

The Influence of a Sensorimotor Handwriting Programme on the Emergent Handwriting Development and Motor Proficiency of Junior Infant Children

The focus of this paper is on the influence of a sensorimotor handwriting programme on the emergent handwriting skills and motor proficiency of junior infant children attending DEIS and non-DEIS schools, and on the practice, knowledge and perceptions of their teachers in relation to sensorimotor development.

The study incorporated a mixed methods approach with two phases of data collection. The first phase involved assessment of fine and gross motor skills of 178 children from three DEIS schools and three non-DEIS schools, using the standardised BOT-2 test (Bruininks & Bruininks, 2005). Assessment results provided the rationale for, and informed the adaptation and implementation of, a sensorimotor handwriting programme across the six participating schools. During phase two, the class teachers participated in a professional development initiative, following which they implemented the sensorimotor handwriting programme with the participating children over a 16-week period. Post-implementation of the programme, children were retested using the BOT-2, and semi-structured interviews were employed to gather information relating to changes in teachers' perceptions, knowledge and practice in relation to sensorimotor development and the sensorimotor handwriting programme.

The key findings of this study revealed that children in the DEIS schools entered junior infants with lower motor proficiency than the children in non-DEIS schools, while post-implementation of the sensorimotor handwriting programme, there was no longer a statistically significant difference. What is clear from the participating teachers' responses is that they gained new knowledge and understanding in relation to sensorimotor development and emergent handwriting skills, and that the sensorimotor handwriting programme was positively received and regarded. All ten of the participating teachers reported that children's enjoyment and motivation in relation to handwriting increased.

Keywords: Handwriting development, motor development, emergent handwriting, Handwriting Programme, infant education

SINÉAD MCCAULEY LAMBE is a former primary school teacher and is now an Assistant Professor in the School of Inclusive and Special Education at the DCU Institute of Education. ÓRLA NÍ BHROIN was an Associate Professor in the School of Inclusive and Special Education at the DCU Institute of Education. MARIE FLYNN is a lecturer in Sociology at the DCU Institute of Education.

Corresponding author: sinead.mccauleylambe@dcu.ie

RELEVANCE AND CONTEXT

The national prioritisation of literacy development is reflected by the recent revision and implementation of the Primary Language Curriculum (PLC) by the National Council for Curriculum and Assessment (NCCA, 2019). The PLC emphasises the key role that communication, including verbal, non-verbal and print-based communication plays in the lives of young children. Proficient literacy skills, including oral language, reading and writing provide opportunities for children “to engage emotionally, socially, cognitively, imaginatively and aesthetically in relationships and cultural experiences” (NCCA, 2019, p.6). For children to be able to acquire skills of thinking, expression, reflection, critique and empathy, and to develop their own identity and to experience full participation in society, they must become literate (NCCA, 2019).

Despite the evidence in relation to policy and curricular commitment to improving literacy skills at a national level, research in an Irish context relating to the decline of children’s motor skills (O’Mahony, Dempsey, & Killeen, 2008) indicates that teachers, particularly those in DEIS settings, are faced with a number of challenges in the junior infant classroom. These challenges include the readiness of children to begin literacy development, in particular in the area of emergent handwriting which is dependent on children’s motor proficiency upon entry into school. Findings from a recent research study in Ireland (O’Brien et al., 2015) indicate that the motor proficiency of young people is in decline, with only 11% of early adolescents assessed achieving mastery or near mastery on nine fundamental movement skills including hopping, kicking and throwing by age six. Anecdotally, many teachers note children’s poor motor skill competency and a lack of school readiness in relation to the development of emergent handwriting skills upon entry into school.

The Contribution of Handwriting to School Success

Problems with the mechanical aspects of handwriting can negatively influence the writing and academic performance of students in a number of ways in the classroom. Firstly, poor motor control will affect a child's ability to write legibly and result in incorrect size or placement of letters, inadequate pencil grip and slow handwriting speed (McGlashan, Blanchard, Sycamore, Blandine-French & Holmes, 2017). Research indicates that as a consequence of poor legibility, readers may be biased in their evaluation about the ideas and quality of a text (Santangelo & Graham, 2016) and written text may be less accessible to others (Graham, 1999). Good handwriting is still regarded by teachers as a sign of academic prowess (Santangelo & Graham, 2016) and a less legible version of a paper will be scored lower than a more legible one, according to research (Graham, 1999).

