Introduction to Machine Learning with Robots and Playful Learning

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Abstract

Inspired by explanations of machine learning concepts in children's books, we developed an approach to introduce supervised, unsupervised, and reinforcement learning using a block-based programming language in combination with the benefits of educational robotics. Instead of using blocks as high-end APIs to access AI cloud services or to reproduce the machine learning algorithms, we use them as a means to put the student "in the algorithm's shoes." We adapt the training of neural networks, Q-learning, and *k*-means algorithms to a design and format suitable for children and equip the students with hands-on tools for playful experimentation. The children learn about direct supervision by modifying the weights in the neural networks and immediately observing the effects on the simulated robot. Following the ideas of constructionism, they experience how the algorithms and underlying machine learning concepts work in practice. We conducted and evaluated this approach with students in primary, middle, and high school. All the age groups perceived the topics to be very easy to moderately hard to grasp. Younger students experienced direct supervision as challenging, whereas they found Q-learning and *k*-means algorithms much more accessible. Most high-school students could cope with all the topics without particular difficulties.

Introduction

Th, guid, lin, s nd conc2, i, 32o3os ls fo2 AI cu22icul 3 y s3, ci l ii, niion io ih, i, chnologic l s3, cis of AI, , s3, ci lly io chin, l, 2ning (Slo n 2009; Bl k, l, y nd B2, z, l 2019; Cl 2k, 2019; Tou2, izky , i l. 2019; Long nd M g, 2ko 2020; Wong , i l. 2020). Child2, n of ll l, v, ls, f2o 32i 2y io high school, 2, , x3, ci, d io b, bl, io co3, wiih ih, c, ni2 l 3 2 dig s of chin, l, 2ning: su3, 2vis, d, unsu3, 2vis, d, nd 2, info2c, , ni l, 2ning (Willi s , i l. 2019; K hn , i l. 2018; J izl u , i l. 2019; Mich , li, S, , g, 2, 2, nd Ro , ik, 2020). Lin , i l. (2020) nd Hii2on , i l. (2019) 2gu, ih i und, 2si nding ih, conc2, i, 32oc, ss, s is 3 2iicul 2ly c2uci l in c2, iing ih, 32o3, 2 , ni l od, ls nd voiding isconc, 3iions. How, v, 2, f, w 332o ch, s focus on king ih, i, chnic l 3 2i of chin, l, 2ning i ngibl, fo2 young l, 2n, 2s (Willi s, P 2k, nd B2, z, l 2019; Willi s , i l. 2019; Lin , i l. 2020). Mosi cu22, ni 332o ch, s , iih, 22, s, bl, bl ck box o2 2, co 3lic i, d nd ihus in cc, ssibl, io 32i 2y- o2 iddl, -school siud, nis (J izl u , i l. 2019).

Wiih ou2 332o ch, w, s, , k io fill ihis g 3. Ins3i2, d by n 22 iiv, i, chniqu, s, d, signs of child2, n's books, nd ih, dv ni g, s of , duc iion l 2oboiics nd visu l 32og2 ing l ngu g, s, w, d, v, lo3, d iwo , xi, nsions[1] fo2 ih, o3, n-sou2c, 3l ifo2 O3, n Rob, 2i L b[i]:

- Th, N, u2 l N, iwo2k Pl yg2ound llows ih, us, 2 io , x3, 2i , ni wiih si 3l, n, u2 l n, iwo2ks. Th, siud, ni c n i2 in ih, n, iwo2k by odifying ih, w, ighis nd di2, cily obs, 2ving ih, , ff, cis on ih, si ul i, d 2oboi uniil ii b, h v, s s d, si2, d. In ihis w y, ih, siud, ni g2 s3s ih, conc, 3i of *k ect supe v s on* – 32oc, ss of djusiing ih, w, ighis in ih, n, u2 l n, iwo2k uniil ih, oui3ui is s iisf cio2y.
- Wiih ih, Q-l, 2ning Pl yg2ound, ih, siud, ni c n iink, 2 wiih ih, Q-l, 2ning lgo2iih by c2, iing uniqu, l, 2ning , nvi2on , nis fo2 ih, 2oboi nd 3l ying wiih ih, 3 2 , i, 2s of ih, lgo2iih . Si, 3 by si, 3, ih, siud, ni c n d, bug ih, lgo2iih nd , x3lo2, how ii is l, 2ning f2o ih, g, ni's 3, 2s3, ciiv, .

W, lso d, v, lo3, d n un3lugg, d ciiviiy io k, unsu3, 2vis, d l, 2ning i ngibl, by d 3iing ih, *k-* , ns lgo2iih . Ou2 , xi, nsions 2, cco 3 ni, d by cu22iculu , which ini2oduc, s young l, 2n, 2s io ih, 2, s3, ciiv, chin, l, 2ning 3 2 dig s.

W, i, si, d ou2 d, v, lo3 , nis wiih 24 3 2iici3 nis s 2, 32, s, ni iiv, s of ih2, , duc iion l, v, ls: 32i 2y, iddl, , nd high school. In ih, , v lu iion, w, , x in, d how child2, n

Codes, learning materials, and a video demonstrating the functionality of the extensions are available at github.com/vlebedynska/openroberta-lab/, retrieved: 17.12.2020.

of diff, 2, ni g, s 3, 2c, iv, d ih, io3ics nd wh, ih, 2 ih, y h d difficulii, s in und, 2si nding ih, .

In ihis 3 3, 2, w, fi2si discuss ih, 2, l i, d wo2k on ih, ini2oduciion of chin, l, 2ning in schools s w, ll s b ck-g2ound siudi, s on ih, us, of 2obois, si ul iion, nd 3l yful l, 2ning in , duc iion. W, ih, n 32, s, ni d, sign 32inci3l, s ih i guid, d us in d, v, lo3ing ih, , xi, nsions nd ih, cu22iculu . W, coniinu, wiih 32, s, ni iion of ih, , xi, nsions nd su3-3l, , ni 2y i, 2i ls nd d, sc2ib, ou2 , v lu iion , ihods. In ih, , nd, w, 32ovid, insighis inio ih, us, 2 siudy, su -2iz, ih, child2, n's f, , db ck nd discuss ih, 2, sulis.

Background and Related Work

Machine Learning in Schools

Alihough ih, 2, is wid, 2 ng, of , sy-io-us, s, 2vic, s ini2o-ducing b, ginn, 2s io su3, 2vis, d chin, l, 2ning, ih, y usu-lly us, only li ii, d nu b, 2 of d, sc2i3iiv, , x 3l, s, such s i g, , i, xi, sound cl ssific iion (T, ch bl, M chin, s, M chin, L, 2ning fo2 Kids), o2 s3, , ch synih, sis (Cogni-i, s)[ii]. Th, in dis dv ni g, of using such 33lic iions in , duc iion is ih i ih, , ch nis s und, 2lying i2 ining nd cl ssific iion 2, in hidd, n f2o ih, us, 2 (Hii2on , i l. 2019; J izl u , i l. 2019). Th, child2, n 3l y wiih high-, nd sysi, s nd 2, dy-i2 in, d od, ls, wiih no o33o2iuniiy io l, 2n how ih, i2 ining is 3, 2fo2 , d nd how lgo2iih s wo2k b, hind ih, sc, n, s. Th, 2, h v, b, , n inc2, sing , ffo2is io o3, n ih, bl ck box of su3, 2vis, d l, 2ning using visu l 32og2 ing l ngu g, s. How, v, 2, , v, n ih, n, ih, s, ofi, n , iih, 2 32ovid, n ini, 2f c, io 3ow, 2ful high-, nd APIs (1 2ug 2018) o2 2, 32oduc, ih, und, 2lying conc, 3is wiihoui d 3iing ih, fo2 ih, young l, 2n, 2. Th, 32o3os l by K hn , i l. (2020) nd K hn , i l. (2018) io i, ch d, , 3 l, 2ning, i g, cl ssific iion, nd s3, , ch synih, sis wiih 32og2 -ing l ngu g, Sn 3! is h 2dly suii bl, fo2 child2, n, du, io iis co 3lic i, d i, chnic l i, 2 inology nd i 3l, , ni iion.

