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### **Connecting Play to STEM Concepts, Practices and Processes: Review of Research on Play within STEM Learning Environments (publication in fourth edition of the International Encyclopedia of Education)**

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Table 2

Information from each included study

<b>Study</b>	<b>Country/Setting</b>	<b>Ages/Grade</b>	<b>STEM Field/Environment</b>	<b>Type of Play</b>
Adbo, K. and Carulla, C. V. (2019)	Sweden; preschool (formal)	age 3-4 years	Science; chemistry hands-on experiments using water, sugar, milk	Guided play - social learning setup
Adbo, K. and Carulla, C. V. (2020)	Sweden; preschool (formal)	age 3-5 years	Science; chemistry hands-on experiments using a leaf, salt, a sugar cube, and a bath bomb	Guided play - social learning setup
Andrée, M. and Lager-Nyqvist, L. (2013)	Sweden; compulsory schools (formal)	grade 6	Science; inquiry-based science lessons, brown paper, different foods, liquids, measuring sticks	Guided play - environmental setup
Atwood-Blaine, D. and Huffman, D. (2017).	U.S.; science center (non-formal)	grade 5-8	Technology; Great STEM Caper is a free-choice, situated mobile	Game play - virtual/digital
Avraamidou, A., Monaghan, J. and Walker, A. (2012)	Cyprus; home (informal)	age 11 years	Mathematics; Sims 2 computer game	Game play - virtual/digital
Bachman, J. and Dierking, L. (2011)	U.S.; home (informal)	homeschooling families, no data about ages	STEM; hands-on situations using toy cash register, volcano, burning pepper on wood stove	Comparison study
Bagiati, A. and Evangelou, D. (2016)	U.S.; pre-K classroom (informal)	age 3-5 years	Engineering; construction using wooden and Lego blocks	Free play - indoor

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Bairaktarova, D., Evangelou, D., Bagiati, A. and Brophy, S. (2011)	U.S.; preschool (informal)	age 3-5 years	Engineering; semi-structured and structured artifacts; sandboxes, water tables, and puzzles	Free play - indoor
Bird, J. (2020)	Australia; Kindergarten (formal)	age 4-6 years	Technology; range of imaginative technologies including mobiles and telephones, still and video cameras, keyboards and laptops	Guided play - environmental setup
Braham, E.J., Libertus, M.E. and McCrink, K. (2018)	U.S.; children museum (non-formal)	age 2.97-5.27 years	Mathematics; budget and healthy eating prompt cards	Guided play - environmental setup
Bulunuz, M. (2013)	Turkey; kindergarten (formal)	age 5-6 years	Science; field trip to school yard, hands-on explorations, learning stations	Comparison study
Caldera, Y.M., Culp, A.M., O'Brien, M., Truglio, R.T., Alvarez, M. and Huston, A.C. (1999)	U.S.; preschool (formal)	age 4-5 years	Mathematics; large box filled with 70 blocks comprising a variety of shapes	Guided play - environmental setup
Callanan, M.A., Legare, C.H., Sobel, D.M., Jaeger, G.J., Letourneau, S., McHugh, S.R., Willard, A., Brinkman, A., Finiasz, Z., Rubio, E. and Barnett, A. (2020)	U.S.; museums (non-formal)	age 3-7 years	Science; 3 gear exhibits: large wooden pegboard with wooden gears in a bin, table with a magnetic surface with hubs and plastic gears; a steel powder-coated square table, a magnetic tabletop and wooden magnetic gears	Guided play - environmental setup

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Carulla, C.V. and Adbo, K. (2019)	Sweden; preschool (formal)	age 3 years	Science; chemistry hands-on experiments using water, sugar, milk	Guided play - social learning setup
Cohen, L. and Uhry, J. (2011)	U.S.; preschool (formal)	age 4 years	Mathematics; blocks	Guided play - environmental setup
Cohrssen, C. and Niklas, F. (2019)	Australia; preschool (formal)	age 4 years	Mathematics; intervention, The NT Preschool Maths Games	Game play - didactical
Danby, S., Evaldsson, A.C., Melander, H. and Aarsand, P. (2018)	Australia; home; Norway, pre-school; Sweden, after-school program (informal, non-formal)	age 4-7 years	Technology; Minecraft, Batman i-Pad game, Momio network	Game play - virtual/digital
DeLiema, D., Enyedy, N. and Danish, J.A. (2019)	U.S.; mixed-age first and second grade classrooms (formal)	age 6-8 years	Science; Science Through Technology-Enhanced Play, mixed reality learning environment	Game play - virtual/digital
Eason, S.H. and Ramani, G.B. (2020)	U.S.; laboratory setting	age 4-5 years	Mathematics; a box with the foods, a wooden knife, a cutting board, and four plates	Comparison study
Edens, K.M. and Potter, E.F. (2013)	U.S.; preschool (informal)	age 5-6 years	Mathematics; observation of classroom activities (e.g., social-dramatic, art, computer, block, manipulatives,	Free play - indoor

