Chapter 4
Learning Initiatives for the Future of Education (LIFE): 'It Takes a Village' to Enable Research-Practice Nexus

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Abstract The Learning Initiatives for the Future of Education (LIFE) are outlined in this chapter with an introduction to the historical developments of education research at NIE. LIFE's aims and goals are to support NIE's vision as a future-ready institution up to 2025 underpinned by cultivating and being the custodian of enduring values even in a challenging milieu of change. Foregrounded by the 4 lives framework, this chapter explicates the 'It takes a Village' project, funded by the Temasek Foundation, and delves into how the project paves the way into enabling research-practice nexus (RPP). We discuss the potentials in the science of learning, artificial intelligence, data analytics, and similar trends in the light of the foundations of values, content knowledge and twenty-first-century learning. The NIE aims to be 'Inspiring Learning, Transforming Teaching, Advancing Research' (NIE (2020). 2020 *NIE strategic vision*. https://www.nie.edu.sg/docs/default-source/spaq/nie-2022_6pp_softcopy-final-editsp2020.pdf?sfvrsn=cbb06543_2). The above constructs are illustrated through a project referred to as 'It Takes a Village.' While this project is only at its first phase, we discuss how its next steps can be incorporating the concepts advocated by LIFE.

4.1 Introduction

This chapter describes and discusses on the Learning Initiatives for the Future of Education (LIFE). The chapter begins by making sense of the past and present efforts

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which have brought the National Institute of Education (NIE) to its current position. The NIE is recognized by the QS rankings to be one of the foremost teacher education institutions in the world (QS Rankings, 2018). Since its establishment in 1991 as part of the Nanyang Technological University (NTU), the NIE has always been grounded on values. Cultivating character with attributes such as integrity and caring-ness for the learner/student has always been evergreen principles even amidst current milieus and global change. The chapter also traces the advent of systematic education research in Singapore since 2003 with the establishment of the Center for Research in Pedagogy and Practice (CRPP) (with 48 million dollars of funding over 5 years) to its present funding provisions of 100 million on the average over five years. Since CRPP, there is also the establishment of the Center for Research in Child Development (or CRCD, with an initial 20 million funding over five years) more recently with a focus on kindergartens and early primary years. CRPP and CRCD together cover the K-12 sector of learning, including the teacher education research across the pre-school and typical schooling range. The Education Minister noted that: '… raising pre-school quality; allowing more movement between streams; cutting non-essential curriculum; targeting help at students from lower-income families; expanding after-school care; diversifying schools; and broadening the definition of success' (Ong, 2019).

The aim of this chapter is to retrospectively consider the past and present LIFE's initiatives and make postulations into the future up to 2025 in support of NIE's vision of being a future-ready institution. In the later sections of this chapter, we discuss on the potentials in the Science of Learning (SoL), Artificial Intelligence (AI), data analytics, and similar trends in the light of the foundations of values, content knowledge, and twenty-first-century learning. The NIE aims to be 'Inspiring Learning, Transforming Teaching, Advancing Research' (NIE, 2020). The above constructs are illustrated through a project referred to as 'It Takes a Village', funded by the Temasek Foundation. While this project is only at its first phase, we discuss how its next steps can be incorporating the concepts advocated by LIFE.

4.1.1 Background of the NIE

The NIE is the one and only Ministry of Education (MOE) recognized institute in Singapore for teacher education and teacher accreditation. It plays a national custodian role in the preservation of positive values, as well as framing perspectives for Singapore education. A key catalyst for enhancing the overall capability and quality of teachers and educators in Singapore in terms of pre-service, in-service, leadership development and research, its continued aspiration is to help build a future-ready teaching workforce for Singapore. Toward this aim, the NIE inspires and supports lifelong learning by inculcating a joy of learning in our students and preparing teachers and educators to manage future learning environments through continuous professional development and education research.