Ini2oducio2y ciiviii, s 2ound 2, info2c, , ni nd unsu-3, 2vis, d l, 2ning 2, 2 2, . Mich , li, S, , g, 2, 2, nd Ro , ik, (2020) conduci, d c s, siudy ini2oducing unsu3, 2vis, d chin, l, 2ning wiih ih, l, 2ning v, cio2 qu niiz iion l-go2iih . How, v, 2, ih, block-b s, d 332o ch us, d in ih, siudy is co 3l, x nd i 2g, is high-school siud, nis. So , c s, siudi, s h v, focus, d on i, ching Q-l, 2ning s on, of ih, 2, info2c, , ni l, 2ning lgo2iih s (J izl u , i l. 2019; Toivon, n, Jo2 n in, n, nd Tuki in, n 2017). Ag in, ih, s, ciiviii, s 2, i , d i und, 2g2 du i, nd high-school siu-d, nis nd do noi 33ly io young, 2 child2, n.

Blocks and Robots

K hn nd Wini, 2s (2017) nd J izl u , i l. (2019) 2gu, ih i block-b s, d 332o ch is child-f2i, ndly, iniuiiiv, , nd si2 ighifo2w 2d. Th, us, of blocks 32ovid, s ih, us, 2 wiih , sy cc, ss nd low b 22i, 2s io , ni2y inio 32og2 ing 3-3lic iions (1 2ug 2018; K hn , i l. 2020). How, v, 2, ih, us, of blocks do, s noi n, c, ss 2ily i 3ly ih, si 3lific iion of ih, coni, ni iis, lf. Alihough blocks y b, us, d io ini2oduc, co 3l, x io3ics, ih, 2, 32, s, ni iion of ih, lgo2iih s 32o-3os, d by K hn nd Wini, 2s (2017) nd J izl u , i l. (2019) is noi suii bl, fo2 young child2, n, du, io iis co 3lic i, d vo-c bul 2y nd nu , 2ous i, chnic l d, i ils.

Th, 2, h v, b, , n f, w ii, 3is io i 3l, , ni 2obois in ih, cl ss2oo io i, ch young child2, n boui chin, l, 2ning. Th, i2 succ, ss nd , ff, ciiv, n, ss h v, b, , n d, onsi2 i, d in s ll nu b, 2 of c s, siudi, s wiih kind, 2g 2i, n nd 32i-2y-school siud, nis (1 2ug , i l. 2018; Willi s, P 2k, nd B2, z, l 2019; Willi s , i l. 2019; Lin , i l. 2020).

Simulation and Modeling

Roboi si ul io2s 2, s b, n, fici l io ih, l, 2ning 32oc, ss s ih, o3, 2 iion of ih, 2, l 2oboi (P 3, 2i 1993). Si ul io2s , v, n h v, d, cisiv, dv ni g, – ih, ii , 2, qui2, d fo2 cod, -i, si-d, bug loo3s is consid, 2 bly l, ss ih n wo2king wiih 2, l 2obois (1 odds , i l. 2006).

Si ul iion is n ciiviiy ih i ciiv, ly , ng g, s wiih od-, ls, nd ii coni ins signific ni l, 2ning 3oi, nii l. In ih, cu2-2, ni vi, w of od, ling s 32 g iic 32oc, ss, s wiih signifi-c ni , 3isi, ologic l 3oi, nii l (G, lf, 2i 2016; Ciul , i l. 2018), ciiv, , ng g, , ni wiih od, ls, o2 "i gin 2y con-c2, i " (Godf2, y-S iih 2009: 108), h s signific ni 3oi, nii l in 2, s, 2ch s w, ll s in l, 2ning (N, 2s, ssi n 2008). Ind, , d, si ul iion is co2, conc, 3i wiih which co 3ui, 2g , s c n b, und, 2siood; ii is c2, iiv, conf2oni iion wiih n 22 iolog-ic l und, 2si nding (A 2s, ih 1998).

On, finds , x3, 2i , ni l, 3l yful, nd 32 ciic l 32obl, solving in ny co 3ui, 2g , s s w, ll s in ih, long his-io2y of g ing nd 3l y (S l, n , i l. 2004; Fl n g n 2009). Ii h s signific ni uni 33, d 3oi, nii l in wid, 2, of 33li-c iions, f2o flighi si ul io2s io ih, 2, c, ni g2owih in g -ific iion. W, b, li, v, ih i ih, boiio -u3 332o ch in ou2 2, -s, 2ch, wh, 2, b sic und, 2si nding of 32 ciic l cyb, 2n, iics is us, d io , si blish ih, b sis fo2 chin, l, 2ning, 32ovid, s 2obusi found iion fo2 fu2ih, 2 d, v, lo3 , ni of i, ching , ihodologi, s g2ound, d in c2, iiv, nd 3l yful od, ling b s, d on si ul iion sysi, s.

Methodology and Curriculum Design

Consid, 2ing ih, sho2ico ings of cu22, ni 332o ch, s, w, 32o3os, cu22iculu fo2 ini2oducing chin, l, 2ning wiih si ul i, d 2obois nd ih, visu l 32og2 ing l ngu g, NEPO.

W, build on ih, iwo "big id, s" of AI – 3, 2c, 3iion nd l, 2ning (Tou2, izky , i l. 2019) – s 32 ciic l guid nc, fo2 d, signing AI cu22icul . Siud, nis 2, , x3, ci, d io c2, i, 3-3lic iions wiih si ul i, d 2obois. This h, l3s ih, io und, 2si nd 3, 2c, 3iion s 32oc, ss in which s, nso2s 2, us, d io , xi2 ci d i f2o ih, , nvi2on , ni. Ai ih, s , ii , , ih, y i , 2s, ih, s, lv, s in ih, ch ll, ng, s of su3, 2vis, d, unsu-3, 2vis, d, nd 2, info2c, , ni l, 2ning by i2 ining n, u2 l n, i-wo2ks nd ini, 2 ciing wiih und, 2lying lgo2iih s.

W, lso iook ins3i2 iion f2o ih, "Fou2 P's of C2, iiv, L, 2ning" (R, snick nd Robinson 2017) s od, 2n f2 , -wo2k ih i , ng g, s siud, nis in c2, iiv, l, 2ning , x3, 2i, nc, s. W, si2iv, io inco23o2 i, ih, i2 id, s of 3l yful l, 2ning (P -3, 2i 1993; R, snick nd Robinson 2017; R, snick nd Silv, 2-n 2005) inio ou2 , xi, nsions wh, 2 v, 2 3ossibl, . Alihough w, d, sign, d so , si2uciu2, d ciiviii, s, such s N, u2 l N, i-wo2k nd R, info2c, , ni L, 2ning C 2ds, io h, l3 l, 2n, 2s g, i si 2i, d, ou2 i is ih i ih, y s, 2v, s si, 33ing sion, nd noi fin l d, siin iion. W, w ni io , n bl, ih, 3 2iici3 nis io 3l y wiih chin, l, 2ning i, chnologi, s nd k, so , -ihing ih i ini, 2 sis ih, , following ih, id, s of consi2uc-iionis (Qu, i2oz , i l. 2020; Mich , li, S, , g, 2, 2, nd Ro-, ik, 2020; P 3, 2i nd H 2, l 1991).

W, odifi, d ih, d, sign 32inci3 l of , bodi, d ini, 2 ciion (Long nd M g, 2ko 2020), by vi2iu lly 3uiiing ih, siud, ni in "ih, g, ni's sho, s." L, 2n, 2s should i , 2s, ih, s, lv, s in ih, b, h vio2 of ih, si ul i, d 2oboi. l oing so llows ih, io look b, hind ih, sc, n, s nd ihus 32o oi, s i2 ns3 2, ncy (Long nd M g, 2ko 2020) – noih, 2 32inci3l, iow 2d , x-3l ining AI.

