), democratising the children’s experiences.

Recorded conversations

In addition to the conversations during the workshops which were video recorded while the children engaged in the FLL programme, the researchers had evaluative conversations with children and parents at the FLL festival. The conversations could be considered to be semi-structured interviews, with questions carefully designed and adapted to the children's ages and abilities.

Ethical considerations:

We obtained ethical approval from the Scientific Research Ethical Committee at the University of Bath (reference S22-007) and adhered to the BERA ethical guidelines (BERA 2018).

The following ethical issues were taken prior to commencing the research:

Video recording

Video recording children while playing could be intrusive. Therefore, we made the conscious choice of purchasing the “spy” cameras, which are smaller than whiteboard markers. Researchers would hold them as a pen and holding a notebook. Therefore, although they were aware that the researcher was recording, it was not “in their face” and the focus was on their creations and the task rather than on the recording device.

Voluntary participation in research project

Parents/carers will be given clear information prior to commencing this research project that participation is voluntary and that participants can withdraw during the study without giving any point. It was made in particularly clear that the children/young people could participate in the FLL programme without taking part in the research project whilst benefitting fully from all opportunities the FLL programme provides. The LEGO® sessions remained as exciting and enjoyable as it always has been, and the primary investigator ensured there was NO difference in their experience regardless of participating in the research project or not. This was communicated through the website, specifically in the participation information section and the digital consent form.
Consent
We have gained informed consent from parents/carers digitally (through an online form) and verbally informed consent from the children and young people. Gaining this consent from the children and young people has been a continuous process underscored by clear communication. At the start of the data collection during the LEGO® sessions, the LEGO® coach always reminded the children of the purpose of the researchers’ presence. The coach reminded them also of the freedom to engage or not with the researchers during the sessions. They were reminded that they can do so by informing the LEGO® coach or the researcher, without giving any reason.

Child Explore 3: Why is she here again?
Coach: To find out how and what you are learning with LEGO®?

Child Explore 3: Wasn’t she here last week?
Coach: Yes, and she will come every week to see everyone’s progress.

Child Explore 3: Well today I do not want to talk to her.
Coach: That’s absolutely fine.

Confidentiality and anonymity
We have adhered to the BERA (2018) guidelines to observe the confidentiality and anonymity of any underage participants. We have anonymised any textual and visual personal data and created pseudonyms for the participants to ensure confidentiality. The anonymisation of any visual data has been performed by blocking any identifying features of any images collected using software that turns the images into a cartoon-like drawing or pixilation.

Vulnerability
Children and young people are classed as a vulnerable population. All researchers in this project obtained a DBS certificate or were supervised and accompanied by someone who has a DBS clearance. Additionally, throughout the research project, we have been reflexive about the power differential between the researchers and the underage participants, ensuring the interactions with the young people were rooted in an ethics of care. This entailed creating a welcoming research environment, being empathic, and caring for our participants’ wellbeing within the confines of the researcher-participant relationship.

Covid19
We were very aware that we are still living amid a pandemic, and had been reminded of this several times when children and research assistants caught the virus. During the 12 weeks, researchers and children had contracted the virus resulting in their absence. We adhered to the government’s latest guidelines at all times by (for example and where relevant) wearing face masks, having hand
sanitiser presents, sanitising workspaces and the LEGO® bricks after every session. All the researchers had been fully vaccinated.

Positionality

The primary investigator (PI) for this project embodies a dual role: being the LEGO® Coach and a researcher on the project. She will address this positionality issue ethically by functioning as a LEGO® Coach for the duration of the sessions and, once they are complete, shifting back into a researcher role. The PI only operated as a LEGO® Coach during the data collection process (during the observations) and was not involved in data collection. Data collection was carried out by the research assistants, with prior agreement and guidance with the whole team discussion on what data to collect and how. Once the data collection phase was complete (once the FLL season ends), the PI ‘re-joined’ the project as a researcher. The reasoning behind this is two-fold:

a. For the PI to practice her role as LEGO® coach in full and give the priority to deliver the FLL programme to the best of her ability without being distracted by the data collection
b. For the children/young people to recognise the role of LEGO® coach to help towards and facilitate the FLL programme, and not being there to observe how they are interacting with the programme

This decision was to ensure that all children/young people get the full experience of the FLL programme. This was also made clear to the parents.

Our sample

The registration for FLL programme was advertised in local home education social media groups. A digital flyer was distributed electronically to parents/carers who had registered their children for LEGO® Club, inviting them to participate in a research project focusing on how children engage with the FLL programme. On responding to the invite, parents/carers were sent a link to a website (https://researchprojectfirstLEGOleague.wordpress.com/) set up specifically for this research project. This website had details of the research aims, a participant information sheet which includes the data collection methods, and a link to the digital consent forms.

