PLYMOUTH COLLEGE of ART

making FUTURES

Bespoke product design and manufacture for disabled children: A case study of products and their perceived effectiveness on user wellbeing

by Associate professor Ross Head, School of Applied Art and Design at University of Wales Trinity Saint David

Abstract

The paper shows a demonstrable process through which beautifully designed and intrinsically useful products can be produced on a bespoke basis for disabled children. These products have been proven to aid inclusion in society, improve health and wellbeing, and form a unique and emotional bond between designer/maker and client. Three examples are discussed, showing breadth of design and variety in requests for help.
Cerebra Innovation Centre are able to improve the wellbeing and quality of life for their clients using intelligent and beautiful designs that enable children to be included in family and social activities. In addition to inclusion, this paper suggests that acceptance into mainstream activities, from which a child might previously have been excluded, also stimulates wellbeing in the child, the family and even spectators.

Introduction

The aim of this paper is to demonstrate how excellent design and small scale/bespoke manufacture fulfils a significant gap in mainstream provision of equipment for disabled children. The author proposes that such bespoke design and manufacture enables and enhances inclusion and promotes wellbeing for the child, family and peer group.

Cerebra Innovation Centre (CIC) designs and makes bespoke products to for children with brain conditions. When mainstream or commercially available products or solutions are unsuitable or do not fulfil the child's complex needs, CIC is able to design and produce physiologically and aesthetically appropriate products which not only fulfil the physical brief, but also address an important human centred approach to inclusion and acceptance. In many instances CIC's approach to design-to-make supersedes expectation and has resulted in boosting the child's confidence and health.

Inclusion is well documented as contributing to improved quality of life (Bailey, 2007; Vuori et al, 1995). Inclusion with peers, family and in sporting activities supports this quality of life improvement and is vital for children who otherwise might get left out (Social Inclusion Unit, 2001). Many children with profound disabilities cannot access sport and activities due to ill-fitting or unsuitable equipment. The CIC team feels this is not an acceptable reason for lack of participation when, reasonably priced and logical solutions can be designed and the benefit of such inclusion is so highly prized by able bodied people. Inclusion within sport/activities can be defined as relational (sense of belonging and acceptance within a club or team) and functional development

(enhancement of knowledge, skills and understanding) (Freiler, 2001). The author proposes that the examples given promote rational and functional inclusion.

In a design industry which has been playing catch-up to high-end aesthetic and highly functional consumer and sporting products (Christophersen 2002, Torrens and Black 2011), CIC has sought a niche market responding to individual requests for a product. Some of these products are then manufactured under license by third party companies, providing an income stream for the charity.

The CIC designers/makers tailor a product to the specific needs of the client. Using mainstream aesthetic and product design principles, high technology and traditional workshop tools, CIC provides bespoke equipment which becomes the envy of others and demonstrates acceptance and admiration for facing and overcoming one's challenges.

Cerebra, a national charity, focuses its attention on children with brain conditions. This includes typical diagnoses such as autism, cerebral palsy, epilepsy, and developmental delay amongst an almost endless list. Many of these conditions manifest in a variety of ways: some limiting mental development, some affecting physical ability and many affecting both in varying degrees of severity. The challenges presented to the child and those surrounding them can be significant. Daily activities that most people take for granted such as preparing and eating food, showering and toileting, mobility, sport and socialising can be extremely difficult and sometimes impossible for individuals without the help from their parents, siblings and carers. Myriad products, systems and services exist to support people of all ages, yet the physical challenges presented by some of these conditions are so specific to the individual that it is impossible to cater for all needs with limited numbers of product iterations on the market. Thus the need for a specialised design team who can react quickly to explore a problem and develop bespoke solutions to enable children to participate with their peers and to be included within their communities and wider society.