W, lso b s, d ou2 332o ch on ih, 32inci3l, of "low floo2s nd wid, w lls" io cco od i, child2, n c2oss v 2-ious , duc iion nd skill l, v, ls (R, snick nd Silv, 2 n 2005). W, h v, d, ii s , sy s 3ossibl, io g, i si 2i, d wiih ih, , xi, nsions, whil, d, signing o33o2iuniii, s fo2 siu-d, nis io div, d, , 3, 2 inio ih, wo2k on ih, io3ics. To ihis , nd, w, iook ins3i2 iion f2o ih, g2 3hic d, sign nd sio2yi, lling of child2, n's books. W, follow, d ih, 32inci3l, s d, sc2ib, d by C si, ll (2018) in k, , 3ing ou2 , xi, nsions nd i, 2i ls 33, ling nd si2 ighifo2w 2d: 1 , signs fo2 child2, n h v, io c i, 2 io , v, 2yon, nd l, v, 2oo fo2 , x3lo2 iion.

Th, , nii2, cu22iculu consisis of fou2 ih, iic odul, s nd l sis 2ound 360 inui, s, which ih, i, ch, 2 c n sho2i, n o2 , xi, nd s n, , d, d.

Modul, 1, "How do, s you2 2oboi l, 2n?," ini2oduc, s chil-d2, n io ih, ih2, , 3 2 dig s of chin, l, 2ning: su3, 2vis, d, unsu3, 2vis, d, nd 2, info2c, , ni l, 2ning (Russ, ll nd No2vig 2016). Th, child2, n discuss iwo , x3, 2i , nis 32o-3os, d by B2 ii, nb, 2g, "F, 2" nd "Lov, " (B2 ii, nb, 2g 1986), which ih, f cilii io2 3, 2fo2 s wiih 2oboi in ih, f2oni of ih, cl ss. W, chos, ih, s, , x3, 2i , nis b, c us, ih, y 2, si 3l, , ni2y 3oini inio ih, qu, siions of wh i ini, lli-g, nc, is nd how ii 2, l i, s io l, 2ning. Afi, 2 ih, discussion, ih, f cilii io2 holds sho2i in3ui l, ciu2, ih i ini2oduc, s -chin, l, 2ning.

In Modul, 2, "T, ching you2 2oboi," ih, child2, n i, ch ih, 2oboi v 2ious b, h vio2s ih2ough di2, ci su3, 2vision. Th, y c2, i, si 3l, n, u2 l n, iwo2ks by co 3osing sho2i 32og2 s in ih, O3, n Rob, 2i L b. Wh, n ih, y si 2i ih, 32og2 on ih, si ul i, d 2oboi, ih, 32og2 is co 3il, d, nd n, u2 l n, iwo2k is c2, i, d. Th, y c n now i2 in ih, n, u2 l n, iwo2k by odifying ih, w, ighis nd obs, 2ving ih, 2, sulis di2, cily f2o ih, b, h vio2 of ih, 2oboi. Th, 32oc, ss of djusiing ih, w, ighis uniil ih, 2oboi b, h v, s s d, si2, d is wh i w, , n by *k ect supe v s on* – ih, siud, nis 2, involv, d in ih, i2 in-ing 32oc, ss of ih, n, u2 l n, iwo2k nd i ii i, ii by nu lly djusiing ih, w, ighis. As ih, child2, n 2, c, iv, i , di i, f, , db ck f2o ih, configu2 iion of ih, n, iwo2k, ih, y b, gin io und, 2si nd how ih, 2oboi l, 2ns. I , 2sing ih, s, lv, s in ih, i2 ining 32oc, ss llows ih, io focus on ih, und, 2ly-ing 32oc, ss, s of su3, 2vis, d l, 2ning. Ai ih, s , ii , , ih, child2, n discov, 2 h nds-on co 3on, nis of n, u2 l n, iwo2ks, such s nod, s, l y, 2s, links, nd w, ighis. Th, y c n si 2i wiih ih, N, u2 l N, iwo2k C 2ds, bui ih, y 2, ih, n , ncou2 g, d io , x3lo2, nd i, si ih, li iis of wh i ih, y c n i, ch io ih, 2o-boi.

In Modul, 3, "L, i you2 2oboi l, 2n f2o , x3, 2i, nc, ," ih, child2, n , x3lo2, ih, Q-l, 2ning lgo2iih using ih, O3, n Rob, 2i L b nd n lyz, how 2oboi l, 2ns ih2ough 2, -w 2ds. W, chos, Q-l, 2ning, b, c us, ii is si 3l, od, l-f2, , lgo2iih ih i h s l2, dy b, , n i, si, d wiih child2, n, nd ii is suii bl, fo2 us, in schools (J izl u , i l. 2019). Th, child2, n c n c2, i, uniqu, l, 2ning , nvi2on , nis fo2 ih, 2o-boi nd , x3, 2i , ni wiih ih, 3 2 , i, 2s of ih, lgo2iih . Afi, 2 ih, y si 2i ih, 32og2 on ih, 2oboi, ih, y obs, 2v, nd n lyz, ih, l, 2ning nd 2, soning 32oc, ss si, 3 by si, 3 wiih ih, Q-l, 2ning Pl yg2ound. Th, y y , x3, 2i, nc, c s, s in which ih, 2oboi f ils io l, 2n nd finds no w y oui, nd ih, y c n ih, n co22, ci ih, lgo2iih in ih, n, xi ii, 2 iion.

Fin lly, in Modul, 4, "C n 2obois l, 2n uiono ously?," ih, child2, n 2, ini2oduc, d io ih, *k*- , ns lgo2iih ih2ough un3lugg, d ciiviii, s. Th, f cilii io2 l, ds discussion on how ih, 2oboi would g2ou3 ih, obj, cis on ih, i bl, wiihoui ny 32, vious knowl, dg, . H, o2sh, ih, n so2is ih, ii, s c-co2ding io ih, *k*- , ns lgo2iih , wiihoui , x3l ining wh i c2ii, 2i w s us, d fo2 ih, g2ou3ing. Th, child2, n 2, , ncou2-g, d io k, gu, ss, s. Afi, 2 discussing ih, g2ou3ing c2ii, 2i nd , x3l ining ih, so2iing 32inci3l, s, ih, siud, nis g2ou3 ih, ii, s ih, s, lv, s nd l, i oih, 2s gu, ss ih, i2 c2ii, 2i . This c-iiviiy i s io ini2oduc, ih, io clusi, 2 n lysis nd wh i ii , ns io b, in g2ou3.

Extensions Design and Learning Materials

W, d, sign, d ou2 chin, l, 2ning 3l yg2ounds b s, d on ih, O3, n Rob, 2i L b, visu l block-b s, d o3, n-sou2c, 32og2 ing 3l ifo2 . W, chos, ihis coding 3l ifo2 du, io iis focus on i, ching 32og2 ing wiih 2obois nd iis d-v nc, d , cosysi, , including 2oboi si ul iion (K, ii, 2l , i l. 2015; Josi , i l. 2014). W, , xi, nd, d ih, 3l ifo2 wiih iwo 3l yg2ounds fo2 ih, si ul i, d LEGO EV3 2oboi.