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Edo, M., Planas, N. and Badillo, E. (2009)	Spain; public school (formal)	age 4-10 years	Mathematics; setting up pretend bakery, calculator	Guided play - social learning setup
Emfinger, K. (2009)	U.S.; STEM summer enrichment program (informal)	age 6-8 years	Mathematics; weekly thematic studies, field trips, guest speakers, outdoor “free play”, “free-choice” center times	Free play - both indoor and outdoor
Enyedy, N., Danish, J.A., Delacruz, G. and Kumar, M. (2012)	U.S.; multi-age classroom (formal)	age 3-4.5 years	Science; Learning Physics through Play Project	Guided play - social learning setup
Ferrara, K., Hirsh-Pasek, K., Newcombe, N.S., Golinkoff, R.M. and Lam, W.S. (2011)	U.S.; laboratory setting, CHILDES database	age 4-5 years	Mathematics; MegaBlocs	Comparison study
Fisher, K.R., Hirsh-Pasek, K., Newcombe, N. and Golinkoff, R.M. (2013)	U.S.; laboratory setting	age 4-5 years	Mathematics; shape-sorting task.	Comparison study
Fleer, M. (2009)	Australia; preschool (informal)	age 3.6-5.9 years.	Science; buckets, pumps, funnels, tubes and mortar and pestle, map and treasure hunt, bug machine	Free play - indoor and outdoor
Fleer, M. (2019)	Australia; preschool (non-formal)	age 4-6 years	Science; story books, cultural devices: hoops, microscope, magnifying glasses	Guided play - social learning setup

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Fleer, M. (2020)	Australia; multi-age preschool and school (non-formal)	age 5.3 and 5.2 years	Engineering; story of Robin Hood of Sherwood Forest	Guided play - social learning setup
Gejard, G. and Melander, H. (2018)	Sweden; preschool (informal)	age 3-5 years	Mathematics; magnetic construction toys/blocks	Free play - indoor
Gold, Z.S., Elicker, J., Choi, J.Y., Anderson, T. and Brophy, S.P. (2015)	U.S.; preschool and Head Start (informal)	age 4-6 years	Engineering; large, manipulative, loose parts,	Free play - outdoor and indoor
Gold, Z.S., Elicker, J., Kellerman, A.M., Christ, S., Mishra, A.A. and Howe, N. (2020)	U.S.; preschool (formal)	age 4.2 years	Engineering & Mathematics; wooden unit blocks	Guided play - social learning setup
Gomes, J. and Fleer, M. (2019)	Australia; home (informal) and preschool (formal)	ages 8, 11, 14 years	Science; activities based on the popular fairytale Jack & the Beanstalk, planting beans, making bread, volcano with vinegar and bi-carb soda	Guided play - social learning setup
Guberman, S.R., Rahm, J. and Menk, D.W. (1998)	U.S.; laboratory setting	age 11 years	Mathematics; Monopoly game Jr. and standard versions	Game play - didactical
Gutiérrez, K.D., Higgs, J., Lizárraga, J.R. and Rivero, E. (2019)	U.S.; after school program (non-formal)	age 3-6 years	Technology; Agentsheets software, YouTube video, El Pueblo Mágico	Game play - virtual/digital
Hallström, J., Elvstrand, H. and Hellberg, K. (2015)	Sweden; preschools (informal)	age 5-6 years	Technology; Lego, wooden blocks and railways (indoors) and ropes, cans, pipes, natural materials, sticks and cones (outdoors)	Free play - indoor and outdoor