The NIE is an autonomous institute of the NTU. NIE leverages on the deep multilateral partnerships with NTU, local schools and the Singapore Ministry of Education (MOE) to provide evidence-informed, practice-focused and values-based programmes and initiatives for teaching professionals and school leaders. The close partnership among NIE, MOE and the Singapore schools forms the cornerstone of Singapore's top-performing education system. As a thought leader in education and education-related disciplines located in Singapore, NIE is also well placed to build and take advantage of east–west collaborations among reputable institutions in the US, Europe and the Asia Pacific regions. NIE's degrees, higher degree and professional development programmes offer global perspectives through international practicum, semester exchanges and a multidisciplinary curricula, while twenty-first-century pedagogies and service learning initiatives aid holistic teacher development.

Before we attempt to discuss the past and how it informs us into the present and future, it is necessary to articulate some future-ready demands, challenges and possibilities from which we take the reference point in designing for the kinds of education we need, including teacher education.

4.1.2 Learning Initiatives for the Future of Education (LIFE)

It is not a stretch of our imagination to recognize that the world in which our children are going into is quite different from the one we have inherited. The explosion in information, the interconnected of global economies, the surge of social media platforms, the rise of machines and robotics, the ease of communications across continents, the volatility of markets and the like are quite mainstream in recent times. The kinds of skills and dispositions needed to navigate these environments, virtual and in physical spaces, become increasingly complex. Boundaries are blurring, and disruptions into sacred spaces and time are also almost inevitable. Stress is increasingly prevalent and obesity in developed countries is on the rise. Poverty remains real in some undeveloped third world countries, and income disparity looms increasingly large. Gig economies are creating new jobs, yet also causing disruptions to traditions which are not well understood to date. Violence and terrorism remain rampant and inequalities an ever-constant phenomena. Ambiguity amidst change also remains here to stay. With recent events such as COVID-19, we realized that the first world countries cannot ignore the plight of under developed third world countries and their healthcare systems as viruses know no borders and the interconnectedness of the world is brought into sharp focus. Such are the complexities of the future world of our children.

With such a challenging milieu for our children, teachers have a severe responsibility alongside parents. Foremost, to reiterate, NIE believes that inculcating values is even more important than ever in helping children to navigate through these complexities. We have all witnessed highly capable individuals succumbing to sexual vices, situations of greed and improper gains and capitalizing on situations where the lines between ethical and not-so-ethical grounds are vague. The challenge for teachers in Singapore is to impart these sound values and character despite having to teach the subject-content necessary to prepare them for examinations, the workplace and life. Critics are increasingly questioning the need to master that much content as stipulated in the syllabus, or whether higher order thinking and criticalities can be the focus through the means of the content.

The Office of Education Research (OER) conceptualized a 4 lives framework that aims to address the challenges described above. See Fig. 4.1.

Values is emphasized in the Life-Wise aspect in conjunction with Life-Long, Life-Deep and Life-Wide learning. Life-Wise also connotes ethical, emphatic wisdom. Life-Wide learning suggests the need for trans-boundary crossings as problems become much more complex, e.g., climate change. Life-Long learning is elaborated in many recent calls as life-span increases, and retirement age gets to be pushed back later as post-career learning is gaining currency. Life-Deep learning has been the traditional space of schooling where content deep specialisations are encouraged. The issue for us at the NIE is to balance these 4 aspects of learning and to calibrate the need according to different learners and their learning needs. The Singapore