Figu2, 1. Block fo2s, iiing u3 ih, l, 2ning b, h vio2

Fi2si, w, , xi, nd, d ih, block c i, go2i, s in ih, O3, n Rob-, 2i L b wiih ih, n, w c i, go2y of AI consisiing of iwo sub-c i, go2i, s: N, u2 l N, iwo2ks nd R, info2c, , ni L, 2ning. Fo2 N, u2 l N, iwo2ks, w, d, fin, d 10 n, w blocks:

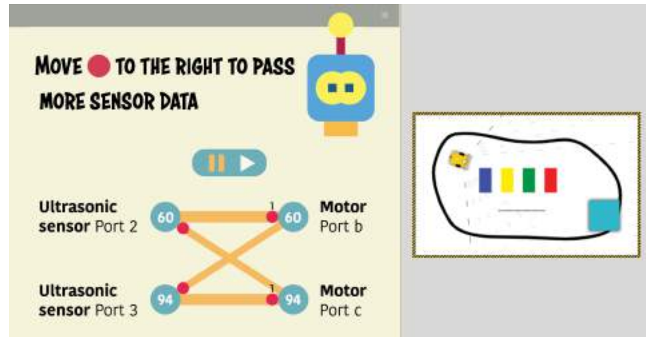
- *Neu al netwo k* h s iwo o3, nings fo2 ih, in3ui nd oui3ui l y, 2s. T, chnic lly, w, includ, d ih, c s, ih i ih, us, 2 c n , xi, nd ih, block wiih hidd, n l y, 2s. How, v, 2, ih, cu22, ni block do, s noi y, i 2, 32, s, ni ihis g2 3hic lly.
- *Neu on* is block wiih lisi in ih, b ck, nd wh, 2, ih, us, 2 c n 3lug in diff, 2, ni iy3, s of in3ui nd oui3ui nod, s. Th, 2, is no li ii io ih, nu b, 2 of n, u2ons in l y, 2
- *Input ank output nokes*, , n bl, ih, us, 2 io 3lug in ih, ul-i2 sonic nd ih, colo2 s, nso2s in lighi, RGB, nd colo2 od, s s ih, n, u2ons of ih, in3ui l y, 2. In ih, oui3ui l y, 2, ih, us, 2 c n 3lug in oio2, LE1 , i, xi, nd sound.

Fo2 ih, subc i, go2y of R, info2c, , ni L, 2ning, w, i -3l, , ni, d fou2 n, w blocks, fo2 which w, d 3i, d ih, 3-3, 2 nc, of ih, lgo2iih conc, 2ning i, chnic l voc bul 2y io k, ih, lgo2iih i ngibl, .

- *Map* llows us, 2s io s, i u3 ih, , nvi2on , ni fo2 ih, Q-l, 2ning lgo2iih .
- *Lea n ng behav o* configu2, s ih, 3 2 , i, 2s fo2 ih, Q-l, 2ning lgo2iih . Figu2, 1 shows how us, 2s s, , ih, block. Ii is n , x 3l, of how w, h v, d 3i, d ih, i, ch-nic l voc bul 2y of ih, Q-L, 2ning lgo2iih fo2 young siud, nis. Th, fi2si 3 2 , i, 2 is Al3h , ih, s, cond is G , ih, ihi2d is Rho, nd ih, fou2ih is Nu.
- *Ga n expe ence* iniii liz, s ih, Q-l, 2ning Pl yg2ound, wh, 2, ih, child2, n c n s3, cify ih, du2 iion in s, conds nd ih, nu b, 2 of , 3isod, s.
- *D aw opt mal path* d2 ws ih, w y fo2 ih, 2oboi io , xii ih, l by2inih.

S, cond, w, i 3l, , ni, d iwo chin, l, 2ning 3l y-g2ounds. In ih, N, u2 l N, iwo2k Pl yg2ound, ih, siud, nis , x3, 2i , ni wiih di2, ci su3, 2vision by djusiing ih, w, ighis of ih, n, iwo2k. Th, Q-l, 2ning Pl yg2ound 32o oi, s ih, i2 ns3 2, ncy of ih, l, 2ning 32oc, ss nd llows ih, us, 2s io si 2i o2 sio3 ih, , x, cuiion of ih, lgo2iih . Th, y c n lso d, bug ih, lgo2iih si, 3 by si, 3.

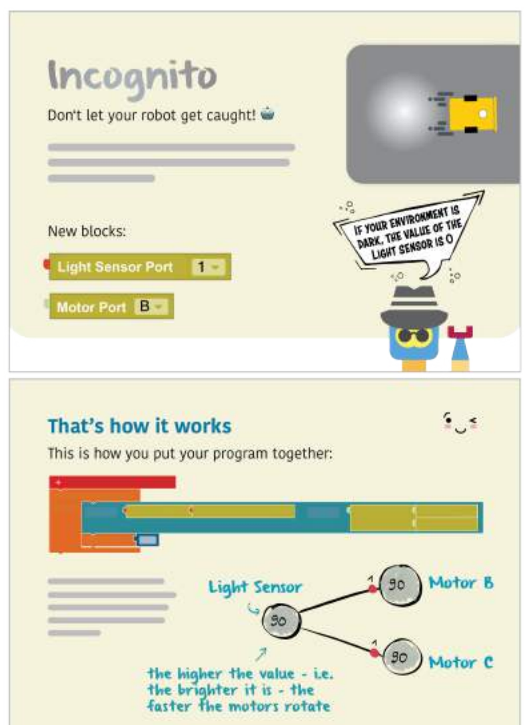
Figu2, 2 d, onsi2 i, s ih, N, u2 l N, iwo2k Pl yg2ound on ih, l, fi nd ih, si ul iion of ih, 2oboi on ih, 2ighi. Th, in3ui l y, 2 h s iwo in3ui n, u2ons, which 2, uli2 sonic s, nso2s conn, ci, d io 3o2is 2 nd 3. Th, oui3ui l y, 2 consisis of iwo n, u2ons (i., ., oio2s conn, ci, d io 3o2is b nd c). If ih, us, 2



Figu2, 2. N, u2 l N, iwo2k Pl yg2ound

djusis w, ighis now, ih, 2oboi i , di i, ly ch ng, s iis b, -h vio2. In Figu2, 2, ih, w, ighi b, iw, , n ih, fi2si in3ui nd fi2si oui3ui n, u2on is s, i io 1. Ii , ns ih i ih, v lu, of ul-i2 sonic s, nso2 i 3o2i 2, which is cu22, nily 60, is co 3l, i, ly i2 nsf, 22, d io oio2 i 3o2i b. Cons, qu, nily, oio2 i 3o2i b 2oi i, s i s3, , d of 60. Th, s , 33li, s io ih, uli2 sonic s, nso2 i 3o2i 3 nd ih, oio2 i 3o2i c. Such configu2 iion of ih, n, u2 l n, iwo2k 2, sulis in ih, following b, h vio2 of ih, 2oboi: ih, clos, 2 ih, 2oboi is io ih, obj, ci, ih, low, 2 ih, v lu, of ih, iwo uli2 sonic s, nso2s, nd ih, slow, 2 ih, co2-2, s3onding 2oi iions of ih, oio2s.

W, c2, i, d , ighi N, u2 l N, iwo2k c 2ds io ini2oduc, ih, us, 2 io di2, ci su3, 2vision nd n, u2 l n, iwo2ks. Figu2, 3 shows ih, l, 2ning c 2d “Incogniio.”



Figu2, 3. N, u2 l N, iwo2k C 2d “Incogniio”

All ih, c 2ds 2, si il 2ly si2uciu2, d. On ih, f2oni sid, , w, d, sc2ib, ih, i sk nd 32ovid, hinis. H, 2, , fo2 insi nc, , w, show ih, n, w blocks ih i ih, l, 2n, 2 n, , ds nd , x3l in why ih, 2oboi will ii, 3i io d2iv, onio ih, whii, 2, . On ih, b ck, w, off, 2 ih, soluiion fo2 ih, 32og2 nd ou2 con-figu2 iion of ih, n, u2 l n, iwo2k.

Th, v, hicl, s 32o3os, d by B2 ii, nb, 2g (1986) w, 2, ou2 in-s3i2 iion fo2 ih, c 2ds. H, nc, , w, d 3i, d iwo sc, n 2ios: "F, 2' i, ch, s ih, 2oboi io b, " f2 id" of obsi cl, s, whil, "F2i, ndshi3" insi2ucis ii io b, f2i, ndly. W, dd, d six fu2ih, 2 , x 3l, s: (1) Ch , l, on – T, ch ih, 2oboi io d 3i iis, lf io ih, , nvi2on , ni, (2) Incogniio – T, ch ih, 2oboi io void b2ighi 3l c, s, (3) Aii, niion – Educ i, ih, 2oboi on ih, i2 ffic 2ul, s, (4) Loud 1 isi nc, – Insi2uci ih, 2oboi io , su2, ih, disi nc, io ih, obsi cl, oui loud, (5) Ini, 2, si – L, i ih, 2oboi , x3lo2, ih, l ndsc 3, , nd (6) R lly – En bl, ih, 2oboi io si, 2 ih, colo2, d cu2v, s.