The LEGO® Club takes place yearly in Swindon. In order to widen the scope of the research and remain within our qualitative exploratory design, more children than usual were registered for the programme. 24 Parents out of 28 children that took part in the FIRST® LEGO® League gave consent for their child to take part in the research project. Children whose parents/carers had not given consent to their participation in the research project still were able to continue with the FLL programme, but their data was excluded from the study. During any discussions and observations, children were not isolated from engaging with the programme, but the researchers excluded their data, in accordance with their parents/carers’ choices. The PI actively ensured that children not participating in the research still experienced and benefitted fully from the FLL programme and that it was not to the detriment of the children. The PI also ensured that regardless of the choice of participation or not, children were not excluded from opportunities of full engagement with other children and the LEGO® coach. The LEGO® coach treated all children equally in learning/participation in the FLL programme. The researchers observing were actively involved with the sessions and engaged with all children/young people to ensure they did not feel "left out" or excluded.
Review of the literature

Prior to the commencement of the research study the PI and RA reviewed the literature available on LEGO® robotics and FLL. Although research FLL is scarce, research on LEGO® is more common, specifically in USA.

Systematic literature reviews of research and LEGO®

There are several systematic reviews about the use of educational robotics in education (Benitti, 2012; Souza et al., 2018). Benitti (2012) has pointed out that by the time when the article was published, much research on robotic technology in education has focused on how robotics can be used in course subjects closely related to this field, like robot programming and robot construction, while only a few articles explore how robotics can replace the traditional approaches and motivate young people to develop skills, like telling a story by creating a mechanical puppet show) in other subjects such as music and art. By systematically reviewing relevant empirical articles, this systematic review (Benitti, 2012) has found that many of them use robotics in classrooms to help students understand the concepts related to STEM areas.

At the same time, Benitti (2012) suggests that future research can focus on the experience of students aged 11-12 with educational robotics since none of the articles reviewed in this study works with this educational level. It also suggests that more research needs to be done to assess specifically how robotics can be used for the development of skills, like thinking skills, problem-solving skills and teamwork skills, since the studies in this area have shown different results. Additionally, a recent systematic review (Souza et al., 2018) on the use of LEGO® robotics in education has confirmed that much research has shown that educational robotics can not only help with the teaching of disciplines but also enable the development of abilities like teamwork, problem-solving and creativity.

Moreover, it points out in the introduction section that among various robotics kits, LEGO® robotics has been seen as the best one considering several evaluation criteria like hardware, modularity level and price. LEGO® Mindstorms might be the most popular modular robotics kit since it is built on the famous LEGO® bricks and with various applications. Not much has been found on LEGO® Spike Essential or Spike Prime.

After reviewing relevant empirical articles on the use of LEGO® robotics in education, this study has found that LEGO® robotics has been applied to various educational practices during classes—it can be used to teach programming, interdisciplinary content, and participation in tournaments, robotics, and computational thinking. The results also show that this type of robotics has revealed positive results at different educational levels — from primary education to undergraduate education.

As it has been suggested above, most relevant studies apply LEGO® robotics to STEM subjects. However, there also exist a few studies which explore the use of LEGO® on other subjects, like English. For example, (Cojocnean, 2019) investigates whether LEGO® bricks can be used as a teaching tool in stories-telling activities in foreign language classrooms to help with pupils’ oral skills, and the results suggest that these young learners have shown engagement with LEGO® bricks. They perform well in story-telling and their language skills have been improved. The findings also prove that LEGO® bricks could create contexts favourable to language learning.
LEGO® Robotics as a form of educational tool has attracted many researchers from diverse disciplines. Not surprisingly, it has been found that the use of LEGO® assists students to engage in meaningful learning alongside providing children opportunities to create and develop through iterations with real world examples. We have also found some articles mentioning the FIRST® LEGO® League, although not within a UK context. The literature reveals that competitions such as FIRST® LEGO® League develop interpersonal skills such as teamworking, communication, problem solving and creativity (Chalmers, 2013), yet a large gap in the literature remains on the effects of the various programmes of the FIRST® LEGO® League on children participating in these competitions.

Research in Education and LEGO®

LEGO® research has increasingly attracted many fields with a mounting focus on its impact on education. Researchers have explored the benefits and importance of LEGO® robotics in the education of particularly young children as they are the main audience for the LEGO® industry in general. Some discussions drew on the use of LEGO® as a visual method for young people to reflect on their experiences inside and outside school. LEGO® in research is being used differently as a method to conduct a study, as a tool to deliver/improve curriculum and as an experiment to improve school performances, especially for young people.

In more detail, hard sciences in education, particularly, witnessed an acceleration due to the use of LEGO® robotics to demonstrate and showcase different scientific subfields like robotics in computer science (Zhao et al., 2008). In biology and Chemistry, many researchers have developed LEGO® designs to undertake experiments in school subjects to help improve and deliver more effective educational programs (Gerber et al., 2017). The use of LEGO® expanded to areas like Mathematics where research also highlighted some cognitive powers students may gain from interacting with LEGO®. IQ levels of students and their performance at school were one of the key areas observed in relation to LEGO® (Hussain, Lindh and Shukur, 2006). Activity-based learning using LEGO® in subjects like Mathematics proved effective with outperforming results compared to traditional ways.