Cerebra Innovation Centre invites applications from parents of children with brain conditions who are struggling to find a product that works appropriately for them. CIC offers a free service to develop specific products that satisfy the needs of the clients, and focuses heavily on function and usability whilst ensuring those products are aesthetically outstanding. Much of the equipment needed to enable daily activities for children is extremely expensive and must, by necessity, be able to suit as wide a range of people as possible. This often requires adjustability to fit a range of sizes, which presents a challenge for aesthetics (Pullin, 2009). Bespoke design enables the design team to focus on the specific attributes required by an individual child and can therefore streamline the design aesthetics. It is extremely important to the ethos of the team that children receive something that not only allows them to take part, but also draws them to the heart of an activity or organisation. For the team, a successful design is measured in the "proudness of ownership" of the children and their families.

Method

The methodology employed for this paper is a case study review of products and their perceived effectiveness on the wellbeing of a child. Case study review of products is the most effective way to show to the work and its perceived benefit. Anecdotal feedback from parents and bystanders is compelling. Results are demonstrated by the child's ability to participate successfully and the improved sense of wellbeing, accomplishment, inclusion and acceptance.

The case studies investigate the suitability of design, the process employed and the perceived effectiveness based on the user's feedback. The three case studies have been chosen from a large database of prior works

to demonstrate a broad range of products in terms of the design, interaction with client, complexity of build and the techniques/technologies employed in the design and build stages.

Case study 1: Ice skating sleigh

A young lady called Enna-Thea was invited to an ice skating themed birthday party to be hosted at a Winter Wonderland. A group of nine classmates were invited. Enna-Thea is intelligent, thoughtful and inspiring. She has cerebral palsy, which affects not only her legs and feet, but also her mobility and balance; but with walking aids she is able to access many activities. However, it would not be possible for her to wear ice skates; since she could neither get them on, nor stand in them. It was felt that spectating at the party would be detrimental to Enna-Thea's wellbeing and confidence, and as such CIC endeavoured to find a solution.

Effect of attending party: The thrill of gliding smoothly, the sound of blades on ice, the cold air on your face as you slide along cannot be replicated. The interaction with other skaters, the smiles, holding hands and skating together; the carnival atmosphere and smell of hotdogs and candyfloss, the twinkling Christmas lights; these feelings provide an experience that promotes wellbeing and generates lifelong happy memories.

Effect of not attending party: Disappointment, exclusion from: friendship group, activity, and elation of skating, exercise and sensory stimulation. Also disappointment for the family and friends, who would need to console her.

The brief was to enable Enna-Thea to go to the ice skating party and participate in the fun.
Starting with research and brain storming ideas, various skating aids used to help learner skaters stand up safely were investigated; none were discovered which would enable Enna-Thea to skate. As such, the team investigated methods by which a seated skating aid could be developed. The concept required that it would be seated, safe and secure, would steer adequately and could be transported to the ice rink.
Based on a traditional Nordic sleigh an initial set of sketches was made, exploring style and the outline concept as shown in figure 1.

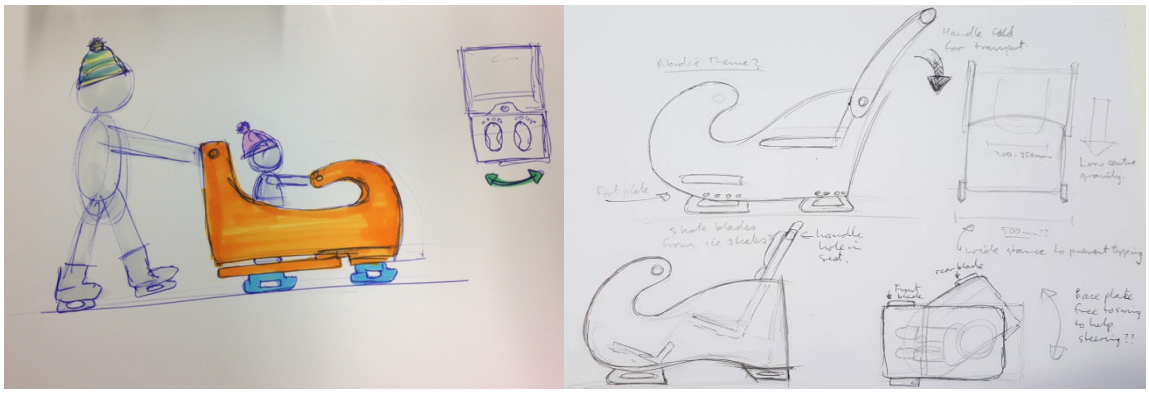

Figure 1 Concept sketches

The design intent had to evoke a sense of fun, pride of ownership, traditional winter sport/activity. The product had to be functional, safe and stable, and also needed to be transported with ease. Moreover, it had to be made in the workshop to a tight deadline with materials that could be processed in-house.