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Han, J., Jo, M., Hyun, E. and So, H.J. (2015)	Korea; Kindergarten (non-formal)	age 5-6 years	Technology; computer-mediated or the robot-mediated augmented reality	Guided play - environmental setup
Hanline, M.F., Milton, S. and Phelps, P.C. (2010)	U.S.; preschool (informal)		Mathematics; blocks, books with pictures of skyscrapers, bridges, pieces of different colored plywood	Guided play - environmental setup
Hao, Y. and Fler, M. (2017)	China; home (informal)	age 4-6 years	Science; home objects, books	Co-opted play
Hassinger-Das, B., Bustamante, A.S., Hirsh-Pasek, K. and Golinkoff, R.M. (2018)	U.S.; Learning Landscapes (informal)	age 1-14 years	STEM; Ultimate Block Party, Supermarket Speak, Urban Thinkscape, Parkopolis	Guided play - environmental setup
Hassinger-Das, B., Palti, I., Golinkoff, R.M. and Hirsh-Pasek, K. (2020)	U.S.; Urban Thinkscape (informal)	age 4 and 2 (T1 ) years age 6 and 4 (T2)	Mathematics; bus stop designs Puzzle Bench, Jumping Feet, Stories, and Hidden Figures	Guided play - environmental setup
Howe, N., Adrien, E., Della Porta, S., Peccia, S., Recchia, H., Osana, H.P. and Ross, H. (2016)	Canada; home (informal)	age 5	Mathematics; naturalistic sibling-directed teaching during play	Guided play - social learning setup
Kliman, M. (2006)	U.S.; home (informal)	age 7-13 years	Mathematics; five games based on a deck of 50 cards with U.S. state and numerical and qualitative data about the states	Game play - didactical
Kjällander, S. and Moinian, F. (2014)	Sweden; preschools (informal)	age 1-4 years	Technology; digital tablets	Free play - indoor

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Lawrence, S.M. (2018)	U.S.; preschool (informal)	age 5 years	Technology; shared iPads	Free play - indoor
Lee, J., Kotsopoulos, D., Tumber, A. and Makosz, S. (2015)	Canada; home (informal)	age 18-25 months	Mathematics; household objects	Guided play - social learning setup
Leung, S.K., Choi, K.W. and Yuen, M. (2020)	Hong Kong; university-sponsored summer program (non-formal)	age 5-8 years	Technology; digital play, zoom in-out, storyboard	Guided play - social learning setup
Levine, S.C., Ratliff, K.R., Huttenlocher, J. and Cannon, J. (2012)	U.S.; home (informal)	age 2-4 years	Mathematics; use of peg-board and jigsaw puzzles	Free play - indoor
Magnusson, M. and Pramling, N. (2018)	Sweden; home (informal)	age 6.5 years	Mathematics; drawing Numberland	Co-opted play
Parekh, P. and Gee, E.R. (2018)	U.S.; public library (non-formal)	age 4-12 years	Engineering; pop-up makerspace with odds and ends supplies	Guided play - environmental setup
Ramani, G.B., Zippert, E., Schweitzer, S. and Pan, S. (2014)	U.S.; preschool (formal)	age 4 years	Mathematics; a set of 65 multi-colored, cardboard building blocks	Guided play - social learning setup
Reikerås, E. (2020)	Norway; childcare centers (informal)	age 2.5 years	Mathematics	Free play - indoor/outdoor not identified
Reinking, A.K., Vetere III, M.J. and Percell, J.C. (2017)	U.S.; nature center (non-formal)	multi-generational, no age identified	STEM; eight stations based on Three Little Pigs story (e.g., Construction Zone)	Guided play - environmental setup

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Schmitt, S.A., Korucu, I., Napoli, A.R., Bryant, L.M. and Purpura, D.J. (2018)	U.S.; preschool and HeadStart (formal)	age 3-6 years	Mathematics; blocks	Guided play - social learning setup
Sikder, S. and Fleeer, M. (2015)	Australia and Singapore; home (informal)	age 10-36 months	Science; (1) small science—press hard, push, roll and change of state of matter under force and (2) small science—blowing air over heated objects	Guided play - social learning setup
Simoncini, K., Forndran, A., Manson, E., Sawi, J., Philip, M. and Kokinai, C. (2020)	Papua New Guinea; playschools (formal, informal)	age 5-7 years	Mathematics; Lego and Duplo Lego blocks, MegaBlocks and a set of wooden blocks	Free play - inside Guided play - environmental setup
Simpson, A., Burris, A. and Maltese, A. (2020)	U.S.; museum, after-school program (non-formal)	age 8-12 years	Science & Engineering; e.g., LEGOs & littleBits, LED lights, and conductive tape	Guided play - social learning setup
Siyahhan, S., Barab, S.A. and Downton, M.P. (2010)	U.S.; after school program (non-formal)	ages 9, 11, 12, 13 years	Technology; Quest Atlantis, a multiuser 3D educational computer game	Game play - virtual/digital
Sliogeris, M. and Almeida, S.C. (2019)	Australia; primary non-government school (formal)	age 5-6 years	Science; Bug Research Lab: mini worm farms, observation of small invertebrates in the school grounds, non-fiction texts	Guided play - social learning setup
Solis, S.L., Curtis, K.N. and Hayes-Messinger, A. (2017)	U.S.; private preschool (informal)	age 3–5 years	Science; blocks; other building materials, and wooden, magnetic train sets, a play crane, marble run equipment	Free play - indoor

