Songs are the tapping of keys… Coding events for Kids

Nigel Beacham

University of Aberdeen
Computing Science, Meston Bldg.
Aberdeen, AB24 3UE, UK
+44 (0)1224 2723878

n.beacham@abdn.ac.uk

Janet Carter

University of Kent
School of Computing
Canterbury, CT2 7NF
+44 (0)1227 827978

J.E.Carter@kent.ac.ukBruce Scharlau

University of Aberdeen
Computing Science, Meston Bldg.
Aberdeen, AB24 3UE, UK
+44 (0)1224 272193

b.scharlau@abdn.ac.uk

**ABSTRACT**

In this pilot study we look at the UK based weeklong Festival of Code, which is organized by Young Rewired State, and has for the last five years, and explore what impact this has had on the 7-18 year old attendees and their subsequent development. This team based coding exercise for children has grown from 50 to 1000 participants and will have important lessons about how we address computational thinking and teaching computing science to the next generation, as well as what lessons can be learned from these informal events.

# INTRODUCTION

Each year Young Rewired State (YRS) organize the weeklong Festival of Code for children aged 7-18 at multiple sites across the UK, which culminates in a weekend event at one location for all participants. The weeklong event has been happening for five years now. We wanted to ask participants what they and their parents have experienced at the events to see if it offered insights into what will follow as more children start to code.

# BACKGROUND

##  Coding for Children Assumptions

For a number of years groups in both the US and the UK have been arguing that children should learn to code, and to understand computational thinking [27]. This is seen in both the Computing at Schools Working Group in the UK [21] and the Common Core State Standards initiative in the US [26], and has led to the ‘hour of code’ approach [12] as a means to introduce children to computational thinking [30].

A number of groups such as Coder Dojo and Code Club sprang up to meet this need. Coder Dojo is for primary and secondary aged children interested in coding and technical skills founded in 2011 [7]. Code Club started in 2012 for primary school aged children and follows a specific lesson plans at each session [25].

Before either of these groups started, YRS was quietly evolving and having an impact on children and parents. It started as a weekend hack event in London in 2009 [19, 28], and has always helped the push for STEM teaching and the need to address the number of women participants, which has grown to about 30% of YRS attendees. However, this paper only addresses the perceptions of the YRS participants and their parents.

## YRS Background

Rewired State launched in 2008 in order to show the power of open data based applications to organisations by framing projects around small experiments with limited resources. The first Rewired State event had few young people, so YRS was launched in 2009 as a means to encourage young people into the joys of community hacking events based around open data, and saw 50 participants at the first event. The 2010 event ran for a week, and had twice the number of participants [22, 19]. In 2014 the YRS week saw 1000 children in 61 centres taking part [19]. This is a lot of participants, which they repeatedly attend if possible, as shown later in Table 3, it makes sense to ask them about their experience, and to see if there are patterns in attentees’ characteristics, beliefs and attitudes, and development.

The Festival of Code week runs as follows: Children are hosted at centres around the UK Monday to Thursday. Each centre provides space, wifi and mentors, plus possibly lunch and snacks depending upon their sponsorship arrangements. Parents drop children off at the centre in the morning and collect them in the late afternoon; all centre staff are vetted for working with children. At the centres teams are formed on the Monday around software application ideas generated by the children with help from mentors, who also guide them during the week. All children, and parents of those under 14 travels to the weekend centre on Friday. Teams present their applications to judging panels on the Saturday, and the final judging panel taking place on the Sunday. While the weekend event was in London for several years, after outgrowing the venue there YRS moved to Birmingham for 2012 and 2013 before taking place in Plymouth in 2014. The venue for 2015 is unknown.

In each of the YRS events the goal is for the children to develop applications using open data [20, 19]. This can be a game, a tool, or anything, which lets the users play, or explore the data, or to better understand and use the data in the app. The apps can range from websites pulling disparate data sets together, to mobile apps and physical hacks based around open data, built around Raspberry Pi and Arduino boards.

The YRS events provide an opportunity for the children to learn from each other while building their apps. The YRS philosophy fits in with the gradual shift since the 1990s away from instructionalism towards creating constructivist learning environments [2] and promoting active learning [1, 3, 4, 6, 10, 11, 13, 14, 17, 23, 30].