Secondly, poor motor skills and handwriting skills may impede children's writing efforts by interfering with other writing processes (Graham et al., 2008). Santangelo and Graham (2016, p.226) refer to the *Writer Effect*, which describes how handwriting "consumes an inordinate amount of cognitive resources" until it becomes a fluent and automatic skill. Graham (1992) points out that until children can produce letters with reasonable speed, they are at risk of losing their ideas as a result of their handwriting speed not being 'fast enough to keep up with their thoughts' (p.3). Children experiencing fine motor difficulties are often fatigued by handwritten tasks in school and often take longer to complete their work (May-Benson et al., 2002). This means that they are likely to lose some writing ideas, as their handwriting is often not fast enough for them to record all of their ideas (Graham, 1999).

Finally, the effect of poor fine motor and handwriting skills on academic achievement is highlighted by the significant proportion of the day allocated to fine motor and written tasks in early years' settings (Cameron et al., 2012). Most learning activities in the classroom involve motor as well as cognitive components. Children's self-perception, self-esteem, and motivation are likely to be negatively impacted as a result (Piek, Bradbury et al., 2008; Gaul & Issartel, 2016). Children with strong fine motor skills, on the other hand, have been found to demonstrate higher academic achievement, mathematical achievement and earlier development of reading (Van der Fels et al., 2015; Roebers et al., 2014; Cameron et al., 2012; Grissmer et al., 2010). Research indicates that because handwriting tasks demand integration of the motor and visual processing systems, handwriting fosters children's early literacy skills (Neumann et al., 2012). Children showing competency in handwriting skills have more sophisticated letter knowledge, phonological awareness and spelling competence (Oberer et al., 2018)

while children's word writing skills at the end of kindergarten have been used to predict children's literacy skills, including spelling, reading comprehension and oral reading, by the end of first grade (Oberer et al., 2018).

THE DESIGN OF THE SENSORIMOTOR PROGRAMME

The Sensorimotor Handwriting Programme (Figure 1) is based on the format of the Handwriting Club programme by Melissa Keller (2001). The programme was adapted in relation to the content, the format, the implementation and the accompanying resources. The adaptations to the programme were based on relevant literature in the area (Dinehart, 2014), and the theoretical framework that underpins the research. The key theory that supports an understanding of the multiple and reciprocal influences on children's motor development is Bronfenbrenner's biological theory (Bronfenbrenner, 1979, 1988, 1992; Bronfenbrenner & Evans, 2000; Bronfenbrenner & Morris, 2006). Supporting this framework and offering a lens through which children's sensorimotor development could be considered are Piaget's (1974) cognitivist approach to sensorimotor development and Ayres's (1964, 1972a, 1972b, 1974) information processing approach. Both these theories consider the interaction between the child and the environment as key to development, as well as the biological features of the child. In addition to the theoretical framework, the quantitative data collected during phase one using the BOT-2 standardised test of motor proficiency was used to inform the design of the programme. Incidental conversations with teachers and principals and observational field notes from the testing period during the initial data collection phase also informed the design of the programme.

Dinehart's (2014) review of current research in the area of handwriting in early childhood education informed the design of the Sensorimotor Handwriting Programme in four major ways:

- (1) The programme should include explicit handwriting instruction relating to letter form rather than take a purely sensorimotor approach;
- (2) The programme should be delivered as early on as possible in the school year to respond to the need to develop 'handwriting readiness' skills for the development of handwriting later in the year;
- (3) Individual and specific planning of instruction to meet individual needs and consistent reviewing of student's progress is key to the success of the programme. Therefore, observations of the programme being implemented took place over the 16-week implementation period;

- (4) An intervention that was easy to implement and deliver by teachers was noted as a benefit. Therefore, professional development days were facilitated for teacher participants and a user-friendly resource pack were key elements of this programme.

Based on those four key findings from Dinehart's (2014) review of the current research and, on observations and incidental conversations with teachers and principals during the initial data collection phase, the following guiding principles for the Sensorimotor Handwriting Programme were developed.