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Stebler, R., Vogt, F., Wolf, I., Hauser, B. and Rechsteiner, K. (2013)	Switzerland; kindergarten classroom (formal)	age 6 years	Mathematics; Shut the Box	Game play - didactical
Sumpter, L. and Hedefalk, M. (2015)	Sweden; preschool (informal)	age 1-6 years	Mathematics; a sheep field with natural resources	Free play - outdoor
Tian, M. and Luo, T. (2019)	China; preschool and kindergarten (formal)	age 3-6 years	Mathematics; unit blocks of varying shapes and sizes	Guided play - environmental setup
Tian, M., Deng, Z., Meng, Z., Li, R., Zhang, Z., Qi, W., Wang, R., Yin, T. and Ji, M. (2018)	China; kindergarten (formal)	age 3-6 years	Engineering; At least 2000 unit blocks with 23 different shapes and sizes	Guided play - environmental setup
Torres-Crespo, M.N., Kraatz, E. and Pallansch, L. (2014)	U.S.; preschool STEM summer camp (non-formal)	age 4 years	Engineering; STEM Centers (e.g., conducting dough with water, flour, salt, cream of tartar, oil, and food coloring)	Guided play - social learning setup
Trawick-Smith, J., Swaminathan, S., Baton, B., Danieluk, C., Marsh, S. and Szarwacki, M. (2017)	U.S.; child development center (informal)	age 2.5 - 5 years	Mathematics; Block center with a set of unit blocks	Free-play - indoor
Trawick-Smith, J., Swaminathan, S. and Liu, X. (2016)	U.S.; preschool (informal)	age 3 and 4 years	Mathematics; learning centres with blocks, dramatic play, books, water play, math and science, art, manipulatives and puzzles, and 2 computers	Free play - indoor

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van Oers, B. (1996)	Netherland; primary school (formal)	age 4-8 years	Mathematics; pretend shoe shop; e.g., a counter, an abacus, notebooks, checks	Guided play - social learning setup
Vogel, R. (2013)	Countries not identified (formal)	age 4 years	Mathematics; wooden sticks, solid figure in a cloth bag, golden treasure with circular wheel of fortune, colored playing pieces	Game play - didactic
Vogt, F., Hauser, B., Stebler, R., Rechsteiner, K. and Urech, C. (2018)	Switzerland; kindergarten (formal)	age 5-6	Mathematics; Various math games, Halli Galli; Shut the Box, Lining up the Fives; More is More	Game play -didactic
Watanabe, N. (2017)	Japan; across school-home settings (informal)	age 3 years	Science; mathematics. Piaget tasks as quizzes while the child was playing with blocks or during snack time.	Playful instructions
Watanabe, N. (2019)	Japan; home (informal)	age 3 (T1) age 6 (T2)	Mathematics; Simple mathematics quiz game with range of materials (e.g., compass, puzzles building blocks, thermometer)	Playful instructions
Willard, A.K., Busch, J.T., Cullum, K.A., Letourneau, S.M., Sobel, D.M., Callanan, M. and Legare, C.H. (2019)	U.S.; children museum (non-formal)	age 1-6 years	Science; Gears and gear exhibits	Guided play - social learning setup
Wohlwend, K.E., Vander Zanden, S., Husbye, N.E. and Kuby, C.R. (2011)	U.S.; laboratory	age 5-8 years	Technology; Online Webkinz world	Game play - virtual/digital

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Wolfgang, C.H., Stannard, L.L. and Jones, I. (2001)	U.S.; longitudinal study from preschool to high school (informal)	age 3-5 years	Mathematics; Blocks	Free play - indoor
Wolfgang, C., Stannard, L. and Jones, I. (2003)	U.S.; longitudinal study from preschool to high school (informal)	age 3-5 years	Mathematics; Lego blocks	Free play - indoor
Worthington, M. and van Oers, B. (2016)	England; nursery classroom (informal)	age 3-4 years	Mathematics; Incidents of mathematics during pretend play	Free play - indoor

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