Apps developed by teams of young coders in the past [33] include Postcode Wars as a way to compare the population, crime and other statistics for UK postcodes; PiCyle to provide navigational information to cyclists using handlebar-mounted LEDs and a RaspberryPi; Tourify to provide custom tours based on your available time; and Miles Per Pound, which tells you how the cost of your driving is broken down by insurance, depreciation, repair, and millage so you know how many miles you can travel on one UK pound sterling.

# THE SURVEY

## Approach

Over the years little research has been conducted observing, monitoring and theorizing the impact such events are having on children’s development. We want to start to change this. We felt that a survey was a good approach to use to explore the children and their YRS experience. We could not reach the children at the event itself, and we could not travel to a number of locations to conduct the surveys in person. This meant internet delivery using Typeform [29] to conduct the survey and exported the results to Excel for analysis.

We prepared a number of anonymous surveys. One was for the participant children under 18, and a second for those participants now 18 and over. A third survey was for the parents of the participating children, because without the parents the children cannot get to the events, and parents have to be there for the weekend events too if their child is under 14.

We proposed almost the same questions for an online survey of parents and children so that we would have comparable results. The questions fell into a number of distinct categories: location, events attended, length of time coding, and questions about the good/bad aspects of the events. Given changes in research policy, we needed to obtain ethical board approval before running the survey, and while approval for those 18 and over was forthcoming, approval for children under18s proved impossible in the timeframe available. Therefore, this is a pilot study and not the full study, which we will run during Young Rewired State 2015.

In order to have a significant uptake of the survey we need to run this in person with children, and not rely upon social media to spread the word about the survey. Our online pilot survey illustrated that our questions worked well. However, we need to couple this with staff asking participants to fill in the survey.

## Children

We wanted to find out what drives the children to participate and what they did afterwards. We asked them the following:

(1) What year were you born?

(2) What is your gender?

(3) Where do you live? (Scotland, Wales, East of England, etc)

(4) What kind of coding or digital design do you do? (HTML/CSS, Ruby, Java, Blender, Unity, etc)

(5) How long before attending a YRS event did you either start to code, or do digital design work?

(6) Did you have any coding/digital design friends before attending a YRS event?

(7) Which YRS events did you go to?

(8) If you went to any weeklong Festival of Code events, did you also go to the weekend part?

(9) How far did you travel (one way) each day to get to the YRS centre host site?

(10) Did you tell others to sign up for the Festival of Code?

(11) What did you enjoy most about the YRS Festival of Code?

(12) What did you enjoy least about the YRS Festival of Code?

(13) If you could change one thing about the YRS Festival of Code, what would it be?

(14) What did you feel you learnt by attending the Festival of Code?

(15) What have you done that’s related to coding or digital design since going to YRS Festival of Code?

(16) Have you used anything you learned from attending Festival of Code after the event?

(17) Please complete the following sentence. Attending the Festival of Code was like….

The questions were aimed at gathering information about the children in general, and also to determine whether the events were helping to grow a community in which participants can establish, share and deepen technical as well as problem solving skills in an inclusive community which are some of the YRS programme goals. [19, 32]

## Parents

Parents are key partners in this venture along with inclusive practices [8], as without them the children do not attend events. Therefore they too should be questioned as many of them stay for the weekend event to help and support their younger children. We asked them the following:

(1) What year was your child born?

(2) What is the gender of your child?

(3) Where do you live? (Scotland, Wales, East of England, etc)

(4) How long before attending a YRS event did your child start to code, or do digital design on their own?

(6) Did your child have any coding/digital design friends before attending a YRS event?

(7) Which YRS events did you go to?

(8) If you went to any weeklong Festival of Code events, did you also go to the weekend part?

(9) How far did you travel (one way) each day to get to the YRS centre host site?

(10) Did you tell others to sign up for the Festival of Code?

(11) As a parent, what was the best thing about the YRS Festival of Code?

(12) As a parent, what was the worst thing about the YRS Festival of Code?

(13) If you could change one thing about the YRS Festival of Code, what would it be?

(14) What have you done, or have you noticed you child doing since going to YRS Festival of Code?

The questions, as with the children’ ones, should point to changes, which help confirm behavior consistent with the goals of the YRS programme [32].

## Results

We had fewer results than expected from our survey so this is a more qualitative than quantitative analysis. We had eleven parents respond (2 male, 8 female, one other), and ten children (4 male and 6 female) respond to our survey over a three-week period in November and December 2014. We ran the survey later than intended with less social media, and other help as our wait for ethical approval meant we missed key events where we could have had more opportunies to gain survey participants.