The programme should:

- be delivered in a mainstream class setting, by non-specialists (teachers) and without the use of expensive equipment
- include a Sensorimotor Handwriting Programme manual and a PowerPoint presentation for the programme to be easily implemented and replicable
- include activities that incorporate the sensorimotor skills that are prerequisites of handwriting: proprioception, visual perception and fine motor skills
- include sensory-based strategies that can be facilitated by non-specialists
- include explicit teaching strategies in relation to letter formation
- be high in intensity and duration
- be evaluative - children to be tested pre- and post-programme using a standardised measure, teacher interviews and parent questionnaires
- take place in an Irish / European context
- be informed by the curriculum (NCCA, 1999), teacher guidelines, and the Primary Language Curriculum support materials for writing (NCCA, 2019)

Figure 1: The Sensorimotor Handwriting Programme



Sensorimotor Handwriting Session Format

1. Gross Motor Warm-Up Activities (5 minutes)

Choose 1 or 2 activities from a selection of activity cards (e.g. crab walk, jumping jacks, balance on one leg, cross crawls)

- Weeks 1-4: Proprioception
- Weeks 4-8: Balance & stability
- Weeks 12-16: Bi-lateral coordination and crossing the midline

2. Fine-Motor Warm up- Activities (5-10 minutes inclusive of distributing materials)

Choose an activity per group / per child each day making sure that all activities are covered over the course of the 16 weeks.

- 4 weeks: Clay, therapy putty, silly putty, play-doh
- 4 weeks: Clothespin games, tongs, tweezers, chop sticks
- 4 weeks: Interlocking construction games, mega blocks, lego, links
- 4 weeks: Squeezy toys and materials, foam balls, rubber balls, popping bubble wrap

3. Visual Perception Work (5 minutes)

Complete one worksheet per session. Worksheets cover the following skills

- Form and constancy
- Visual discrimination
- Visual Closure
- Visual Sequencing

Figure 1: The Sensorimotor Handwriting Programme (continued)



4. Letter Introduction (2-3 minutes)

- Teacher models writing the letter on the board and describes the steps (can use Jolly Phonics here)
- If not introducing letters yet, explicit modelling of pre-writing patterns
- Students imitate by writing in the air using large arm movements and repeating the steps aloud
- Students then continue to say the steps while writing on the table with pointer finger

5. Guided Practice (10 minutes)

- Write on board
- Write on another student's back and have him or her guess the letter
- Write on large sheets using a range of materials: colour change markers, scented markers, battery operated pens, paint, chalk, finger paint, shaving foam.
- Write in sand, rice, lentils, glitter bags

6. Semi-independent practice (5-10 minutes)

- Write in handwriting copy or sheet with teacher monitoring

7. Independent Practice Homework

METHODOLOGY

A mixed methods approach, often aligned to the pragmatist paradigm, appeared to be the most suitable methodology in terms of this research study. Pragmatism is focused on framing or answering the research question or problem (Clarke & Visser, 2019; Biesta & Burbules, 2003). It uses a variety of methods because they are fit for purpose. This study therefore employed a mixed methods approach, drawing on both qualitative and quantitative methods of data collection. Mixed methods are effective in addressing multiple research questions that cannot be satisfactorily answered by a singular approach.

Phase one of this research study employed a largely quantitative approach. This phase of the study sought to identify a baseline measure of motor proficiency of 178 junior infant children across six schools, three DEIS schools and three non-DEIS schools in the Dublin area, using a standardised test of motor proficiency - the Bruininks-Oseretsky Test of Motor Proficiency (BOT-2), (Bruininks & Bruininks, 2005). Once a baseline measure across all schools was identified, the researcher sought to compare measures of motor proficiency across DEIS schools and non-DEIS schools. Throughout this initial data collection phase, the researcher also made qualitative field notes based on observations of the children in each school, and based on incidental conversations with teachers and principals in each school.

Phase two of this research study employed a mixed methods approach, whereby both qualitative and quantitative approaches were used. Phase two involved the adaptation of, and the implementation of, a sensorimotor handwriting programme (Keller, 2001). The sensorimotor handwriting programme, described in more detail later, was informed by the data gathered in phase one, and supported by the relevant literature.