With the concept design agreed, the design team moved to Computer Aided Design (CAD) tools quite quickly. This enabled dimensions to be confirmed and framework built around this known entity (figure 2). Manufacture would comprise computer numerical controlled (CNC) router for birch plywood and traditional woodworking and finishing.

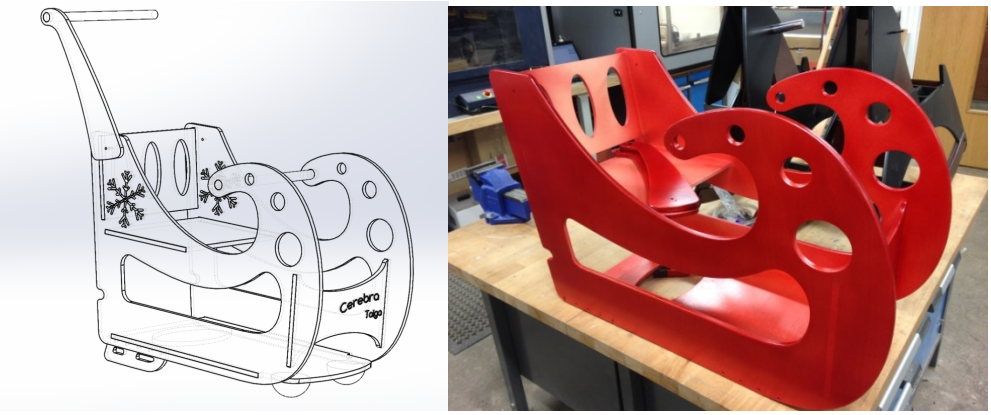

Figure 2 and 3 Computer aided designs for sleigh and assembly in workshop

The parts were assembled using exterior wood glue and mechanical fixings to ensure superior strength and reduce likelihood of failure as shown in figure 3.

Results

Figure 4 Enna-Thea and Raoul

Feedback and photos (figure 4) from the parents show that being able to participate in the event, feeling included and enabled had a profound effect on Enna-Thea and also those around her.
Verbally feedback stated that the staff at the ice rink was queuing up to skate with Enna-Thea and that everyone enjoyed the experience. Having been able to participate with friends and family boosted her confidence and gave her much needed interaction with her community. Enna-Thea sat in the chair whilst being pushed by friends and professional skaters.

Enna-Thea's mother wrote:

"Enna Thea had the most wonderful time in the sleigh. She got in and exclaimed at the comfy cushion, and loved the shape and decorations. Me too!
I had not skated since I was a child so was very slow, but there was a fantastic helper called Raoul who raced her round in twirls and arabesques.
I had been worried Enna-Thea would be too passive but with his energy she had to move and coordinate her movements to stay upright at each turn. She also put out her arm for left and right turn, directing Raoul. He also made sure Enna-Thea was able to join in with her friends.
And I loved it too as I had forgotten how lovely it is to skate. We are going again next week!
Thank you so incredibly much; please let us know if there is anything we can help with. CIC is an amazing organisation!"

Case study 2: Horse riding helmet.

Tommy-Lee is autistic. His school class attended weekly horse riding lessons but he was unable to partake due to his very large and unique head shape preventing him wearing a helmet. Without a well-fitting, certified helmet riding is not possible, yet Tommy-Lee went along for the day and helped groom the horses, clean them out and watch his class mates ride. He was desperately lonely and felt left out but he felt a keen connection with the horses and enjoyed his time with them. This had taken place for one year by the time the school contacted the CIC team.