The children were born between 1994 and 1997, and the children of the parents were born between 1997 and 2000. This makes almost all of the participant children part of the 97er generation [19], who are digital natives and who are aware of social media from their youngest age. These are digital natives, who grew up after Windows 95 was released and after the Internet and the Web became mainstream.

Less than half of the participants had coding/design friends before taking part in an YRS event. 50% of the children, and 6 of 11 parents’ children had no coding/design friends before attending.

Most people told others about the YRS events after they found out about them. 8 of the 10 children, and 10 of the 11 parents did this.

Almost all people went to the weekend event after attending the weeklong event. This ends up being due to prior family arrangements, and the location of the weekend event.

Survey participants came from across the UK.

**Table 1. Participant’s home locations**

|  |  |  |
| --- | --- | --- |
| **Home** | **Parent’s**  | **Children** |
| London | 4 | 1 |
| South East England | 1 | 2 |
| South West England | 0 | 4 |
| East of England | 1 | 2 |
| Northwest England | 1 | 2 |
| West Midlands | 2 | 0 |
| Yorkshire and the Humber | 1 | 0 |

Table 1 shows that survey responses were from across a range of locations.

The importance of parental support for out-of-school group coding activity as provided by the YRS Festival of Code week is highlighted by the distances travelled by participants as shown in Table 2. More than half of them travel at least 10-20 miles to arrive at their weekly hosting centre.

**Table 2. Distance to the YRS host centre**

|  |  |  |
| --- | --- | --- |
| **Distance** | **Parents’**  | **Children** |
| < 5 miles | 1 | 2 |
| 5-10 miles | 3 | 2 |
| 10-20 miles | 1 | 4 |
| 20-40 miles | 2 | 1 |
| > 40 | 4 | 1 |

The children and parents make an effort to attend the event because of a long-standing interest in the area for most children, which suggests that they hoped to find it a special event. This is also why they almost all told someone about it too.

Participants like to repeatedly attend YRS events as shown in Table 3. None of our participants were born in 2001, which leaves that year empty. Table 3 combines all of the participants across both the children and parents surveys.

**Table 3. Survey participant attendance at YRS events**

|  |  |  |
| --- | --- | --- |
|  |  | **YRS events** |
| **Participants** | **Born** | **2011** | **2012** | **2013** | **2014** |
| 2 | 1994 |  | 2 |  |  |
| 3 | 1995 |  | 1 | 2 | 1 |
| 4 | 1996 | 1 |  |  | 3 |
| 3 | 1997 | 1 | 2 | 1 | 2 |
| 3 | 1998 | 1 | 1 | 3 | 3 |
| 2 | 1999 |  |  | 1 | 2 |
| 2 | 2000 |  |  | 1 | 1 |
| 0 | 2001 |  |  |  |  |
| 1 | 2002 |  | 1 | 1 | 1 |
| 1 | 2003 |  |  | 1 |  |

The children also showed a wide range of skills across both coding and design as seen in Table 4. ‘Other’ here includes Haskell, Perl and bash scripting as well as Visual Basic.

**Table 4. Language and Skills Abilities**

|  |  |
| --- | --- |
| **Language/Skills** | **Number** |
| HTML/CSS | 9 |
| Javascipt/Jquery | 6 |
| Ruby | 2 |
| Python | 4 |
| Java | 3 |
| C# | 2 |
| Photoshop | 3 |
| Other | 3 |

Given the small numbers it is hard to draw any conclusions about the coding and design skills here other than to point out the preponderance of web skills, which also shows up in the types of hacks developed by the teams over the years [33]. Beyond this we can speculate that web skills are an easy entry point for those wanting to learn to code, and that compiled languages are probably learned in order to do something specific like a Minecraft mod using Java, or to pursue a game idea using the Unity game engine in C#.

These coding and design skills have developed over time as seen in Table 5.

**Table 5. Time coding before attending YRS**

|  |  |  |
| --- | --- | --- |
| **Time** | **Parent’s**  | **Children** |
| 1-6 months | 2 | 2 |
| 6-12 months | 2 | 2 |
| Over a year | 1 | 2 |
| Over 2 years | 4 | 0 |
| Longer | 2 | 2 |

More than half of the children had been coding for more than a year before attending YRS and some for over two years. This implies that the participating children find coding something more than a passing interest.