Figu2, 4 d, onsi2 i, s ih, Q-L, 2ning Pl yg2ound. Afi, 2 ih, l, 2n, 2 h s c2, i, d 32og2 using ih, blocks nd i2 ns-f, 22, d ii io ih, 2oboi, ih, Q-L, 2ning Pl yg2ound is g, n, 2- i, d dyn ic lly. Th, , nvi2on , ni 2, fl, cis ih, 3 2 , i, 2s ih i ih, us, 2 h s s, i in ih, 2, info2c, , ni l, 2ning blocks. On 32, ssing ih, si 2i buiion, ih, us, 2 si 2is ih, l, 2ning 32oc, ss, which c n b, obs, 2v, d in ih, n vig iion b 2 i ih, io3 nd on ih, 3. Afi, 2 ih, l, 2ning is finish, d, ih, o3ii l 3 ih oui of ih, l by2inih is d2 wn, nd ih, 2oboi c n now follow ii. Figu2, 4 shows ih, l si si, 3, wh, 2, ih, 2oboi follows ih, o3ii l 3 ih.

W, cco 3 ni, d ih, Q-l, 2ning Pl yg2ound wiih ih, - i, 2i ls, such s ih, Q-l, 2ning c 2ds (on which ih, us, 2 c n i k, noi, s), Q&A, block d, sc2i3iions, nd flow di g2 on how Q-l, 2ning wo2ks. Th, i, 2i ls d, v, lo3, d i io k, ih, Q-l, 2ning lgo2iih i ngibl, , v, n fo2 young l, 2n, 2s.

Fo2 ih, un3lugg, d ciiviiy ih i ini2oduc, s ih, *k*- , ns l-go2iih , ih, f cilii io2 only n, , ds s, i coni ining so , ob-j, cis nd diff, 2, ni colo2, d Posi-iis. W, ss, bl, d ou2 col-l, ciion f2o v 2ious d2inking v, ss, ls nd coni in, 2s.

Figu2, 4. Q-L, 2ning Pl yg2ound

Th, f cilii io2 siicks Posi-iis on 3o2iion of ih, 2 ndo ii, s ih i s, 2v, s s ih, clusi, 2 c, ni, 2s. Th, 2, ining ob-j, cis in ih, s, i 2, ih, n co 3 2, d wiih , ch clusi, 2 c, ni, 2 b s, d on c2ii, 2ion known only io ih, f cilii io2. Afi, 2 co - 3 2ing , ch ii, wiih ih, clusi, 2 c, ni, 2s, ih, f cilii io2 3l c, s ih, obj, ci b, hind ih, on, clusi, 2 c, ni, 2 ih i h, o2 sh, ihinks is ih, b, si fii. Th, v, 2sion of ih, *k*- , ns lgo2iih ih i w, 3, 2fo2 , d wiih ih, child2, n w s si 3lifi, d. Ii co - 32is, d only ih, fi2si si g, of ih, lgo2iih wiihoui 3osi-clus-i, 2ing. How, v, 2, ii c n b, , sily inco23o2 i, d inio ih, , x-3, 2i , ni.

User Study

W, i, si, d wh, ih, 2 ih, l, 2ning , x3, 2i, nc, wiih ih, , xi, n-sions d, v, lo3, d fo2 chin, l, 2ning 32o oi, s ih, chil-d2, n's und, 2si nding of ih, und, 2lying conc, 3is of ih, sub-j, ci. In 3 2iicul 2, w, , v lu i, d how ini, 2, siing nd how dif-ficuli ih, siud, nis found ih, individu l io3ics. W, lso sk, d ih, child2, n wh i ih, y ihoughi AI nd chin, l, 2ning w, 2, , boih i ih, b, ginning nd ih, , nd of ih, s, ssion. In ddiiion, w, qu, siion, d ih, i2 oiiv iion io coniinu, wo2k-ing on chin, l, 2ning.

Method

Participants

Ou2 i in d, v, lo3ing ih, , xi, nsions nd i, ching i, 2i ls is io 2, ch child2, n of diff, 2, ni g, s nd wiih no 32io2 knowl, dg, in chin, l, 2ning. Th, 2, fo2, , w, conduci, d c s, siudy wiih siud, nis in v 2ious g, g2ou3s. Tw, niy-fou2 child2, n 3 2iici3 i, d in ih, siudy (G2 d, s 3–4: fou2 boys nd fiv, gi2ls; 5–6: six boys nd on, gi2l; 7–9: s, v, n boys only). W, could noi s, l, ci ih, 3 2iici3 nis ou2s, lv, s, sinc, ih, s, s-sions w, 2, o2g niz, d s 3 2i of su , 2-v c iion 32og2 nd h d io b, si ff, d on "fi2si co , , fi2si s, 2v, " b sis. So , 3 2iici3 nis ii, nd, d ih, s, ssion on ih, i2 3 2, nis' 2, c-o , nd iion nd w, 2, iniii lly noi , nihusi siic boui ih, wo2ksho3s. Th, f cilii io2 w s info2 , d ih i so , of ih, siud, nis h v, s3, ci l n, , ds.

W, h, ld ih2, , s, ssions in ioi l, on, 3, 2 d y. E ch s, ssion l si, d six school hou2s (45 inui, s) nd w s conduci, d in block wiih sho2i b2, ks. On ih, fi2si d y, w, i, si, d ih, , x-i, nsions wiih ih, high-school siud, nis in G2 d, s 7–9 (G1), on ih, s, cond d y wiih ih, 32i 2y-school siud, nis in G2 d, s 3–4 g2 d, s (G2), nd on ih, ihi2d d y wiih ih, id-dl, -school child2, n in G2 d, s 5–6 (G3). All ih, child2, n h d 32io2 knowl, dg, of wo2king in ih, O3, n Rob, 2i L b wiih 2, l LEGO EV3 2obois, s ih, y h d 3 2iici3 i, d in n ini2o-ducio2y s, ssion on ih, 32, vious d y.

Procedure

In , ch s, ssion, w, follow, d ih, odul, s s d, sc2ib, d in ih, "M, ihodology nd Cu22iculu 1 , sign" s, ciion. W, d, -sign, d ou2 32, s, ni iion nd insi2uciions wiih si2ong focus on ih, young, 2 siud, nis nd us, d ih, fo2 ll ih, g, g2ou3s. Fi2si, w, info2 lly 32, - ss, ss, d ih, knowl, dg, of ih, child2, n on chin, l, 2ning nd AI. W, ih, n co - 3l, i, d ih, odul, s in o2d, 2 Ai ih, , nd, ih, child2, n fill, d oui sho2i qu, siionn i2, s. On ih, s, cond nd ihi2d d y, w, ch ng, d ih, o2d, 2 of ih, odul, s, b, c us, ih, , x3, 2i, nc, s f2o ih, fi2si d y indic i, d ih i 2, info2c, , ni l, 2ning w s ioo difficuli io b, i ckl, d in ih, fi, 2noon; ih, conc, ni2 iion of ih, siud, nis w s low, 2 in ih, fi, 2noon ih n in ih, o2n-ing. W, 2, co2d, d ih, s, ssions, nd n obs, 2v, 2 logg, d ih, ciiviii, s fo2 ll ih2, , d ys.