The sensorimotor handwriting programme was implemented by 10 junior infant class teachers in all six schools of the 178 participating children from phase one. The programme was implemented over a 16-week period (October 2018 - March 2019). During this phase, the necessary supporting resources for the implementation of the sensorimotor handwriting programme were planned and produced. The teachers of the participating children from phase one attended two professional learning days (October 2018, January, 2019), in relation to delivering the sensorimotor handwriting programme during this second phase of the study. The initial training day (October, 2018), happened prior to implementation of the programme and the second training day (January, 2019), took place at the halfway point, 8-weeks into implementation of the programme. Throughout the 16-week

implementation period, the researcher visited each site on one occasion to observe the research participants (teachers and children), engaging with the sensorimotor handwriting programme.

Post-implementation of the programme, a quantitative approach was employed for the second time, whereby all of the participating children were retested using the same standardised test of motor proficiency – the BOT-2. This second testing period took place throughout May and June 2019. Post-implementation of the programme, a qualitative exploratory approach was also taken, whereby semi-structured interviews were conducted (June 2019), to explore the knowledge and understanding of the participating teachers of the participating children, in relation to motor development and emergent handwriting skills. The semi-structured interviews were used also to determine the perceived efficacy by teachers of the sensorimotor handwriting programme. Ethical considerations were addressed carefully throughout each phase of this research study. The researcher was guided and informed by the DCU Ethical Guidelines and received ethical approval from DCU's ethical governing body in May, 2018. Figure 2 overleaf illustrates the overall research design for this study.