Correlating age of the child with how long they were programming before starting with YRS shows that 8 of 19 children, who coded for two years or longer were born between 1996 and 2000. This means there are a growing number of children, who are starting to code when they are aged around ten, which is usually well before they start any formal computing science in school. This is something, which needs to be explored further with a larger sample.

The open-ended questions provided more insight into what the attendees gained from the event.

The children thought the best thing about YRS was: Collaborating on a project for a week, where you get to meet like-minded people and make new friends and develop their interest.

The parents saw similar benefits: This was a free chance for them to help support their child’s interest with knowledgeable mentors in a way that would boost their social circle, and also build their self-confidence.

The problems the children saw included the judging be only partially based on the technical ability; the groups becoming too big so each person contributed less, that the weekend might be too far away, when you did arrive, the vegetarian pizza might be all gone, and depending upon the venue, the wifi and sleeping arrangements for the weekend might be a problem.

The parents saw similar problems too. For parents the issues revolve around how they can support their children. The first issue might be what to do while their child is at YRS during the week and it is too far to head home. Then comes the consideration of whether the weekend part is too far away. The parents also find the judging unclear, and mostly wish they had heard about it two years sooner.

The YRS Festival of Code is not perfect, and everyone would change something if they could. The children would change things this way: change the weekend location and increase publicity so more children attend; make it more frequent than once a year; add workshops to the weekend event; enforce the competition rules more strictly; also allow those over 18 to attend.

The parents would like to see a central weekend location and clearer competition and judging criteria while adding events and activities for those not presenting, or perhaps remove the competition aspects as not all children care about that aspect. Other parents would like to enable more robotic kits and other hardware for the children to use, and to have people register for food to reduce the wastage at the event.

So far we have explored basic expectations of children and parents about events. However, we also wanted to know about what happened next. “What did you feel you learnt by attending the Festival of Code?” The children felt they learned a variety of direct computing things as well as transferable skills. They gained new technical skills and gained some insight into career options, and found ways to get involved with various companies. Some express regret at not finding out about YRS sooner, because they found there are a lot of young coders out there. Some pushed their skills further by teaching and mentoring others in programming

Under transferable skills the children gained presentation skills, and teamwork and time management. Others found that they are now better at working with others and have used this to help them with their school studies, and used this experience in their personal statements for university admissions.

And what happened next? Where did YRS participants take this experience? The children said that they are doing many things. Some give back to the community by taking part in more hackathons, helping local code clubs, and contributing to open source projects. Others continue learning by studying computing at higher levels in schools, or computing science/electrical engineering at university. Others have gone on to entrepreneurship and released an app with a friend, another is a freelance software engineer, and some work for startups. Others moved into the corporate world and participated in a company internship, or, work for an ISP, and some work other organisations.

The parents said that their children have changed. Their children have grown in confidence and started moving into hacking things with coding skills, and are keen to learn more. Some children have continued their YRS project further, and now think in terms of ‘projects’, and continue going to other coding events. One parent has started an YRS hyperlocal centre so that children in their area can attend YRS events more frequently.

The final question was aimed at finding out what else there is of the YRS experience that we might have overlooked. We asked the children to complete the sentence “Attending the Festival of Code was like…” Here are the answers of those who completed the question:

“Attending the Festival of Code was like… an escape.”

“Attending the Festival of Code was like… An insight into the world of coding and hackathons which made me want to learn more.”

“Attending the Festival of Code was like… a chance to be myself and find people who understand my interests.”

“Attending the Festival of Code was like… becoming part of a mad hyperactive family of awesome people.”

“Attending the Festival of Code was like… being in a room with a bunch of teachers, willing to share their passion.”

“Attending the Festival of Code was like… a music festival but where there's as much pizza as mud and the songs are the tapping of keys...”

# DISCUSSION AND CONCLUSIONS

Coding events for children provide all of the expected ‘upfront’ benefits that we would expect. The children do gain in self-confidence; they do help each other learn new skills, and do learn how to work together as a team to achieve a specific goal. This was revealed in the answers to our open ended questions. Event activities such as these align particularly well with situated learning theory [16], problem-based learning and experiential learning [15].

We also found a wider range of outcomes too. The children gain a better understanding of career options, and gain opportunities to practice their craft through networking with other children and adults at the events too. They find that they are not alone. This is possibly the most important outcome. Whilst not part of formal mainstream education, the learning environments created by the events provide evidence of good inclusive practices. They promote key pedagogical principles, such as co-agency, working with others and trust; core ideas underpinning transformability and the capacity to learn [9].