A significant outcome of the inclusion of LEGO® into education is problem-solving skills (Castledine and Chalmers, 2011). This kind of research related reality with the virtual designs LEGO® can offer to help students in classrooms to solve problems (Chambers, Carbonaro and Rex, 2007; Castledine and Chalmers, 2011). Problem-solving requires critical thinking skills that research has emphasised to be improved by including LEGO® in the education process (Chambers, Carbonaro and Murray, 2008; Álvarez and Larrañaga, 2013; Korkmaz, 2016; Kucuk, 2017). The inclusion of LEGO® robotics was encouraged to be enforced in classrooms with different subjects due to the advantages they provide in the learning experience as a whole (Portz, 2002).

Further research into LEGO® robotics has implied its great impact on not only improving different educational but also fostering social skills for students with different age groups, from elementary school pupils (Kucuk, 2017) to secondary education students (Job, 2016). Research of children using LEGO® has included specific areas such as providing therapy to children with autism (Levy, 2020). Using LEGO® as a visual method with students with autism has been shown to improve social interactions between children in LEGO® therapy groups.

Although LEGO® research has been explored thoroughly from different angles, particularly within the educational field, there is still a gap in exploring and understanding reflections and interactions between LEGO® robotics and children. There is a need for research to be more inclusive to all
educational backgrounds of children, not only school students. Correspondingly, this project is trying to look closely at this particularity by potentially filling this gap and observing the contexts of interactions between young people and LEGO®.

Research on LEGO® as an intervention method in special educational needs (SEN)
Although it is widely acknowledged that LEGO® robotics help students’ learning and developing skills including social ones. However, there is a growing body of literature that recognises LEGO® as a tool to deliver intervention for children with SEN (Evans and Bond, 2021). Inclusion of children with SEN in mainstream schools is challenging due to the deficit of social skills which contribute to problems to interact with others (Bellini et al., 2007). Thus, they are most likely to face difficulties in their academic and social development. It is claimed that use of LEGO® as an intervention method is motivating and naturally reinforcing because it draws on the child’s interests to promote the development of social, communication and play skills as LEGO® perceived to be a highly structured, predictable and systematic toy (Owens et al., 2008). LEGO® based interventions were found effective to improve social skills, positive social behaviours (Levy and Dunsmuir, 2020).

Based on the literature above, we believe that this report will add new insights into the experiences of children taking part in the FIRST® LEGO® League across different ages and programmes. the importance and originality of this study are that it explores the interactions between children and the programme and the LEGO® kits from the children’s perspective and their voice remained central to this research project due to the methods used. The findings should make an important contribution gain an understanding an insight in the lived experience of children participating in the FIRST® LEGO® League in England. Since the sample of this study was limited to home educated this report does not provide a generalisable review of children participating the FLL, as it excludes participation through schools or clubs. It would be beneficial for future research to explore children from various contexts and geographical locations.

The next sections will present the findings of each programme separately, (Discover Programme, Explore Programme and Challenge Programme) and will conclude with an overall conclusion.
Findings

**FIRST® LEGO® League Discover Programme**

**Engagement with FLL Programme**

The structure of the Discover programme was effective and restrictive at times. The start-up activities were seen as a fun opportunity to warm up. Due to the background of the children taking part, the warm-up activities were perfect to set up the scene of the remaining sessions. The children had not seen each other for a week and this was the perfect opportunity to remind them of the theme and to open the space for their creativity and interpretation of the theme.

"the coach started a warm-up activity, they started following her and were paying attention to the instructions during the activity" (observation 1)

**Structure of programme**

Although the programme has a structure and focuses on the theme, there was space for the uniqueness of the child, its creativity and interpretation to come through their LEGO® models. At some points parents indicated that their children were not familiar with some concepts introduced in the programme.

*My child doesn’t know what cargo means. I don’t know if he still understands it now.* (parent)

The RA saw multiple occasions that the structure of the programme interrupted the child’s interaction with LEGO®. The opening of the big blue bag containing the LEGO® Steam kit was intriguing and children were eager to dig in. The coach eventually decided to keep the big bags at a slight distance until after the warm up activity and setting up the task for the session. The purpose of the FLL naturally enforced a task with clear aims and objectives. For this age group, there were obvious opportunities for children to explore with LEGO®, however there was a limitation to explore the topic further due to the structural nature of the programme. Although there was space for creativity and fun, free play time was not implemented in the workshops which may have caused feelings of disappointment to some children.
The programme introduced difficult concepts like “function” and “destination” and it was the coach’s task to explain this throughout the programme. Although they may not have understood or remembered the word itself, they did understand the task related to it.