Figure 2: Research Design of the Study

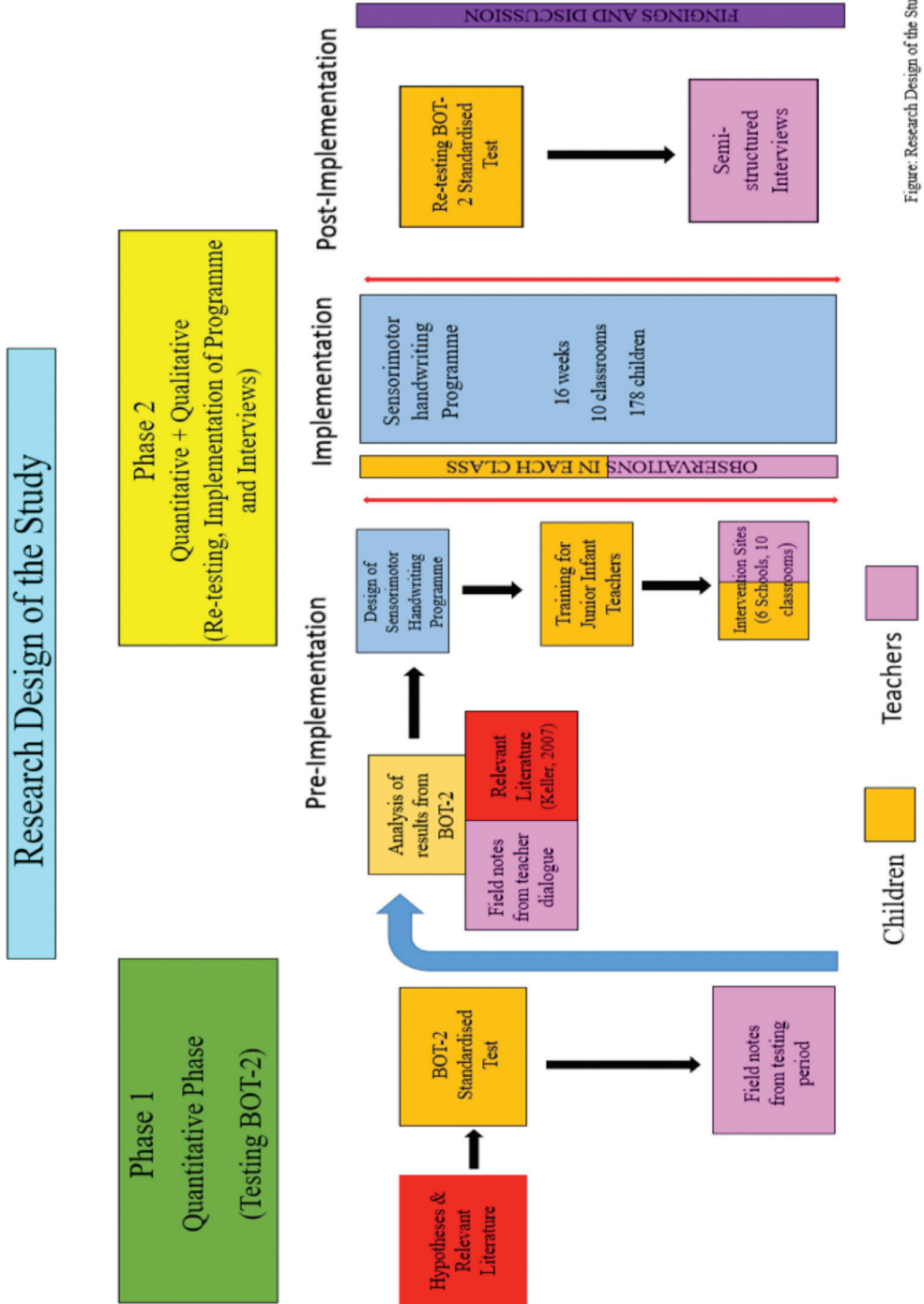


Figure: Research Design of the Study

FINDINGS AND DISCUSSION

The quantitative findings for this research study show that the mean standard score for motor proficiency of all of the participating children across the six schools improved post-implementation of the programme. The mean standard score for all participating children across all six schools increased from 45.1718 pre-implementation of the programme to 47.7178 post-implementation of the programme. Qualitative findings support the statistical data, with all ten of the participating teachers reporting that children's motor skills and emergent handwriting skills had improved post-implementation of the programme.

All of the participating teachers in the study reported that children's motivation, enjoyment and confidence significantly improved as a result of engagement with the sensorimotor handwriting programme. Research in the area of motivation and writing largely focuses on motivating children to engage in the cognitive processes of writing (Boscolo & Gelati, 2019; Bruning & Kauffmann, 2016; Kaplan & Patrick, 2016), rather than on the mechanical process of handwriting. This research study adds to current research in that it highlights specific elements of the sensorimotor handwriting programme detailed below, that teachers believed improved children's motivation to engage in handwriting tasks and subsequently their enjoyment and their confidence in relation to handwriting.

Resources and Materials

In particular, teachers referred to the variety of materials and the types of activities, believing that these were influencing factors on children's motivation, enjoyment and confidence. Participating teachers (Isla and Hannah, School E) reported that children "cheered" when it was time for the handwriting session and that handwriting was "now their favourite thing". It emerged from the qualitative data that using a variety of new and novel writing tools was a contributing factor to children's motivation and enjoyment in relation to handwriting sessions. Making handwriting time a 'discreet time' with 'discreet materials' appeared to have added to children's enjoyment of the sessions. During the professional development days, teachers were issued with a box of handwriting materials and asked to use the box only during the handwriting sessions, rather than making it available to children throughout the day or for free play time. This appeared to be an additional contributing factor in children's enjoyment of the sessions, with one teacher reporting that "they are always asking when they are using (researcher's name) stuff".

A further significant finding in relation to children's improved confidence was the inclusion of blank pages for practice writing as part of the programme. All

of the participating teachers reported that the children loved using blank pages to mark make. Teachers stated that they had not previously used blank pages, rather they had used copybooks from the beginning of the year and throughout the year. The ‘Guided Practice’ step of the programme encouraged children to explore blank space using a variety of materials, before moving to the next step (Semi-independent Practice), which was to write the letters into their copies using their pencils. The purpose of the Guided Practice step was to provide an opportunity for children to explore and play with mark making, in a manner which was free from expectation. Research supports the idea of invitation versus expectation and allowing children some freedom to create. The blank page “presents children with an invitation to make meaning” as opposed to an expectation (Trehearne, 2011, p. 26) All of the participating teachers reported that they would continue to use blank pages for those children who were not developmentally ready to move to copybooks, and that this was helpful in providing those children with opportunities to succeed rather than fail.