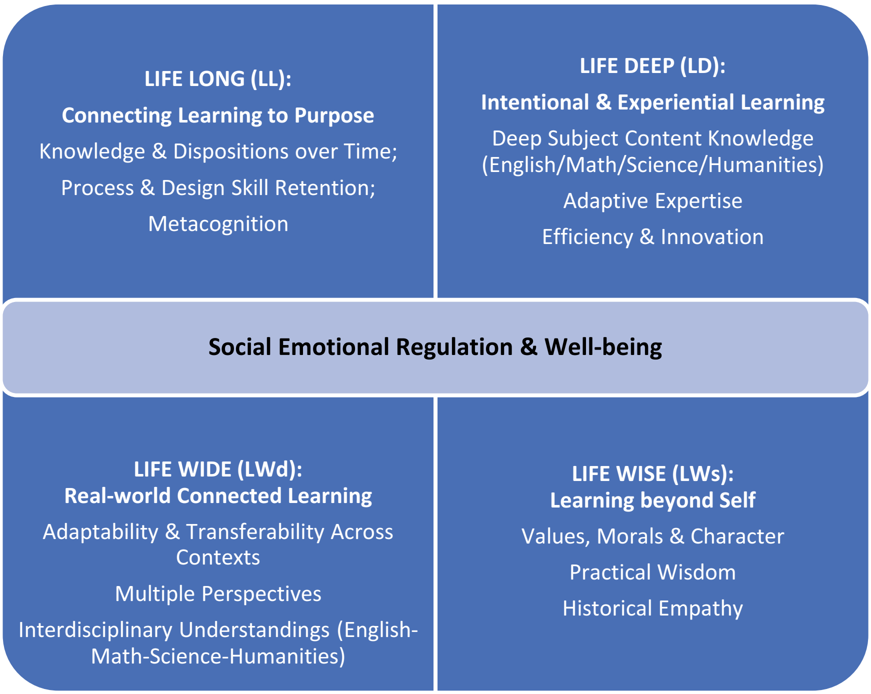

Fig. 4.1 The 4-lives framework developed by the Office of Education Research. *Source* Koh et al. (2018)

Education Minister noted that 'only a passion-driven learning process will be self-directed, lifelong and resilient to disruption because the young person is motivated to learn, unlearn and relearn continuously. In this system, the goal post has shifted from teaching a student enough so that they can graduate, to helping students learning to learn so that they actually never really graduate' (Ong, 2018a). 'The education system must strike a pragmatic balance between opposite yet related perspectives—between [for example] individual aspirations and social needs. We can balance and synergize the opposing tensions' (Ong, 2018a). In other words, the Singapore education system is presently at the crossroads of change and transformation, preparing students for that which is aspirational for both society and the individual. '… [M]astery, passion, guidance, and a multifaceted education experience' (Ong, 2018b) is desirable going forward.

Summarizing the 4-lives learning framework along the desired outcomes for learners, our aspiration for teacher competencies to enable such attainment can be conceptualised as follows. See Fig. 4.2.

In order to prepare teachers for a school system that is progressive yet rooted in strong values, we extend the typical dimensions of values, skills and knowledge to include wisdom. The specific details of Fig. 4.2 would be elaborated in the later sections of this chapter. Based on the above WVSK model, teachers need:

- To develop a *repertoire of skills* that can appropriate pedagogical toolkits for differentiated instruction (at different stages of learners' development);
- To be *sensitive to learners* needs and to care for their well-being;
- To have the *continuous learning dispositions* and competencies to embrace new methods and sciences of learning and to be literate on advances in technologies such as AI in order to appropriate these understandings to different learners;

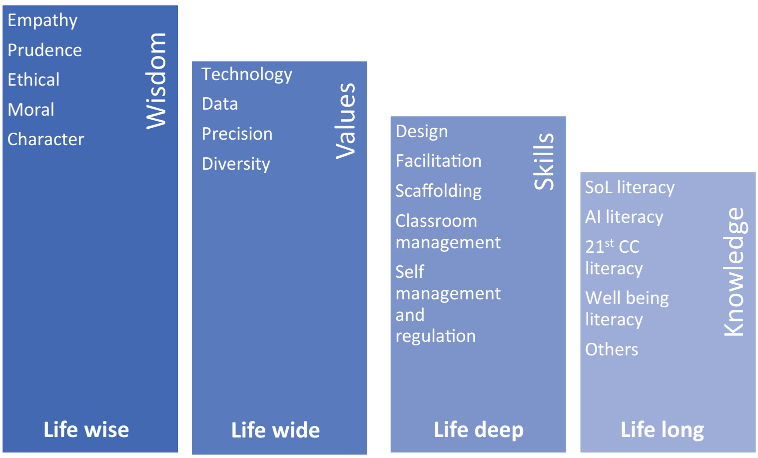

Fig. 4.2 Wisdom, values, skills and knowledge (WVSK) for teacher competencies

- To instill in their learners/students the same lifelong learning dispositions and competencies which they themselves possess and *role-model*; and
- To work with other stakeholders, e.g., parents and other education providers with a focus on the individual child or learner with a view to the learner's well-being and continuous improvement.