Initially the team was unsure how to proceed; it seemed prohibitively expensive and would require processes and testing, which would be financially out of reach. However, an intensive concept generation session proposed a radical solution using a digital scanner to achieve an accurate head form, 3D printer to make a mould, CNC manufacture for the foam inserts and Kevlar outer shell. This was to be a very long project but with the goal to get Tommy-Lee horse riding before the summer holidays.

Effect of participation in horse riding: Inclusion with group, bond with horses, exercise, fresh air, sensory input, and medical benefits such as mental and muscle relaxation and therefore significant increase in wellbeing.
The brief for this project was to enable Tommy-Lee to go horse riding by providing him with an appropriate protective helmet. Research showed that bespoke helmets are available but within certain sizes and tolerances. Tommy-Lee fell outside of this maximum size.

The first step was to meet with the child and scan his head form using an Artec Eva digital scanner. The scanner works by taking a sequence of photographic images, transmitting them to a laptop and software which "stitches" them together to form a three dimensional model. The process, whilst not physically intrusive, is quite intensive. The subject is required to sit quite still and shield their eyes from the flashlight. A tight fitting rubber swim cap was worn by the subject to pull his hair tight to the skull. The hat was marked with reference points to help the software with orientation of the resultant computer model.

Once the overall head shape and size was known, a CAD model of the helmet was developed, ensuring that at its thinnest point the helmet inner skin would be 25mm thick. Due to the irregular skull shape the wall thickness varies considerably as shown in figure 5. The helmet was designed to replicate an existing horse riding helmet style in order that the child would appear like the others.

Figure 5 Proposed helmet design

In order to comply with testing regulations, five identical helmets were submitted for destructive testing. This required that a mould be made to ensure precise replication of each unit. The outer shell shape was transposed into a mould that was 3D printed using ABS plastic as shown in figure 6. To aid part removal the mould was built in four parts. Once sanded smooth and release agent applied, layers of fibreglass and Kevlar were laid into the mould with an epoxy-bonding agent.

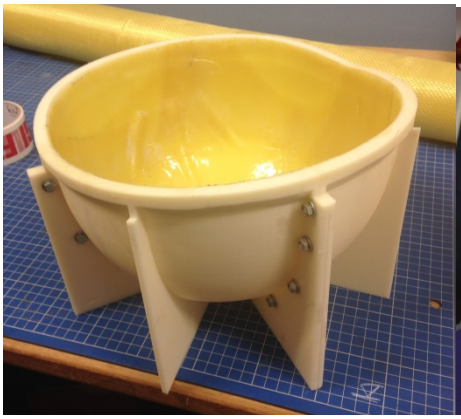

Figure 6 3D printed mould

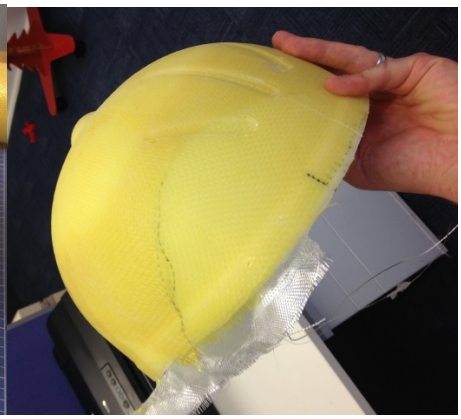

Figure 7 Kevlar shell removed from mould

The Polystyrene inner skin was machined using a robotic arm-milling cutter. The inner skins were bonded into the outer shells and straps fitted. The five test samples were then submitted to the British Standards Institution (BSI) who generously offered to test and certify the helmets free of charge. They were tested to VG1

01.040 2014-12 helmet for equestrian use, which submits them to impact testing, drop testing, lateral crush testing and all repeated at -20°C and 40°C.

The sixth helmet was finished with a fabric inner lining for comfort and sprayed with a textured black coating to replicate regular riding helmets.