Play-based versus instructional teaching and learning

The participating teachers also referred to the range and type of activities as a contributing factor to children’s enjoyment and motivation. One teacher stated that “I *definitely* don’t think the interest would have been as high...without all the different activities”. The programme activities and tasks were largely play-based activities that included an instructional element. It appeared from an analysis of the qualitative data that the activities being both play-based and instructional was a key contributing factor to the success of the programme. One teacher noted how her perceptions of play-based learning had changed. She suggested that she would feel “almost like a guilt” in allowing children to play with playdough for a prolonged period of time. The programme however added focus and structure to what she would have regarded as ‘free-play’ with the playdough. She gained a new awareness of how to integrate direct instruction into play-based activities, and how to scaffold development by being more aware of the specific components of motor development while observing children playing with the playdough. She noted which children were able to roll and to pinch the playdough and how they were seated during the activity and was enabled to extend and develop learning by providing feedback and offering prompts. This finding is significant in that it illustrates a potential misconception about play-based learning and the role of the teacher during play.

IMPLICATIONS FOR PRACTICE

1. *Video clips of programme in action:* The addition of video clips illustrating each stage of the programme would be beneficial to teachers in implementing the programme. Video clips would clearly outline the teaching points for each stage, and help to draw teachers' attention to the specific motor skills that the programme aims to develop. The researcher aims to develop these video clips over the next year as part of the sensorimotor handwriting programme, and they will be made available to teachers on a CD Rom as part of the whole programme package.
2. *Sensorimotor Handwriting Programme:* Teachers benefited from having a discreet list of activities and resources that promote motor development. Handwriting programmes should describe specific activities and resources that are easily replicable for teachers to implement in the classroom. Handwriting programmes should include a teachers' manual that shows an image of the activity and that outlines the key teaching points associated with the activity.
3. *A Balanced Approach:* An approach to teaching handwriting that incorporates playful pedagogy and explicit instruction is effective. A handwriting programme should address children's fine and gross motor skills and visual integration in a fun, enjoyable and playful manner. Children should be provided with opportunities to explore and to develop confidence in relation to emergent handwriting skills. The use of blank pages instead of copies is effective in motivating children in the early stages of mark-making. Children should also be provided with opportunities for formal writing in copybooks, with explicit instruction and feedback in relation to letter formation.
4. *Wider Implementation of the Programme Across Schools:* Informed by the findings of this research study, it is recommended that the final iteration of the sensorimotor handwriting programme should be implemented in the infant classroom in all schools. For this to happen, the programme would be finalised to include a Teachers' manual, a CD Rom with video clips to demonstrate the fine motor and gross motor activities and a pupil Visual Perceptual Skills workbook. The researcher would carry out a number of webinars relating to the implementation of the programme through the Education Centres across the country. There is potential also to build a network of teachers whereby those who were involved in this research study could work with a cluster of teachers in their own geographical areas. To date, the researcher has revisited two of the participating research schools to work with the participating teacher to upskill other teachers in the schools in relation to the implementation of the programme going forward.

FURTHER RESEARCH AND CONCLUSIONS

This study sought to explore the interplay between young children's sensorimotor development and their emergent handwriting skills. In particular, it focused on how teachers employed a sensorimotor handwriting programme in the junior infant classroom to address the emergent handwriting needs of young children. Stemming from this research, a number of areas for further research were identified:

1. Children entering junior infants in DEIS schools have lower levels of motor proficiency than children in non-DEIS schools. The sample for this study was relatively small, however, involving six schools confined to the Dublin area and 178 children. It would be beneficial for this study to be replicated with a larger sample of students across a range of contexts on a national level.
2. Findings from the research suggest that the sensorimotor programme was impactful in relation to children's enjoyment, motivation and confidence in relation to handwriting. The evidence for these findings was based on the participating teacher's perceptions of children's enjoyment, motivation and confidence. Further research focusing on the child's voice could be conducted in relation to the efficacy of the programme.
3. This research indicates that the role of preschools is critical in relation to children's motor development and handwriting development. Participating teachers suggested that early childhood education teachers might benefit from further training or upskilling in these areas. Further research would be beneficial in establishing the need for motor skills and handwriting development with early childhood educators. Further research could also explore the current knowledge, perceptions and practice of early childhood education teachers in relation to motor development and handwriting development.
4. Findings from the research suggest that the sensorimotor handwriting programme was effective in improving children's proficiency in the areas of motor development and handwriting development. While the BOT-2 was employed to support the qualitative findings in relation to children's motor proficiency, the BOT-2 did not provide evidence for improvements relating to children's handwriting. Further research examining the efficacy of the sensorimotor handwriting programme on handwriting using more scientific methods of data collection would be beneficial.