Kai made a train with various additions with same function: to make it faster. He created a train with an engine and also a “windstopper” (like a sail). (observation 2)

In one of the unique interactions with the RA, Lucas explains the model he built with functions: a boat with boosters and eyes.

“He said while giggling that the eyes and can help deliver the cargo to the right destination” (observation 3)

Sophie also learnt the word destination and repeated this word within the sessions:

“Sophie: I am building a bridge so that I move to my destination” (observation 4)

Despite the structure or the advanced vocabulary, there was space for children with individual differences/ specific needs/abilities to take part in the FLL programme.

Lucas for example would not talk during the session but show us and his peers by pointing or holding LEGO® models. This was observed by the research assistant several times.

“Lucas had a gap under his train but when the coach asked him, he showed her instead how it can fly. (He did this many times throughout the workshops).” (observation notes)

We also noticed that the interactions with the workbook were limited due to some children not yet being able to read and write or having no pencil grip yet, thus unwilling to draw or write. The workbook as a result was rarely used or referenced to by the children or parents.
Problem solving within the programme
There were ample of opportunities for children to be exposed to challenges and how to approach these.

SOPHIE was trying to figure out moving a LEGO® truck on the bridge she built but it wasn’t fast enough for her. She then brought another bridge and tried to attach it. The RA asked her why she was doing that she said: to make it higher and faster, I fixed it! (observation 2)

This is an example where the session set a focus on ramps and the functions of ramps. This participant had noticed by herself that when ramps are higher the cars go down faster.

Another example with Sophie when building her ramp and it didn’t balance in a way she wanted. She went to find another brick:

“a double brick works!” (Video evidence)

Connection with the mat
The mat was a significant instrument in the programme. It was a reminder for the children of the theme but also influenced the collaboration between the participants. Although the parents’ role in keeping their models focused on the theme, the mat helped the role-play and discussions around the theme.

An interesting thing happened when he (Lucas) was building the beach house. Kai was next to him constructing something different. Then he brought the boat to float on the water and help bring people/things from the beach house that Lucas built. They co-constructed on the mat, and that was so good.” (observation notes)

Grace on the other hand very rarely focused on the theme “cargo” and rarely interacted with the coach or RA. On one occasion the RA asked her near the end of the session:
RA: What part did you enjoy most?

Grace: It was all fun!

RA: What’s the fun part?

Grace: THIS! (pointing to the mat)

The mat was also significant as a base for the narrative children created. Their models had to have a space on the mat, and they created over the weeks their narrative of transportation of their goods.

Collective Interaction with LEGO® vs Individual interaction

There were some participants who had the willingness for collective interactions and others who preferred individual interactions. The coach had four bags filled with LEGO® steam kits and our LEGO® FLL kits. This was sufficient for the participants. The two siblings Grace and Isaac shared a kit and mat, the non-participant was occasionally happy to share, Kai was flexible as he knew Sophie and Lucas, and Leo occasionally was happy to share with Sophie. Sophie was flexible sharing with anyone. The reasons behind this could be due to Sophie’s relationship with the Coach (mother-daughter relationship) or due to her personality treats. Therefore, children’s interaction with the tasks varied from session to another. Sometimes they showed interest in sharing with others and other times did not.

In the warm up activities, it was mostly the parents doing it with them. However, once on the mat, they were more open for collaboration, although limited for the reasons stated above.
Space for Creativity and imagination

The theme of creativity came forward strongly in this study. The models the children built ranged wide and far. The programme provided the space and the time for children to use their imagination and creativity in relation to the theme being explored. The children created various models as solutions to deliver goods:

- Sea planes
- Trucks
- Trains with sails
- Cargo
- Rocket launcher
- Ramps
- Engines
- Boats with wings
- Boats with eyes
- Boats with boosters
- Flying cars with boosters
- Fun fairs
- Animal parks
- Life boats
- Life trains
- Train with sails
- And 2 blades to fly

The goods that were delivered ranged from cupcakes to food for the penguins. The space for their imagination impacted their interpretation of the tasks. This created a very rich range of narratives depending on each child or team. At the end of the 12 weeks, each one of them had their own narrative of what happened on their mat and how their goods were delivered.
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Figure 6 Connecting all mats together
creating a world of cargo deliveries

Figure 7 A Solution: rocket delivering cargo
Impact of LEGO® and FLL

Parents indicated that although they may own LEGO® Duplo at home, their children were keen on using the smaller LEGO® bricks. Their children associated LEGO® Duplo with “baby LEGO®” due to the size of it. However, since taking part in the FLL programme the LEGO® Duplo had been used at home and they continued playing with their family members along the theme of cargo; building trains and airplanes. [example quote]

_Parent 1: Our box of LEGO® Duplo has come out again since he started the LEGO® club. Kai was showing his dad a train and an aeroplane out of the bigger bricks._

_Parent 2: Yes, Lucas too!