The children want to know that they are not the only ones who are interested in the coding and developing apps. They too want to know other children, who share their same interests. [19]

The experiences of the survey participants seem to confirm studies of high achievers in computing too. Competitions, such as those run by the BCS, ACM, Microsoft and IBM, can motivate some students – winning looks good on the CV – but the challenge may not fit well with student knowledge and experience and may, ultimately, prove to be a discouragement; children may not be in a position to be able to enter, or parents may lack enough knowledge to be able to support them. Activities designed in the specific context of students’ life experiences, such as YRS seeks to provide, can therefore have greater educational strengths. Furthermore, students can be encouraged to learn new skills and extend those that we consider important for their future [5].

It is also accepted that in order to motivate our more gifted students we need to engage them in a different way from the rest of the cohort. It seems the success of these approaches is entirely dependent upon the skill and enthusiasm of the instructor leading the initiative. YRS works with this by using skilled mentors and providing a peer-led educational experience where the students study at their own pace, which improves the learning experience [5].

For some children it appears that these events show that not all paths have to lead through the doors of a university, but that a coding career is feasible straight out the door of the school. However, this is the experience of our small survey sample, and a wider sample size might show this as a small segment. We have also skewed our results insofar that we are only gathering results from those now aged 18 and over. Younger children might have different outcomes, or might not yet have reached their peak.

# THE FUTURE

We found that this is an area worth exploring further. We have shown that there is useful data waiting to be collected from the YRS participants and their parents. We now need to plan how to achieve this before the next event so that the ethical committee is satisfied that we will meet their requirements for the under 18 children.

We intend to do this by working with YRS to achieve more responses during and after the next Festival of Code in 2015. We aim to bring you more quantitative results next year.

# ACKNOWLEDGMENTS

Our thanks to Emma Mulqueeny, and Ruth Nichols as well as the other Young Rewired State staff, who helped make the survey possible.