REFERENCES

- Ayres, A. J. (1964). Tactile functions: Their relation to hyperactive and perceptual motor behavior. *American Journal of Occupational Therapy*, 18, 6–11.
- Ayres, A. J. (1972a). *Sensory integration and learning disorders*. Los Angeles: Western Psychological Services.
- Ayres, A. J. (1972b). Types of sensory integrative dysfunction among disabled learners. *American Journal of Occupational Therapy*, 26, 13–18.
- Ayres, A. J. (1974). Occupational therapy for motor disorders resulting from impairment of the central nervous system. In A. J. Ayres (Ed.), *The development of sensory integrative theory and practice: A collection of the works of A. Jean Ayres* (pp. 34–53). Dubuque, IA: Kendall/Hunt.
- Biesta, G. J. J., & Burbules, N. C. (2003). *Pragmatism and educational research*. Lanham, MD: Rowman and Littlefield.
- Boscolo, P. and Gelati, C. (2019). 'Motivating writers. Best practices in writing instruction.' In: S. Graham., CA. MacArthur & M. Herbert (Eds). *Best Practices in Writing Instruction*, New York: The Guilford Press, pp.51-78.
- Bronfenbrenner, U. (1979). *The ecology of human development*. Cambridge: Harvard Press.
- Bronfenbrenner, U. (1988). Interacting systems in human development: Research paradigms: Present and future. In N. Bolger, A. Caspi, G. Downey, & M. Moorehouse (Eds.), *Persons in context: Developmental processes* (pp. 25–49). Cambridge: Cambridge University Press.
- Bronfenbrenner, U. (1992). Ecological systems theory. In R. Vasta (Ed.), *Annals of child development. Six theories of child development: Revised formulations and current issues* (pp. 187-249). London: Kingsley.
- Bronfenbrenner, U., & Evans, G.W. (2000), Developmental science in the 21st century: Emerging questions, theoretical models, research designs and empirical findings. *Social Development*, 9, 115-125.
- Bronfenbrenner, U., & Morris, P. A. (2006). The bioecological model of human development. In R. M. Lerner, W. Damon (Eds.) *Handbook of child psychology: Vol. 1: Theoretical models of human development* (6th ed., pp.793–828). Hoboken, NJ: John Wiley & Sons Inc.

- Bruininks R.H., & Bruininks B.D. (2005). *Test of Motor Proficiency. 2nd edition Manual*: Circle Pines: AGS Publishing.
- Bruning, R. H., & Kauffman, D. F. (2016). Self-efficacy beliefs and motivation in writing development. In C. A. MacArthur, S. Graham, & J. Fitzgerald (Eds.) *Handbook of writing research* (pp. 160–173). The Guilford Press.
- Cameron, C. E., Brock, L. L., Murrah, W. M., Bell, L. H., Worzalla, S. L., Grissmer, D., & Morrison, F. J. (2012). Fine motor skills and executive function both contribute to kindergarten achievement. *Child Development*, 83, 1229-1244.
- Clarke, E., & Visser, J. (2019) Pragmatic research methodology in education: possibilities and pitfalls, *International Journal of Research & Method in Education*, 42(5), 455-469.
- Dinehart, L.H. (2014) Handwriting in early childhood education: Current research and future implications. *Journal of Early Childhood Literacy*. 15(1), 97-118.
- Gaul D, Issartel J. (2016) Fine motor skill proficiency in typically developing children: On or off the maturation track? *Human Movement Science*. 46, 78–85.
- Graham, S., (1992). Issues in Handwriting Instruction. *Focus on Exceptional Children*. 25(2), 2-16.
- Graham, S., (1999). Handwriting and Spelling Instruction for Students with Learning Disabilities: A Review. *Learning Disability Quarterly*, 22(2), 78-98.
- Graham, S., Harris, K. R., Mason, L., Fink-Chorzempa, B., Moran, S., & Sandler, B. (2008). How do primary grade teachers teach handwriting? A national survey. *Reading & Writing* 21: 49-69.
- Grissmer, D., Grimm, K. J., Aiyer, S. M., Murrah, W. M., & Steele, J. S. (2010). Fine motor skills and early comprehension of the world: Two new school readiness indicators. *Developmental Psychology*, 46, 1008–1017.
- Kaplan, A., & Patrick, H. (2016). Learning environments and motivation. In Wetntzel, K, & Miele, D (Eds) *Handbook of motivation at school* (2nd ed., pp.251-273). Routledge.
- Keller, M. (2001) Handwriting Club: Using Sensory Integration Strategies to Improve Handwriting. *Intervention in School and Clinic*. 37(1):9-12.
- May-Benson, T., Ingolia, P., & Koomar, J. (2002). Daily living skills and developmental coordination disorder. In S. Cermak & D. Larkin (Eds.), *Developmental Coordination Disorder* (pp. 140-156). Albany, NY: Delmar.