Limitations

Sinc, w, could noi influ, nc, ih, co 3osiiion of ih, 3 2iic-i3 ni g2ou3s, w, w, 2, noi bl, io b l nc, ih, by g, nd, 2. W, lso could noi coll, ci d, i il, d info2 iion boui ih, b ckg2ound of , ch 3 2iici3 ni.[iii] l u, io , su2, s g insi co2on vi2us dis, s, (COVI1 –19), w, h d iwo o2g niz - iion l 2, si2iciions: (1) Only s ll nu b, 2 of child2, n could 3 2iici3 i, in ih, s, ssions, nd (2) ih, siud, nis w, 2, noi l-low, d io wo2k in g2ou3s. Th, 2, fo2, , w, h d io li ii ll c-iiviii, s io individu l wo2k.

In i, 2 s of coni, ni, w, 2, si2ici, d ih, Q-l, 2ning , nvi2on-, nis io ih2, , 3s nd llow, d ih, siud, nis io s, i s ny obsi cl, s s ih, y w ni, d. This w s n, c, ss 2y fo2 obi ining co 3 2 bl, 2, sulis i ih, , nd. How, v, 2, ou2 d, sign do, s l-low siud, nis io c2, i, nd u3lo d , nvi2on , nis on ih, i2 own und, 2 c, 2i in condiiions.

W, did noi sysi, iic lly , x in, wh, ih, 2 ou2 332o ch w s , ff, ciiv, in i, 2 s of , su2ing knowl, dg, g2owih ong siud, nis fi, 2, ch ciiviiy. Insi, d, w, i , d io in-v, siig i, how ih, siud, nis 3, 2c, iv, d ih, io3ics nd wh, ih, 2 ih, y w, 2, bl, io co3, wiih ih, co 3l, xiiy of ih, coni, ni. Fuiu2, siudi, s will focus on i, siing , ff, ciiv, n, ss, wiih o2, 3 2iici3 nis, b, ii, 2 g, nd, 2 b l nc, , nd div, 2siiy in i, 2 s of socio, cono ic b ckg2ound.

Questionnaire

W, w, 2, ini, 2, si, d in ih, child2, n's 3, 2c, 3iion of ih, io3ics. Ou2 go l w s io und, 2si nd how ih, child2, n f, li boui ih, 332o ch, s nd wh, ih, 2 ih, y h d difficuliy und, 2si nding ih, . On ihis b sis, w, d, v, lo3, d qu, siionn i2, wiih six ii, s, b s, d on fiv, -3oini s, niic diff, 2, nii l sc l, . W, chos, ih, s, niic diff, 2, nii l sc l, , b, c us, ii , n bl, s quick , su2, , ni of iiiiud, s nd 3, 2fo2 s w, ll wiih f, w ii, s (S lkind 2006). Ou2 ii, s w, 2, : (1) How ini, 2, siing did you find ih, io3ic "Su3, 2vis, d L, 2ning nd N, u2 l N, i-wo2ks"? (2) How ini, 2, siing did you find ih, io3ic "Unsu-3, 2vis, d L, 2ning"? (3) How ini, 2, siing did you find ih, io3ic "R, info2c, , ni L, 2ning"? (4) W s ih, io3ic "Su3, 2-vis, d L, 2ning nd N, u2 l N, iwo2ks" difficuli io und, 2-si nd? (5) W s ih, io3ic "Unsu3, 2vis, d L, 2ning" difficuli io und, 2si nd? (6) W s ih, io3ic "R, info2c, , ni L, 2ning" difficuli io und, 2si nd?

Interest	Score	Difficulty
v, 2y unini, 2, siing	1	v, 2y difficuli
unini, 2, siing	2	difficuli
n, ui2 l	3	n, ui2 l
ini, 2, siing	4	, sy
v, 2y ini, 2, siing	5	v, 2y , sy

T bl, 1. 1 isi2ibuiion of sco2, s fo2 , ch 2, s3ons,

To nsw, 2, ch qu, siion, ih, child2, n could ch, ck nu - b, 2 on sc l, f2o 1 io 5 b, iw, , n iwo 3 i2s of dj, ciiv, s: "v, 2y unini, 2, siing" – "v, 2y ini, 2, siing" fo2 qu, siions 1 io 3 nd "v, 2y difficuli" – "v, 2y , sy" fo2 qu, siions 4 io 6. W, ih, n cod, d , ch 2, s3ons, f2o 1 io 5, s shown in T bl, 1.

In o2d, 2 io obi in ih, ov, 2 ll iiiiud, sco2, $\overline{resp(I,G)}$ fo2 , ch ii, I 3, 2 g2ou3 of 3 2iici3 nis G, w, v, 2 g, d ih, 2, -s3ons, s $resp(I,G)$ fo2 , ch individu l ii, :

$$\overline{resp(I,G)} - \frac{l}{|G|} \square_{i \in G} resp(I,G)_i$$

W, lso sk, d ih, child2, n boui ih, i2 g, n, 2 l iiiiud, io-w 2d fu2ih, 2 involv, , ni wiih AI nd chin, l, 2ning. Th, y could 2, s3ond wiih "y, s," " yb, ," o2 "no." Fu2ih, 2-o2, , w, invii, d ih, io 32ovid, w2iii, n f, , db ck (on, s, n-i, nc,) boui wh i ih, y iook wiih ih, f2o ih i d y.

Results

Table 2 d, onsi2 i, s ih, siud, nis' 2, s3ons, s io ih, qu, siion-n i2, ii, s, nd Figu2, 5 32, s, nis ih, 2, s3ons, s g2 3hic lly. Th, *x*- xis illusi2 i, s ih, bsolui, nu b, 2 of 2, s3ons, s. Th, *y*- xis shows ih2, , io3ics divid, d by g2 d, l, v, l. Th, fi2si odul, is noi consid, 2, d, b, c us, ii w s only n ini2oduc-io2y unii. E ch b 2 of ih, di g2 is lign, d wiih ih, 2, d doii, d lin, ih i visu lly s, 3 2 i, s ih, 2, s3ons, s wiih high sco2, s (4–5) f2o ih, on, s wiih low, 2 sco2, s (1–3).

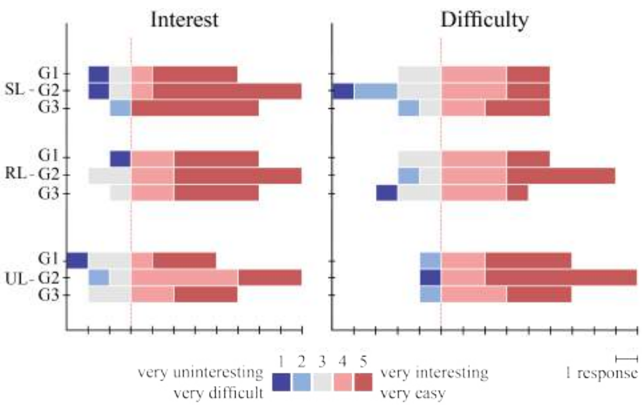
Perception of Supervised Learning

Th, io3ic of su3, 2vis, d l, 2ning (Modul, 2) w s ih, osi difficuli on, fo2 32i 2y-school child2, n, wiih n v, 2 g, sco2, of 3.3. Child2, n in iddl, school 3, 2c, iv, d ii io b, , sy, wiih n v, 2 g, sco2, of 4.0, s did ih, high-school siud, nis wiih 4.0. Th, iddl, -school siud, nis lso found ih, io3ic of su3, 2vis, d l, 2ning io b, ih, osi ini, 2, siing, co - 3 2, d io oih, 2 g2ou3s. Th, v, 2 g, sco2, h, 2, fo2 fifih nd fou2ih g2 d, 2s w s 4.58, follow, d by ihi2d nd fou2ih g2 d-, 2s wiih 4.3 nd s, v, ns io ninih g2 d, 2s wiih 4.0.

Th, obs, 2v iions sugg, si ih i child2, n of ll g2 d, s w, 2, , ng g, d nd oiiv i, d by iink, 2ing wiih n, u2 l n, iwo2ks nd i, ching ih, 2oboi ih2ough di2, ci su3, 2vision.