Although some children didn’t have LEGO® at home, parents did mention that at home the children continued to reference the FLL theme to other siblings and family members. This indicates that the programme has wider impact beyond the interaction in the FLL. It has opened conversations when they saw trains or trucks in public and parents actively relate their reality to the FLL theme.

Limitations

We believe that the background of the children, being home educated, could have provided this study with a very specific outcome. The collaborations between the participants were very limited due to not knowing each other. They only saw each other for one hour a week during LEGO®. Moreover, the attendance was flexible, so some children did not attend all 12 weeks which in turn would affect building the relationships within the group.

Additionally, the attachment to their parent was significant. Parents had to speak on their behalf and on some occasions build models for them. Although this may be seen as a positive interaction, it did sometimes hinder the RA in collecting data. The RA as well as the coach sometimes interacted with the participants with the understanding that they had built the model, only to find out later the parent or an older sibling built it.

In some ways the parents’ presence could be seen as enabling and disabling the children’s learning and socialising at the same time. It was enabling as children had a sense of safety and were encouraged positively by the parents. They also acted as an intermediate between the child and the coach or the child and the FLL programme by helping their focus on the theme/task. At certain times it was disabling as the parent was acting, interpreting and speaking on the child’s behalf. The attachment between the children and the parents was strong. Therefore, the researchers felt that due to the participants’ home education background it was difficult sometimes to allow the children to explore and express their own ideas.
The unique abilities also may have played a part in this study. Although not necessarily announced (except for one parent) the RA and coach agreed that some children may have special educational needs which impacted their interactions with the programme. Some children were not responding verbally to the RA but instead just continued interacting with the LEGO®, showing them by pointing or holding their creations or hiding behind their parent. On the other hand, the coach was aware of their needs and allowed them to interact in their own way.

This was shown eventually in week 9 when some children suddenly interacted on the mat and the theme beautifully. It showed that although it “seemed” they were not “interacting” within their group, they actually were, but in their own way.

We believe that had this study been taken in another context, for example a school context, the verbal interactions may have been more frequent. Also, it would have been delivered much more structured with less flexibility and space for creativity due to the number of children and less autonomous teaching methods.
Conclusion

We believe the discover programme is a very effective introduction to the FIRST® LEGO® League programme, despite the occasional constraint or abstract language for the target age. However, depending on the context and the coach flexibility this study has shown there is space for individual needs and creativity.
**FIRST® LEGO® League Explore Programme**

The Explore programme was delivered to a total of 14 children aged 6-10 who were all home educated. 4 children had experienced FFL before and were familiar with the format and structure of the programme. The venue was laid out for three teams due to having three kits for the Cargo Connect theme. However, the team participants were not divided equally despite attempts to have maximum 5 in each team. Due to being home educated, the children again did not all know each other and some preferred to stay with siblings or someone they knew. As coach I encouraged mixing the teams up at the beginning through group warm up activities and small tasks, but after week 3 they settled in the groups they felt comfortable in.

The themes that came strongly across in this programme are as follows and will be explained below each in turn.

**Levels of Competence and growth in competence through the programme**

Due to the fact that all children who registered were home educated it was expected that all children will be at different levels and abilities. As coach (and home educator) I was prepared for this. However, the data from the observations showed various forms incompetence in essential skills which caused challenges and may have restricted to a certain extent the full experience of the FLL. There are some sub themes that emerged from the data with reference to this theme.

**Literacy**

The age range for this group was 6-10 years old, 57% were unable to read or write beyond their first name. Some had very limited literacy skills, not enabling them to independently write or read a text. This hindered the children’s ability to interact with the workbook significantly. Although as a coach I had expected a level of support needed in writing and reading tasks, on this occasion the number of children who needed help was much more than expected which made me less concerned using the workbook. Instead, each week I referred to the notebook for the children who were to read and write and asked them to complete the tasks in the workbooks in their own time at home.

This disparity came notable in the final weeks of the programme, in preparation for the presentations for the festival. The children who were not able to write relied heavily on images I printed out for them to display their progress and asked me or the research assistant to write on their behalf. Moreover, none of the children who were unable to write or read took part in the team presentation. Other factors may have had some bearing on their decision, e.g. level of shyness, nervousness and
confidence. However, the researchers unanimously agreed that their inability to read and write may have influenced these other factors too.

Skills needed for collaborative teamwork
Despite four children having participated in the FLL previously, all children were assigned a LEGO® kit they had never used before. The four children had previously used LEGO® WeDo 2.0 and this time were allocated LEGO® Spike Essential. This was done consciously in order to give children a kit that was suitable to their age and aptitude to coding. The competence in coding varied from one child to another. Although all children were given opportunities in coding the robot, many challenges associated with their readiness and competence were presented.