- McGlashan, H.L., Blanchard, C.C.V., Sycamore, N.J., Blandine-French, R.L., & Holmes, N.P., (2017) Improvement in Children's Fine Motor Skills following a computerized typing intervention. *Human Movement Science*, 56 (B), 29-36.
- National Council for Curriculum and Assessment. (1999). *Curriculum online*. Retrieved from <https://www.curriculumonline.ie/Primary>
- National Council for Curriculum and Assessment (NCCA) (2019). *Primary Language Curriculum*. Retrieved from <https://www.curriculumonline.ie/Primary/Curriculum-Areas/Primary-Language/>
- Neumann, M.M., Hood, M. & Ford, R. (2012). Mother-child joint writing in an environmental print setting: Relations with emergent literacy. *Early Child Development and Care*, 182(10), 1349-1369.
- Oberer, N., Gashaj, V., & Roebbers, C.M. (2018). Executive functions, visual-motor coordination, physical fitness and academic achievement: Longitudinal relations in typically developing children. *Human Movement Science*, 58, 69-79.
- O'Brien, W., Belton, S. & Issartel, J. (2015). Fundamental movement skill proficiency amongst adolescent youth. *Physical Education and Sport Pedagogy*, 21(6), 557-571.
- O'Mahony, P., Dempsey, M., & Killeen, H. (2008). Handwriting speed: duration of testing period and relation to socio-economic disadvantage and handedness. *Occupational Therapy International*, 15(3), 165-177.
- Piaget, J. (1928). *The Child's Conception of the World*. London: Routledge and Kegan Paul Ltd.
- Piaget, J. (1930). *The Child's Conception of Physical Causality*. New York: Harcourt Brace & Company.
- Piaget, J. (1960). *The Psychology of Intelligence*. Totowa, NJ: Littlefield Adams & Co.
- Piaget, J. (1974). *The Origins of Intelligence in Children*. New York: International Universities Press.
- Piaget, J. & Inhelder, B. (1956). *The Child's Conception of Space*. New York: W.W. Norton Company.
- Piaget, J. & Szeminska, A. (1952). *The child's conception of number*. London: Routledge & Kegan Paul.

- Piek, J. P., Bradbury, G. S., Elsley, S. C., & Tate, L. (2008). Motor coordination and social-emotional behaviour in pre-school-aged children. *International Journal of Disability, Development and Education*, 55, 143–15.
- Piek, J., Dawson, L., Smith, L., & Gasson, N. (2008). The role of early fine and gross motor development on later motor and cognitive ability. *Human Movement Science*, 2(5), 668-684.
- Roebers, C. M., Röthlisberger, M., Neuenschwander, R., Cimeli, P., Michel, E., & Jäger, K. (2014). The relation between cognitive and motor performance and their relevance for children's transition to school: a latent variable approach. *Hum. Mov. Sci.*, 33, 284–297.
- Santangelo, T., & Graham, S. (2016). A Comprehensive Meta-analysis of Handwriting Instruction. *Educ Psychol Rev*, 28, 225-265.
- Trehearne, M.P. (2011). *Learning to Write and Loving it!* London: Sage.
- Van der Fels, I.M.J., Wierike, S.C.M., Hartman, E., Elferink-Gemser, M.T., Smith, J., & Visscher, C. (2015). The relationship between motor skills and cognitive skills in 4–16 year old typically developing children: A systematic review. *Journal of Science and Medicine in Sport*, 18(6), 697-703.