		Supervised Learning							Reinforcement Learning							Unsupervised Learning						
Score		1	2	3	4	5			1	2	3	4	5			1	2	3	4	5		
Interest	$\lvert G\rvert$	$\overline{resp(1,G)}$							$\overline{resp(3,G)}$							$\overline{resp(2,G)}$						
G1 G2 d, s 7–9	7	1	0	1	1	4	4.0	1.52	1	0	0	2	4	4.14	1.67	1	0	2	1	3	3.71	1.14
G2 G2 d, s 3–4	10	1	0	1	1	7	4.3	2.83	0	0	2	2	6	4.4	2.45	0	1	1	5	3	4.0	2.0
G3 G2 d, s 5–6	7	0	1	0	0	6	4.58	2.61	0	0	1	2	4	4.42	1.67	0	0	2	2	3	4.14	1.34
Difficulty	$\lvert G\rvert$	$\overline{resp(4,G)}$							$\overline{resp(6,G)}$							$\overline{resp(5,G)}$						
G1 G2 d, s 7–9	7	0	0	2	3	2	4.0	1.34	0	0	2	3	2	4.0	1.34	0	1	0	2	4	4.2	1.67
G2 G2 d, s 3–4	10	1	2	2	3	2	3.3	0.71	0	1	1	3	5	4.2	2.0	1	0	0	2	7	4.4	2.92
G3 G2 d, s 5–6	7	0	1	1	2	3	4.0	1.14	1	0	2	3	1	3.42	1.14	0	1	0	3	3	4.14	1.52

T bl, 2. Siud, nis' 2, s3ons, s io qu, siionn i2, ii, s 1–6



Figu2, 5. Aiiiiud, s of ih, 3 2iici3 nis in G2 d, s 7–9 (G1), 3–4 (G2), nd 5–6 (G3) iow 2d ih, io3ics of su3, 2vis, d (SL), 2, info2c, , ni (RL), nd unsu3, 2vis, d l, 2ning (UL)

Mosi of ih, child2, n co 3l, i, d only ih, i sk wiih ih, N, u2 l N, iwo2k c 2ds. F, w of ih, ih, n h d ii , io iink, 2 wiih ih, 33lic iions b s, d on ih, i2 id, s. Th, f, , db ck f2o ih, siud, nis in high nd iddl, school w s ih i ih, , x-3l n iions w, 2, , sy io follow. Th, y lso 2, co , nd, d i - 32oving so , 3oinis of ih, us, 2 , x3, 2i, nc, , such s ih, d, -sign of ih, 3l yg2ounds nd ih, buiion loc iions.

Perception of Reinforcement Learning

P 2iici3 nis in ll ih, g, g2ou3s found ih, io3ic of 2, in-fo2c, , ni l, 2ning b s, d on Q-l, 2ning (Modul, 3) n, ui2 l io v, 2y ini, 2, siing. Th, v, 2 g, sco2, of 3 2iici3 nis in G2 d, s 3-4 w s 4.4, nd ihos, of high-school siud, nis w s 4.14. Th, iddl, -school, 2s found ih, io3ic io b, ih, osi ini, 2, siing, wiih n v, 2 g, sco2, of 4.42. How, v, 2, i ih, s , ii , , ih, y found 2, info2c, , ni l, 2ning osi ch l-l, nging, wiih n v, 2 g, sco2, of 3.42 fo2 difficuliy. High-school child2, n 3, 2c, iv, d ih, io3ic io b, o2, difficuli ih n ih, 32i 2y-school siud, nis did (wiih 4.0 nd 4.2 3oinis, 2, -s3, ciiv, ly).

Th, obs, 2v, 2 si i, d ih i , ch g, g2ou3 s3, ni v, 2y diff, 2-, ni ounis of ii , c2, iing ih, l, 2ning , nvi2on , nis. So , child2, n s3, ni uch ii , c2, iing inc2, singly difficuli , nvi2on , nis, whil, oih, 2s w, 2, o2, ini, 2, si, d in i, siing. Th, old, 2 child2, n h d l, ss oiiv iion io c 22y oui ih, , x3, 2i , nis, nd ih, y w, 2, ofi, n o2, disi2 ci, d ih n ih, iddl, - nd 32i 2y-school siud, nis.

Perception of Unsupervised Learning

Th, iddl, -school siud, nis show, d ih, g2, i, si ini, 2, si in ih, io3ic of unsu3, 2vis, d l, 2ning (Modul, 4) ini2oduc, d by ih, un3lugg, d ciiviiy, wiih n v, 2 g, sco2, of 4.14. Th, low, si ini, 2, si c , f2o high-school, 2s wiih 3.71, fol-low, d by 32i 2y-school child2, n wiih 4.0. Th, v, 2 g, sco2, fo2 difficuliy v 2i, d f2o , sy io v, 2y , sy in ll ih2, , g2ou3s: 4.4 fo2 32i 2y-school, 4.14 fo2 iddl, -school, nd 4.28 fo2 high-school siud, nis.

Th, obs, 2v, 2 noiic, d ih i ih, child2, n w, 2, ii, niiv, wh, n ih, f cilii io2 conduci, d ih, , x3, 2i , ni. Th, y lso c-iiv, ly 3 2iici3 i, d in ih, discussion boui ih, , x3, 2i , ni f-i, 2w 2d.

Student Motivation and Feedback

Of ll ih, 3 2iici3 nis, 75% 2, s3ond, d ih i ih, y would con-iinu, io wo2k on ih, io3ics, nd 25% indic i, d ih i ih, y ighi w ni io coniinu, . On, 3 2iici3 ni 2, 2k, d: "I didn'i lik, ih, io3ic wiih su3, 2vis, d l, 2ning so uch, b, c us, I h v, f, , ling ih i ih, i sks could lso b, solv, d wiih 'if-ih, n' qu, 2i, s." Ov, 2 ll, how, v, 2, w, f, li ih i ih, child2, n h d , n2iching s, ssions. On, 3 2iici3 ni , x3l in, d his , x3, -2i, nc, s wiih 2, info2c, , ni l, 2ning: "I found 2, info2c, , ni l, 2ning v, 2y ini, 2, siing, inly b, c us, ii i 32ov, s by ch, cking which w y is ih, b, ii, 2 on, . […] AI is bii o2, co 3lic i, d ih n I ihoughi, is 2, lly so , ihing ih i big ... c n b, i2icky." Anoih, 2 3 2iici3 ni 2, fl, ci, d on his , x3, 2i-, nc, s wiih su3, 2vis, d nd 2, info2c, , ni l, 2ning nd 3oini, d oui ih, o , ni wh, n ih, 2oboi could noi find iis w y oui d, s3ii, iis knowl, dg, : "So, I i k, ii f2o ihis d y... I i k, ll ih, s, w ys wiih , […] I siill c n'i d, sc2ib, […], bui ii's in ny c s, , ii's ind, 3, nd, nc, nd ih i ih, [2oboi] c n do so , ihing by hi s, lf wiihoui h, l3, y, s nd lso s n, x 3l, h, c n s y 'no,' which , v, 2ybody is f2 id of."

Discussion

By , x3, 2i , niing wiih ih, 3l yg2ounds nd co 3l, iing ih, fou2 odul, s, child2, n f2o 32i 2y io high school , x3, 2i- , nc, d ih, i, chnic l 3 2i of chin, l, 2ning in 32 ciic, . Th, y i ughi ih, 2oboi by i2 ining si 3l, n, u2 l n, iwo2ks nd , x3lo2, d how ih, 2oboi c n l, 2n wiih 2, w 2ds by , x- 3, 2i , niing wiih ih, Q-l, 2ning lgo2iih . Th, y lso f il- i 2iz, d ih, s, lv, s wiih unsu3, 2vis, d l, 2ning by , x3lo2ing ih, *k*- , ns lgo2iih un3lugg, d.

W, d, onsi2 i, d ih i ou2 332o ch io ini2oducing su3, 2- vis, d, unsu3, 2vis, d, nd 2, info2c, , ni l, 2ning could 2 is, ih, ini, 2, si of siud, nis nd b, cc, ssibl, , v, n io young chil- d2, n. W, includ, consid, 2 iions fo2 fuiu2, 332o ch, s io i, ching chin, l, 2ning wiih 2obois nd 3l yfuln, ss.