Teamwork required building trust and rapport with team members. Hence this took time for each team to develop, at different paces. One team was unable to collaborate until the last day due. This could be due to suspected SEN, the home education approach the family is using, or a combination of these. However, that has been noted in the teams where there were children who had experience in teamwork from other clubs or past experience in schools, they had less difficulties understanding and valuing being a team member.

Instead of building one team model together, some children struggled not having their own individual model on the mat, resulting in a very busy mat with over 20 models. Eventually the team decided to reduce models and individual children “compromised” by removing their models, and ended up with 11 models. The other two groups had similar issues, although not as many models, they were able to construct a narrative by connecting the relation among all models. As the research assistant retells:

> Although they didn’t plan the final layout of the mat together like a team, the way they created the background story to make sure every piece of LEGO® block they built can fit into the overall narrative was still amazing. They could tell the individual story of each design, even when not designed or built by themselves, and these stories can be smoothly accepted into the larger picture. Some may say it’s not teamwork in the most conventional way, but I would argue that it shows how they internalised the concept of teamwork.
LEGO® as a tool of agency and autonomy in the FLL
With the various backgrounds, abilities and competences, the LEGO® kits and the mat created an opportunity for the children to express their agency and autonomy within the programme. Each individual child brought their own unique ideas to the team, from floating prisons to time travel machines. Also, an example of agency within the programme was prioritising finding solutions for different problems. As the research assistant explains:

they were planning to add music in coding, but quickly discovered that it was not executable. They decided to get rid of the music part straight away. When I asked why, Laila explained that their priority here is to get the sorting centre to work. Music or no music, it wouldn’t be their ultimate goal. Secondly, they found a loophole when dealing with the colour recognition issue in the sorting centre that can be manipulated manually. So they decided to make use of such a loophole while perfecting their coding as well. These not only indicated their problem-solving skills, but also showed their organisation skills, as well as how they pay attention to details.

This came also forward with children with Special Educational Needs. Although not all parents shared this information with us, four parents indicated they either suspected or had a diagnosis of ADHD or/and autism. Despite this, all children participated in all activities and withdrew from certain activities when they preferred. This empowered some children to excel in some tasks and take their time in other tasks. LEGO® bricks facilitated communication within the teams and with the coach. In one session one participant spent nearly an hour exploring the cogs and tires in the FLL kit. Although he did not want to take a role in programming the robot, he explored the function of the cogs in the model. At the end of the session, he created a model made of 5 pieces representing the part of the robot. He then decided it could be used as a model on the mat as a tool to replace tyres on a broken-down truck. The team members valued his input and included the model on the mat. This event reinforced FLL’s core values teamwork and inclusivity.

Figure 9 Exploring functions of cogs
The impact of learning environment and background on relatedness and level of engagement in FLL programme

Due to the context of the participants of this research project, this theme came through very strongly. Although it may also be the case in other contexts, such as schools or other extra-curricular clubs, in this case the learning environment is their home and with family. There was a significant difference in the way children interacted with the programme. One research assistant noted the following:

_The most obvious example would be that Sonya and Aziza were much more comfortable of using the word “robot” compare to others in the group. It came out very nature when they talked about the actual LEGO® blocks and the stories and ideas behind the LEGO® blocks. One of the reasons could be that they aren’t strangers to the workshops, but I think their father as a robotician who insists on playing robots with them at home may have a stronger link to it._

Home educators are known to promote autonomous and individualised learning. The FLL has a structured programme with a theme, aim, objectives, and tasks related to these. At some points it was observed that the structure or content of the programme supported some children and facilitated their progress. On the other hand, it was also noticeable how the structure contradicted their usual learning environment in which they learn less structurally and freely. These children felt restricted and sometimes frustrated to keep up with the theme or the tasks for that week. Despite this axis the researchers believe that there is space to adjust to children’s abilities, needs and interest. It seems impossible to deliver a programme such as FLL some kind of structure, theme or weekly tasks.

Also, what was noticeable that some children were immensely attached to their parents, which sometimes obstructed their engagement with the tasks and their team members. On other occasions parents were able to intervene as assistance in challenges or conflicts within the team.

Conclusion:
As the research assistant explains:

_it was quite an interesting and magical journey seeing how much children learn and change during the FFL. LEGO® was unifying, a way to express their inner world, a tool to play and have fun and an opportunity to learn from peers. Grouping children who are literate and illiterate would be fair for the next grouping sessions. My recommendation would be creating a structured Explore Programme which they can express themselves freely without worrying about finishing tasks as it destroys the fun bit of FLL for this specific age group._
**FIRST® LEGO® League Challenge Programme**