# REFERENCES

1. Beck LL and Chizhik AW, *An experimental study of cooperative learning in cs1*, proceedings of the 39th SIGCSE Technical Symposium on Computer Science Education, Portland, 2008
2. Ben-Ari M, *Constructivism in Computer Science Education*, Journal of Computers in Mathematics and Science Teaching 20(1), 2001
3. Biggers M, Yilmaz T and Sweat M, *Using collaborative, modified peer led team learning to improve student success and retention in intro cs*, proceedings of the 40th ACM Technical Symposium on Computer Science Education, Chattanooga, 2009
4. Boyer KE, Dwight RS, Miller CS, Raubenheimer CD, Stallmann MF and Vouk MA, *A case for smaller class size with integrated lab for introductory computer science*, proceedings of the 38th SIGCSE Technical Symposium on Computer Science Education, Covington, 2007
5. Carter, Janet, White, Su, Fraser, Karen, Kurkovsky, Stanislav, McCreesh, Colette, and Wieck, Malcolm. ITiCSE 2010 working group report motivating our top students. In *Proceedings of the 2010 ITiCSE working group reports* (ITiCSE-WGR '10), Alison Clear and Lori Russell Dag (Eds.). ACM, New York, NY, USA, 29-47. http://doi.acm.org/10.1145/1971681.1971685
6. Chinn D, Martin K and Spencer C, *Treisman workshops and student performance in CS*, proceedings of the 38th SIGCSE Technical Symposium on Computer Science Education, Covington, 2007
7. Coder Dojo. https://coderdojo.com/about/ visited 28 December 2014.
8. Gamarnikow, Eva, Green, Anthony G. The third way and social capital: Education action zones and a new agenda for education, parents and community?, *International Studies in Sociology of Education*, 9:1, 3-22, DOI: 10.1080/09620219900200032
9. Hart, S., Dixon, A., Drummond, M.J. and McIntyre, D. *Learning without limits*, New York: Open University Press, 2004.
10. Hendrix D, Myneni L, Narayanan H and Ross M, *Implementing studio-based learning in CS2*, proceedings of the 41st ACM Technical Symposium on Computer Science Education, Milwaukee, 2010
11. Horwitz S, Rodger SH, Biggers M, Binkley D, Frantz CK, Gundermann D, Hambrusch S, Huss-Lederman S, Munson E, Ryder B and Sweat M, *Using peer-led team learning to increase participation and success of under-represented groups in introductory computer science*, proceedings of the 40th ACM Technical Symposium on Computer Science Education, Chattanooga, 2009
12. Hour of Code. http://hourofcode.com visited 28 December 2014.
13. Hundhausen C, Agrawal A, Fairbrother D and Trevisan M, *Does studio-based instruction work in CS 1?: an empirical comparison with a traditional approach*, proceedings of the 41st ACM Technical Symposium on Computer Science Education, Milwaukee, 2010
14. Huss-Lederman S, Chinn D and Skrentny J, *Serious fun: peer-led team learning in CS*, proceedings of the 39th SIGCSE Technical Symposium on Computer Science Education, Portland, 2008
15. Kolb, D. A. (1984). Experiential learning: Experience as the source of learning and development (Vol. 1). Englewood Cliffs, NJ: Prentice-Hall.
16. Lave, Jean, Wenger, Etienne. *Situated Learning. Legitimate peripheral participation*, Cambridge: University of Cambridge Press.
17. Lewandowski G, Johnson E and Goldweber M, *Fostering a creative interest in computer science*, proceedings of the 36th SIGCSE Technical Symposium on Computer Science Education, St. Louis, 2005
18. Mulqueeny, Emma. *Introducing the 1997 Digital Natives, 97ers, and their networked communities of learning* http://mulqueeny.wordpress.com/2014/02/02/97ers/ visited 28 December 2014.
19. Mulqueeny, Emma. *One thousand children, one room and a lot of code - welcome to the future.* http://www.theguardian.com/technology/2014/jul/31/children-code-young-rewired-state-festival-of-code-plymouth visited 28 December.
20. Open Data Institute. *What makes data open?* http://theodi.org/guides/what-open-data Visited 10 Janauary 2015.
21. Peyton Jones, Simon. “The computing at school working group” In *Proceedings of the 18th ACM conference on Innovation and technology in computer science education* (ITiCSE '13). ACM, New York, NY, USA, 1-1. http://doi.acm.org/10.1145/2462476.2483794
22. Rewired State. http://www.rewiredstate.org/legend visited 28 December 2014.
23. Shackelford R, McGettrick A, Sloan R, Topi H, Davies G, Kamali R, Cross J, Impagliazzo J, LeBlanc R and Lunt B, *Computing Curricula 2005: The Overview Report*, ACM SIGCSE Bulletin 38(1), 2006
24. Slay, Julie. *Creating Stronger and More Inclusive Communities* http://www.neweconomics.org/publications/entry/creating-stronger-and-more-inclusive-communities visited 10 January 2015.
25. Smith, Neil, Sutcliffe, Clare, Sandvik, Linda. Code Club: Bringing Programming to UK Primary Schools through Scratch. 2014. *SIGCSE* ’14, March 05 - 08 2014, Atlanta, GA, USA. http://dx.doi.org/10.1145/2538862.2538919
26. Stephenson, Chris, Gal-Ezer, Judith, Humphreys, Simon, and Julie King. Transforming computer science in schools. In *Proceedings of the 18th ACM conference on Innovation and technology in computer science education* (ITiCSE '13). ACM, New York, NY, USA, 309-310. http://doi.acm.org/10.1145/2462476.2462510
27. Strauss, Valerie. *All students should learn to code. Right? Not so fast.* http://www.washingtonpost.com/blogs/answer-sheet/wp/2014/05/29/all-students-should-learn-to-code-right-not-so-fast/ visited 28 December 2014.R
28. “Teenage hackers: Making a better world” BBC News http://www.bbc.co.uk/blogs/legacy/technology/2009/08/teenage\_hackers\_making\_the\_wor.html visited 28 December 2014.
29. TypeForm. http://www.typeform.com visited 10 January 2015.
30. Williams L, *Lessons learned from seven years of pair programming at North Carolina State University*, SIGCSE Bulletin 39(4), December 2007
31. Wing, Jeannette M. “Computational Thinking”. *Communications of the ACM* 49,3 (March 2006), 33-35. DOI=http://dx.doi.org/10.1145/1118178.1118215.
32. Young Rewired State. http://www.yrs.io visited 10 January 2015.
33. Young Rewired State Hacks. http://hacks.rewiredstate.org and http://hacks.youngrewiredstate.org visited 28 December 2014.