The new literacies which teachers need to embrace are Science of Learning (SoL) in education, AI in education, new forms of assessment, differentiated instruction, data analytics and sensitivity to special needs where appropriate (Table 4.1).

Now that we have articulated aforehand the broad strokes of what is needed in LIFE, we take a step back and ground LIFE with the assumptions of learning or how learning occurs, and comparably how instruction should occur with respect to learning.

4.1.3 How Learning Occurs

Learning is the *interaction* between the individual and the environment (Cullingford, 2010) that, or all of the above in a continual-historical process that can be positively or negatively oriented. Negative experiences refer to when the interaction leads to a non-positive process outcome, where the learner concludes with an interpretation of that learning experience negatively. However, positive or negative is relative against a body of established knowledge or normative experiences as reified (Fig. 4.3).

A teacher's role is thus to enable the interaction, albeit in a high-quality fashion, between the learner/individual and the environment (which could be other individuals, content, resources, or just phenomena). The quality of classroom processes such as the interactions between teachers and students has been linked to positive student developmental outcomes (Abry et al., 2013). Thus, a teacher's role is to design for the interaction to achieve the highest quality of thinking, acting and deciding on the part of the learner.

Genes or heredity considerations account for 50% of the learning equation, which up to more recent times cannot be tweaked, and environment accounts for largely the other 50%. We are hypothesizing that the interaction can potentially influence and change both the individual and the environment, making all three aspects of individual, environment and interaction dynamic. As such, every individual is unique with its own identity and there are no identical individuals, including non-identical twins. With the biological genes constant, the interaction with the environment is not identical and hence resulting in similar but identical constitutions (Larsen et al., 2019).

Table 4.1 4-Lives and the new learning initiatives (i.e., LIFE) needed for teachers

	SoLE	AIE—Big data	Assessment	Differentiated Inst	AIE—ITS/Apps	Special needs
Life-Long	Learning to learn	Patterns and profile of learners	Formative and process evaluations	Pacing learning for different learners	ITS, etc	Universal design
Life-Wide	Adaptabilities, structural learning	Trans context sensitive information	Transfer potential	Pedagogies/ designs for adaptivity across contexts	MOOCs and equivalent	Situated learning
Life-Deep	Engagement, motivation and interest		Representational forms of deep dives	Pedagogies and scaffolds within context	ITS, learning companion, etc	
Life-Wise	Perseverance	Ethics of AI and data privacy	Wisdom recognized	Teachable moments		Design thinking

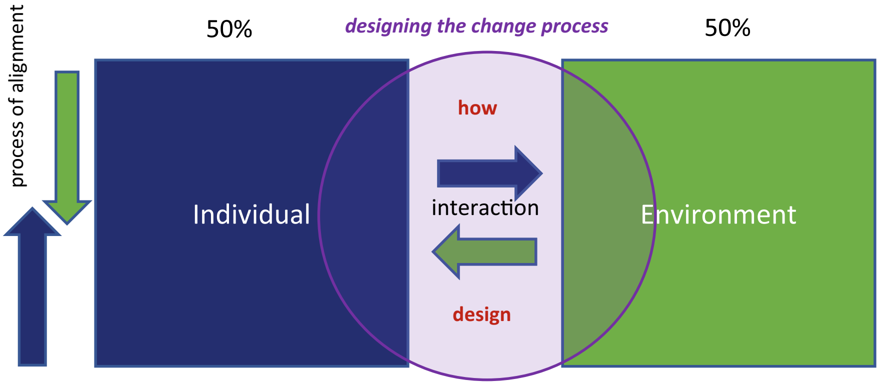

Fig. 4.3 Individual-and-environment dialectics

4.1.4 Overcoming Challenges or Disadvantages Through Learning and Instruction

There are three kinds of disadvantages. The first arise from individual factors, e.g., genetic makeups that are hereditary. Another is environmental that has implications to the individual. For example, arising from low SES, infants are malnourished, and this in turn influences the individual resulting in poor attention, memory, etc. Poor or low quality environments include distracting or distrusting conditions leading to low quality interactions between the individual and the environment. Including other individuals into the 'environment,' the interaction could lead to a low trust culture in organizations, for instance. A third disadvantage is when there is low scaffolding in the interaction between learner and the learning environment. Especially before learners are able to regulate themselves with the agency to decide on how to manage the 'interaction,' teachers and parents play an important role in enabling the child or learner to interact with its object in a dynamical and instructive fashion. Learning to learn or learning to manage that interaction for oneself is typically referred to as metacognition. Higher ability students are more attuned to metacognitive enactments.