The FLL Explore programme was delivered to six young people aged between 10 and 13 years old, but only four parents gave consent for their children to participate in this research project. The six young people were divided equally in two teams. Like the other teams all of them were home educated and none of these young people knew each other prior to this programme (except for the 2 non-participants who were siblings) and none of them had any experience in the FLL or LEGO® Robotics. The motives for signing up varied, but it was clear there was a passion for LEGO® and a keenness to learn how to program. The Challenge FLL programme can be seen as two programmes combined in one, needed a combination of skills to complete: the research element which requires a presentation, and the programming of the robot in order to complete mission on the table. As with the other teams, due to the educational background of the participants, not all young people were interested in all aspects of the FLL programme. Only two young people were interested in completing a research project and present their findings and solutions. Others were only interested in programming and one was only interested in building the missions. The educational approaches within the home education community vary significantly. Home educated young people will likely have been accustomed to an appropriate educational approach at home, which may range from an unschooling approach to a more autonomous approach. This may be related to their learning needs, or the parent’s educational philosophy. In order to be inclusive in the LEGO® club the coach had to be aware of these approaches and allow flexibility in allowing the young people to invest in tasks that they wanted to invest in. This had an impact on the FLL core value: teamwork. The presentations of the research projects therefore were not a product of teamwork, instead Sandra and Ismail worked on their project and presentation individually at home.

The analysis of this team brought up three themes which are described below.

**Engagement with the ROBOT**

The young people’s engagement of children with the programme and the LEGO® kit varied from one to another. The level of engagement depended on their skills but was stimulated by a combination of passion and excitement. The participants who were passionate about LEGO® and programming were eager to learn programming and building the robot. There were many problem-solving situations which were dealt with individually or in teams. The excitement came through when their programme was trialled. The skills required in order to engage with the robot varied from the aptitude and readiness to follow instructions, to negotiation and perseverance.

Another factor in the level of engagement with the robot was the handling of the laptop. It was observed that when teamwork was hindered, the laptop seemed to be a symbol of power. The person in control of the laptop also seemed to perform in the role of the team.
leader. The control derived from handling the programming codes on the laptop which determines the movement of the robot. At the same time, it should also be noticed that when the team cooperated well, the laptop was just a computer without standing for any power. In this case, one child controls the robot and another one controls the laptop. They discussed together in an equal power relationship.

Interaction with team members
Due to Covid and out of term holidays, we experienced a lot of absences throughout the sessions. There were weeks when Sandra was on her own in her team. This was a good opportunity to have full access to the laptop and robot and to develop her programming skills in her own pace and way. During these weeks we observed a significant improvement on her programming skills and on her confidence in handling the robot. However, this did not limit her interaction with other team members, instead as the only member in her team, she had the opportunity to interact with members from the other team.

Hannah was happy to change team for a while to help out Sandra with her programming skills. Sandra was behind the other team as she struggled with a task related to the robot picking up a cube. Although Sandra asked the coach for help, the coach did not give any answers. Instead the coach asked Sandra to look at the codes and try to understand the function of each code. Hannah heard this conversation and left her team to join Sandra and said:

Let’s do this together, we are one team. (observation notes)

Although, it may not have happened if Sandra’s team members were present. Yet, the fact that Hannah volunteered to help Sandra out, created a lively and friendly learning environment. The fact that they did not know each other prior to coming to this LEGO® club did not stop Hannah from taking the initiative to help out Sandra.
It was observed that the participants interacted with team members because of the following factors:

- Participant own competence in programming
- Other participant’s competence in programming
- Other’s perception of each other’s competence in programming
- Relationship between the participants and group dynamics

To give an example how this effected interaction within the team we give the following example.

On occasions, we found that a participant was not feeling confident in a programming task. This caused them to withdraw slightly from the group and their withdrawal would be picked up by other team members. When a suggestion or comment was made, this in turn was not taken seriously due to the other team members sense of lack of competence from this participant. Levi for example was often being excluded as he indicated he was not interested in programming the robot. Instead in the first few weeks Elli would focus solely on building the missions. Although they would start all on the robot table discussing the tasks for the session, after a while Levi would do back to building the mission. Once all the missions were built, he never wanted or attempted to have an input in programming the robot. As a result, the other team members continued working together on the missions, whilst Levi just watched them. This was then discussed with him and his parent, but he indicated he had no interest in learning to programme because he saw how hard it was.

Role of the coach

The role of the coach in the CHALLENGE programme is more of a facilitator rather than a teacher. Over time we found that the participants took time to build rapport with the coach. The coach offered tools and techniques to help towards solving problems, instead of giving answers to their questions. The coach’s lack or expertise in programming, combined with extended experience in home education and professional background in educational philosophy influenced approach in how the coach fulfilled her role. Below is an example from the researcher’s observation:

After amount of tries, the children found that the robot still stopped in the middle and failed to arrive in the destination. The coach came up and offered hands-off suggestions that the children should add more codes to make the robot continue moving forward. The children took the advice and went back to modify their codes. In this way, the coach helped with the improvement of children’s coding skills.