Figure 8 Tommy-Lee horse riding

Results

With encouragement Tommy-Lee was able to ride immediately on delivery of his new helmet. He was able to enjoy multiple benefits of horse riding, including health, fitness, relationship with animals, and inclusion with peers. The enjoyment was clearly visible on Tommy-Lee whilst tentative with the riding itself. The overall excitement was unmistakable. The benefit of inclusion with his classmates and closer animal bond was clearly visible; Tommy-Lee was beside himself with joy and excitement. Whilst the team only witnessed a short riding session, the school fed back to CIC that the day had a profound effect on Tommy-Lee's confidence and that he was looking forward to future horse riding lessons with anticipation.
Some weeks later Tommy-Lee wrote to the team via his schoolteacher to say that he had progressed to learn to ride a tricycle (which was restricted to helmet wearing pupils) using the helmet and that the overall experience had made him "very happy".

Case study 3: Triathlon equipment.

A young lady with quadriplegic cerebral palsy asked for assistance to participate in triathlons with her father. CIC responded with a stable, yet hydrodynamic boat and unique running chair that transforms into a bike trailer. The equipment is high tech and sporting in appearance and function.

This case study demonstrates the ability and effectiveness of excellent small scale design and manufacture to change lives and deliver wellbeing and health benefits through inclusion and ability to access activities that were previously out of reach.

Whilst investigating potential sporting activities within which the father-daughter team could participate together, they stumbled upon the idea of Triathlon. At first, the idea was quite fanciful as Poppy is does not have voluntary control of any of her limbs. Poppy is a positive and remarkable human being who continually pushes boundaries and belies medical professionals with her ability. And so the triathlon dream was born. The plan was for her father to tow and push Poppy around the Cardiff Triathlon course; which required a watercraft that would be easy to tow whilst swimming, stable, comfortable and with the appropriate harnesses

and supports for Poppy. Additionally, a wheel chair was required that would enable stability at running speeds yet enough manoeuvrability to navigate the course. The design team made an early-decision in the process to combine the running chair with the cycling trailer to reduce the amount of kit required; thus only one chair was required that could serve two disciplines.

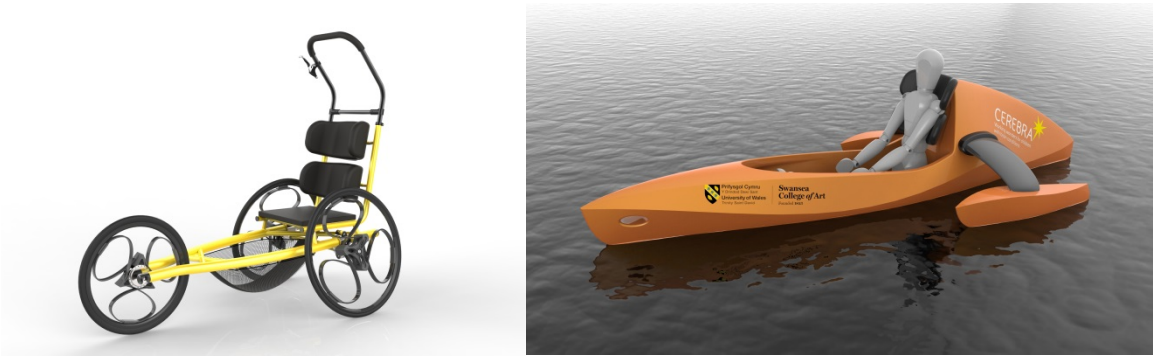

Figure 9 Computer aided design proposals

The designs were devised as shown in figure 9. The proposed designs were discussed with Poppy's family and numerous medical professionals to ensure safety and suitability and to fine tune. The design intent was for high-level competitive sport equipment in appearance and function: an equipment that implied speed, professionalism and sporting prowess.

Manufacture for these products was outsourced for some components such as the CNC machined polystyrene for the boat and the tube bending and welding for the running chair. All other aspects were manufactured in house by the CIC team as shown in the photo collage, figure 10. This includes shaping, sanding, fibreglass, finishing, spray painting, CNC work, 3D printing, welding, machining and sewing amongst many other processes.