Science of learning techniques is able to capture individual factors such as working memory and related cognitive aspects, self-regulatory dimensions and other well-being propensities. To date, there are no established boosting 'pills' or medication widely practiced in mainstream education to increase individual capacities for learning. We are not suggesting that this silver bullet approach is to be encouraged.

There are training applications such as working memory games but these act similar to muscle exercising but have little transfer effects to meaning making or conceptualization efforts with domain specific situations. The environment, on the other hand, lends itself to the policymaking realm where good policies can mitigate social environmental conditions. Good schools and the environments they afford is an example of resources being pumped into schools to enable a better and more conducive learning milieu. Good school environment has much to do with school leadership, enabling teachers to do their pivotal roles of supporting and designing for high-quality interactions.

If learning is largely defined around the interaction between the individual and the environment, a teacher can assume to place constant the two factors, i.e., working on the interaction affordances despite the kind of learner or the environmental constraints or otherwise. Good learning can occur as a function of the interaction, and not the function of either the learner or the environment. The interaction speaks to the coupling relationship between the learner-and-environment. An analogy is the user-interface present in most smart phones. The user-interface is designed in a way that affords fluent and intuitive between the user and the applications used. Decades ago, the operating systems were without an object-oriented drag and drop interface more akin to daily actions and enactments, and a larger general population could not have easy access to computers. Today, the '-and-' is made fluent for most mainstream users. Similarly if teachers had the skills-set to adapt and make fluent learning for all kinds of learners, with the knowledge afforded by science of learning, AI and other literacies to aid them as better designers and careers of learning and well-being respectively, education would make significant leaps in the right direction.

4.2 Grand Hope

With the establishments of CRCD and CRPP, NIE hopes to be able to understand the risks and opportunities of different learners in their developmental trajectories through K-12 schooling and mitigate risks early and prevent the stacking of these risks (see Fig. 4.4).

A functioning workable model for LIFE would have to include:

- *Policy mechanisms* for bridging the gap for the three disadvantages;
  - Provisions that can level up the 'socially' disadvantaged, e.g., MOE kindergartens; bilingual programmes and societal levers; assessment norms that foster diversity of talents; etc.;
- *Socio-technical mechanisms* for enabling quality 'interactions';
  - Time and space opportunities; quality professional and integrated services for learning needs and difficulties; other design affordances at classroom, school, after school and community levels;
  - Data analytics and AI affordances that make visible aggregated data of interactional patterns;
- *Teaching and Learning mechanisms* that level up learning process and learning outcomes;
  - Evidenced-based designs that are situated and scalable; technologically enabled interventions for pre-academic and academic functions;