On some occasions the coach’s role was to help scaffolding their thought process when solving problems. This resulted in moral support and encouragement which helped in building their confidence and competence. This has a great impact as it gave them agency and autonomy in their learning and development in the skills that are needed for that particular occasion.
In the session where Sandra was asked to finish the task alone, she was shy and not confident. The coach kept encouraging her by saying “You can do it!” “Let’s try!” “Well done!”. Though Sandra was not able to do some simple things such as connecting the robot to the Bluetooth, the coach was very patient to help with her by telling her what to do. Therefore, it can be seen the emotional support provided by the coach was very essential for children to do tasks. (observation)

Additionally, the coach as an adult sometimes used their power to make marginalised participants heard. There was an incident between Sandra and the non-participants. Sandra had prior to that week 2 consecutive weeks of full access to the robot and laptop and made a significant progress. While she was behind the other teams previously, Sandra managed in the two weeks to complete one mission. However, upon the return of her team members while working on a mission together, her suggestions were not heard and she was not given access to the laptop. The coach stepped in and asked for Sandra to be included. Although Sandra did not verbally ask for the coach to intervene, her withdrawal and change of behaviour indicated that she needed the adult support to make her heard. As a result, for the remainder of the session Sandra was more included and given access to the laptop to work collaboratively on the laptop. This intervention from the coach was vital for Sandra in order to be heard and be included.
Overall conclusion

We have noticed evidence that may suggest that the FLL, unintentionally, was an intermediation for children with SEN. Parents state how attending a programme like this was very beneficial for their children’s social skills and learning to work with others. Children who have SEN were able to feel included in certain activities without the pressure to do it in a specific way.

There is current literature that supports LEGO® play as an intervention for SEN. Although FFL is not aiming to intervene in children with SEND but data from this study, including data from EXPLORE team, suggests that the young people’s social skills, collaboration, teamwork, and problem-solving skills improved during the whole eight weeks of observations. Children who are in suspect of having SEN in the EXPLORE team, had made huge progress in certain areas. Thus, we would like to argue that FFL has an effect on children with SEND (Special Educational Needs and Disabilities) unintentionally and could be used as an intervention.

Unfortunately, the coach did not have an expertise in SEN. However, the research team included expertise in this area and therefore it came up during the analysis process. As a result, we believe that this could have been better explored and implemented if the coach has the appropriate experience or training.

Also, the flexibility for some children to opt in and out of certain activities, although it had an impact on the core value of teamwork did allow the programme for children to exercise agency in their learning.

Although we started this project with the intention to use a Froebelian theoretical framework, during the data collection, we realised for this study it was necessary to bring forward the experience of the participants and to have a more exploratory approach. However, two theories did come to the surface and returned serval times during our discussions:

1. Self-determination theory (SDT)
2. Zone of proximal development (ZPD)

Self-determination theory (SDT)

SDT is a theory within psychology which relates to how a person may perform to the best of their ability. Deci and Ryan (2000) argue that a person has three basic psychological needs that need to be fulfilled: autonomy, relatedness and competence. Once these three needs are fulfilled, SDT argues that that is when humans perform, work or learn best. Much literature is available on learning while being intrinsically motivated, although we believe is out of this report’s scope. Nevertheless, we do believe we have seen in the EXPLORE and CHALLENGE team that autonomy, relatedness and competence had a great impact on the level of engagement with the programme and the interaction within their teams.
The educational philosopher Vygotsky (1978) developed a theory for learning and development. This theory is well recognised in educational research and extensively written about. A key construct within this theory is the ZPD, which is a space between what a learner can do unassisted and what a learner can do with guidance. (The zone of proximal development)

In all three teams there was evidence of tasks which the participant was able to do unaided and with guidance of a parent/coach/research assistant/team member. In the EXPLORE and CHALLENGE team we noticed that the development of their skills to perform the tasks (may this be collaborative skills or programming skills) was not a linear development. Their development varies immensely and was influenced by other factors, such as their readiness, who was present or absent in their team, what skills needed to perform the tasks. On some occasions, the in the EXPLORE team it also depended on whether the parent was nearby or not.

The role of the coach is significant within this theory and this was noticeable in this research study. The coach made clear throughout the sessions that she had no experience in coding and never coded a robot in her life. This statement was reinforced when participants asked for help (when they were in their ZPD). On most occasions, the coach did not give answers but, asked more questions and to scaffold their approach to solve the problem. Despite this happening unintentionally, during the analysis process this was identified and strongly recognised.

The two theories are relevant to this study and to the FLL programme. Although it has a positive competitive nature, this study showed that there is space for flexibility, and inclusivity for young people with specific needs. In this study this was very much needed due to the home education context. However, it may be that the FLL be used as an intervention within schools or other educational provisions. SDT and ZPD are eminent and principal educational theories, and we argue that the FLL, based on these two theories, can have significant impact on young people’s development and learning besides mainstream education, in alternative provisions. We highly recommend further research in this area.
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