The team worked closely with the relevant occupational therapists and seating specialists V-Trak to ensure the work was suitable for Poppy's complex needs. Additionally, the team worked with professional nutritionists, physiologists and trainers within University of Wales and very closely with the triathlon organisers and Triathlon UK.

Figure 10 Overview of some manufacturing processes employed

Results

Poppy considers herself an ambassador for cerebral palsy and used the events as a platform to reach thousands of people and show them what is possible with a can-do attitude.

The event itself and the preparation for it had a profound effect on Poppy, her family and a number of people who had volunteered their services. The event thrust this small team of people into the middle of a large-scale event, including television crews and a 10,000 strong crowd; it was both inspirational and emotional. Families who had never thought it possible that their child might be involved in something so radical realised that everything is possible with a small helping hand.

Figure 11 Poppy and Rob during triathlon

Poppy's father commented:

"I was starting to feel that I was failing Poppy by not being able to help her do the things that she wanted to do. It would have been too easy to say we cannot do that because of Poppy's disability; that concept did not sit well with me, it was not an acceptable answer. The experience has affected Poppy in so many positive ways. We now know that we can go beyond limits. It has gone beyond Poppy's dream, she has inspired other people to push boundaries, this is a dream that lots of children and families can have and can have a go at things that previously felt they weren't entitled to. We have now completed Cardiff and Swansea triathlons and Poppy and I are completely hooked on competing, the buzz is incredible".

Poppy experienced medicinal benefit from the motion and uses the equipment regularly to play in water and to get out with her family. Additionally she experienced a gain in confidence and has since gone on give inspirational talks, complete half marathons, full marathons and numerous triathlons. The overall increase in wellbeing through participation and inclusion in team sports for Poppy through the use of the CIC equipment has been astounding.

Conclusion

Cerebra Innovation Centre's bespoke design service has demonstrated an alternative method of design thinking and tailored manufacture that solves physical problems whilst specifically increasing inclusion and acceptance of disabled children in mainstream activities. In many instances being left out had been shown to have been something that the children/families would previously have expected or accepted. Proof of increase in wellbeing is evident in the children's ability to participate in events that they longed to participate in with friends and family. In most cases, the smile on their faces is indication enough that they are happy and feel included.

Proof of acceptance is evident in the crowds of onlookers, spectators and well-wishers giving encouraging comments and support. It is argued that the concept of increased wellbeing also affects this wider audience; supportive comments from hundreds of spectators at a triathlon and the media attention focused on Poppy when she races shows that friends, family and general public enjoy being part of the event.

Whilst this paper concerns only a small sample of products and clients, CIC aims to make up to sixty new products per year that would enable a superior study to be carried out. Further examination and by more rigorous methods are required to investigate these proposals and to produce statistically robust results to support these anecdotal results. In which case, it is suggested that a "before and after" scenario would produce the most viable results, so the case studies would have to be built up over time rather than use pre-existing examples such that the family can be questioned before receiving a product and afterwards to see any apparent change in wellbeing.

References

Bailey, Richard (2007) Evaluating the relationship between physical education, sport and social inclusion

Christophersen, J (2002) Universal Design: 17 Ways of Thinking and Teaching. Husbanken.

Freiler C (2001) From experiences of exclusion to a vision of inclusion: what needs to change?

Pullin, G. (2011) *Design meets disability*. Cambridge, Mass.: MIT Press.

Social Exclusion Unit (2001) *National Strategy for Neighbourhood Renewal: Policy Action Team audit* (London, Cabinet Office)

Torrens, G and Black, K (2011) 'Equipment design in inclusive physical activity and disability sport', in Roibas, A (ed) Design for Sport. Farnham: Gower, pp. 153-178.

Vuori, I.; Fentem, P.; Svoboda, B.; Patriksson, G.; Andreff, W.; Weber, W. (1995) *The significance of sport for society: health, socialisation, economy* (Strasbourg, Council of Europe)