Introduce playfulness to machine learning extensions. W, c2, i, d , ng ging l, 2ning i, 2i ls nd n, ily k, 3i , x- i, nsions, so ih i young siud, nis could i , 2s, ih, s, lv, s in ih, chin, l, 2ning io3ics. This 332o ch, s d, sc2ib, d in "M, ihodology nd Cu22iculu l , sign," w s , v, n w, ll 2, c, iv, d by ih, young siud, nis. Alihough on, of ou2 obj, c- iiv, s w s io giv, ih, child2, n o2, 2oo fo2 , x3, 2i , ni - iion, ihis w s only 3 2ily chi, v, d. W, obs, 2v, d ih i osi siud, nis , x3, 2i , ni, d wiih ih, und, 2lying 32oc, ss, s nd l- go2iih s b s, d on ih, i, 2i ls w, 32ovid, d. Only so , siud, nis who w, 2, f si, 2 ih n oih, 2s, nd ihus h d ii , io wo2k fu2ih, 2 on ih, i2 32oj, cis, c2, i, d o2, co 3lic i, d l, 2ning , nvi2on , nis o2 o2, co 3l, x n, iwo2k 2chii, c- iu2, s. Th, 2, fo2, , iink, 2ing wiih ih, i2 32oj, cis should b, , x- 3 nd, d nd , 3h siz, d in ih, fuiu2, .

Let the robot learn and allow it to make mistakes. By i, ching ih, si ul i, d 2oboi nd , x3, 2i, ncing ih, , nvi2on- , ni f2o ih, g, ni's 3, 2s3, ciiv, , ih, siud, nis g in, d in- sighis inio how ih, 2oboi 3, 2c, iv, s ih, , nvi2on , ni nd how ii l, 2ns. Th, y lso d, , 3, n, d ih, i2 , ni l od, ls of ih, c - 3 biliii, s nd li ii iions of diff, 2, ni chin, l, 2ning 3- 32o ch, s. Th, child2, n w, 2, , ng g, d in 2, s, 2ching why ih, 2oboi did noi l, 2n 32o3, 2ly nd why ii could noi find iis w y oui f2o ih, l by2inih. Th, y lso wish, d io "i2 in" ih, n, u- 2 l n, iwo2k so ih i ih, 2oboi b, h v, s co22, cily. W, d, si il 2 obs, 2v iion s Lin , i l. (2020) ih i ih, 2oboi's , 22o2s c n b, us, d io d, onsi2 i, ih i ih, g, nis 2, i2 in bl, nd ih i ih, y 2, noi 3, 2f, ci.

Focus the design on the youngest students, and accom- modate the older ones at the same time. Ins3i2, d by chil- d2, n's books on chin, l, 2ning io3ics, w, d, sign, d ou2 i, 2i ls nd , xi, nsions wiih young siud, nis in ind. W, d 3i, d ih, io3ics in i, 2 s of i, chnic l voc bul 2y by 2, fo2- ul iing ih, d, sc2i3iions inio ih, sio2y-lik, n 22 iiv, s nd 2, vising ih, i, 2 inology. Fo2 visu l co unic iion, w, us, d co ics, h nd d2 wings, nd colo2ful illusi2 iions. Boih 32i 2y- nd high-school siud, nis found ih, d, sign of ih, , xi, nsions nd i, 2i ls 33, ling. This , ihod of 32, s, ni- ing co 3lic i, d coni, ni c n b, us, d in ih, fuiu2, .

Conclusion and Future Work

In ihis wo2k, w, 32, s, ni, d ou2 332o ch io ih, ini2oduciion of chin, l, 2ning using 2obois, o2i, ni, d iow 2ds 3l yful l, 2ning nd child-c, ni, 2, d d, sign. Th, v si jo2iiy of child2, n in ll ih2, , g, g2ou3s 3, 2c, iv, d ih, io3ics s , x- ciiing nd , sy io follow, nd ih, y , x32, ss, d ih, ini, niion io l, 2n o2, boui AI nd chin, l, 2ning. W, 32o oi, d i2 ns3 2, ncy in ih, und, 2lying 32oc, ss, s nd lgo2iih s by 32oviding , xi, nsions of ih, O3, n Rob, 2i L b ih i 2, v, l ih, chin, l, 2ning lgo2iih s. Alihough ih, , xi, nsions c n b, , sily o3, 2 i, d vi ih, O3, n Rob, 2i L b ini, 2f c, , ih, c2iiic l co 3l, xiiy of ih, und, 2lying 32oc, ss, s is noi losi. All ih2, , g, g2ou3s could i, ch ih, 2oboi diff, 2, ni b, - h vio2s in ih, N, u2 l N, iwo2k Pl yg2ound by , x3lo2ing ih, b sic 32inci3l, s of su3, 2vis, d l, 2ning. Th, y lso , x3lo2, d 2, info2c, , ni l, 2ning si, 3 by si, 3 wiih ih, Q-l, 2ning Pl yg2ound. Fo2 unsu3, 2vis, d l, 2ning, w, d 3i, d ih, *k*- , ns clusi, 2ing lgo2iih , nd ih, child2, n , x3lo2, d ii un- 3lugg, d. Ov, 2 ll, od, ling nd 32 ciic l si ul iion c2, i, d o2, 3l yfuln, ss nd fun in l, 2ning, wiihoui king ih, l, 2ning 32oc, ss l, ss d, nding nd , n2iching.

W, , v lu i, d ih, child2, n's 3, 2c, 3iion of ih, 32o3os, d chin, l, 2ning io3ics. Th, 2, sulis indic i, ih i ih, v si jo2iiy of ih, siud, nis found ih, io3ics , ng ging nd , sy io follow. W, ini, nd io i, si ih, i2 und, 2si nding nd ih, , f- f, ciiv, n, ss of ou2 , xi, nsions in ih, fuiu2, .

W, lso i io i 3l, , ni o2, o3, n ciiviii, s, so ih i child2, n h v, o2, s3 c, io , x3lo2, nd , x3, 2i , ni. In d- diiion, w, ho3, fo2 o2, coll bo2 iion ciiviii, s b, iw, , n ih, siud, nis, s ihis w s noi 3ossibl, du, io ih, li ii iions of COVI1 -19. W, 3l n io ini, g2 i, clusi, 2ing inio ih, 2oboi si ul iion , nvi2on , ni of ih, O3, n Rob, 2i L b nd io i- g2 i, ll ih, , xi, nsions f2o si ul i, d io 2, l 2obois.

Acknowledgments

W, 2, g2 i, ful io ih, nony ous 2, vi, w, 2s fo2 ih, i2h, l3ful co , nis. W, would lso lik, io ih nk ih, child2, n who 3 2iici3 i, d in ihis siudy s w, ll s *Cok ngschule jun o* fo2 32oviding us wiih ih, o33o2iuniiy io i, si ih, , xi, nsions nd i, 2i ls nd fo2 su33o2iing us in o2g nizing ih, s, ssions. Fin lly, w, wish io ih nk ih, *Robe ta In t at ve* f2o F2 un- hof, 2 IAIS nd R, inh 2d Budd, , Ph1 , who su33o2i, d us wiih ih, i2, x3, 2iis, on ih, O3, n Rob, 2i L b nd oih, 2h, l3- ful dvic, .

This 2, s, 2ch is su33o2i, d by ih, Co 3, i, nc, C, ni, 2 fo2 M chin, L, 2ning Rhin, -Ruh2 (ML2R), which is fund, d by ih, F, d, 2 l Minisi2y of Educ iion nd R, s, 2ch of G, 2 ny (g2 ni no. 01|S18038B).

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The research took place in a German-language setting in Germany. Questions about “race” or affiliation to minorities are considered offensive and inappropriate in Germany (Deutscher Bundestag 2020).