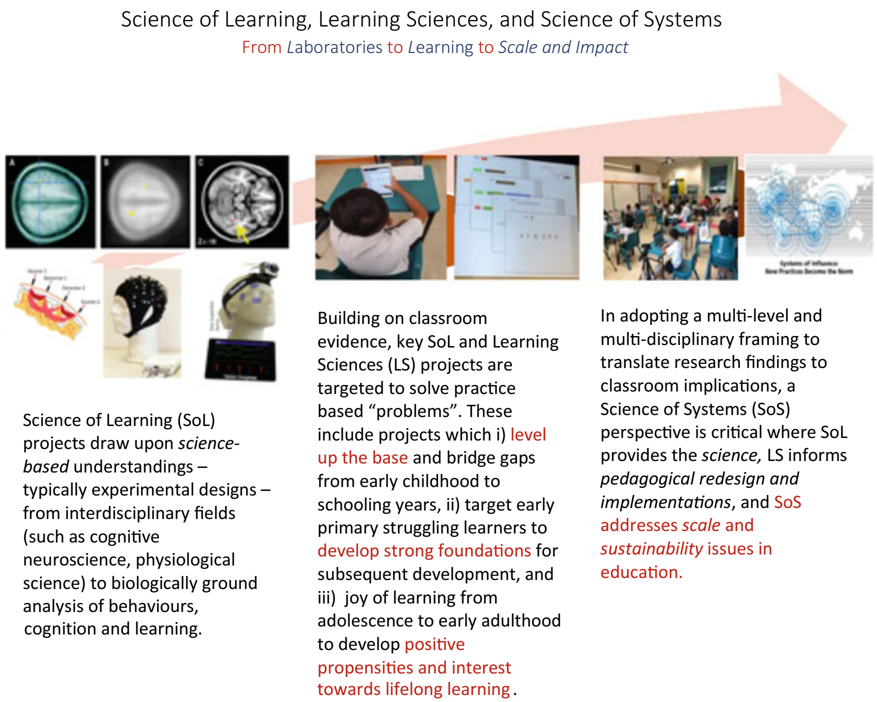

Fig. 4.4 Integrated approach to understand learners and learning developmentally

- Assessment for learning affordances and designs that enable differentiated learning and instruction;
- Data and learning analytics with ITS to enable learning for diverse learners.

From CRPP's past research, we have understood how learning interventions occur and sustain in schools among teachers. We refer to this as the science of systems (SoS). School leadership plays a critical role in enabling cultures and organizational norms to be changed and sustained in order to sustain desired instructional practices. The learning sciences (LS) refer to the design-based experiments conducted in the last decade on all subjects with implementation traction in classrooms across schools in Singapore. Here, teacher capacities and epistemic change occurs, when they do. The recent emphasis in science of learning (SoL) enables us to venture into learner situations and profiles which observable techniques such as classroom operations do not enable us to yet understand why a learning episode arises the way it does. Hence, 'below the surface' methods such as neuro-imaging and other physiological approaches might aid us in unpacking the phenomena. Figure 4.4 depicts these three approaches. We need a concerted and integrated understanding of SoL, LS and SoS.

4.3 The 'It Takes a Village' Project—Findings

It would take the space of a whole book in order to describe all the learning interventions undertaken in the last decade. In gist, the learning sciences interventions expanded learning to outside classrooms (also known as informal learning) with clear linkages back to the subject curricular at hand; delving into learners' intuitive understandings through experiential and embodied ways of learning, including notions of near and far transfer; learning analytics in support of learning progressions with implications to formative and summative assessments, including forms of student collaboration and creativity; and constructing and building knowledge individually and collectively with school structures to sustain these practices among varying learners, including academically more challenged students (at least from the yardstick of summative examinations). Thus instead of describing the multiple classroom and school interventions, we discuss a project which works with academically lower achieving students in a typical secondary school (from which the findings should be generalizable to typical heartland schools in Singapore). The project takes a holistic 'village' metaphor where research-practice partnerships between the school science teachers, teacher education researchers from the NIE, the (National) science center practitioners, and also well-being counselors from the community. The journey of participation among the various stakeholders was far from straightforward as each party forged their own goals before converging on common understandings, language, trust and seeing the student as the center of common concern. Most importantly, in developing this partnership, we seek to acknowledge and respect each other's expertise and knowledge, contributing equally and collaboratively, to influence the services provided for targeted students by taking into account the demographics and contextual factors of the schools. Therefore ideally, this working relationship could work toward a longer term for the purpose of scaling and sustaining educational innovations, to benefit the wider community of the education sector. Figure 4.5 depicts the partnership and the various roles performed.

The school's teachers led in the design and implementation of tinkering activities as advised by the science center with alignments to school syllabus. We were guided by a set of principles for designing tinkering activities shown in Fig. 4.6. Students can start off their projects easily and quickly, have multiple pathways that they can explore and choose to follow through and decide on the varying levels of complexity they want to achieve for the end product of learning. They collaborate and learn with their peers by constructing artifacts. Students provide social scaffolding in learning new ideas in the process. Through cycles of experimenting, failing and doing, they learn iteratively.

Based on these principles, the Tinkering Science Activities included the construction of artifacts:

- Marble Machine (properties of material, friction, forces and energy);
- Light maze (properties of light, interaction of materials with light);
- Digital wearable (circuits and electricity);
- Coolest Building (heat and energy).

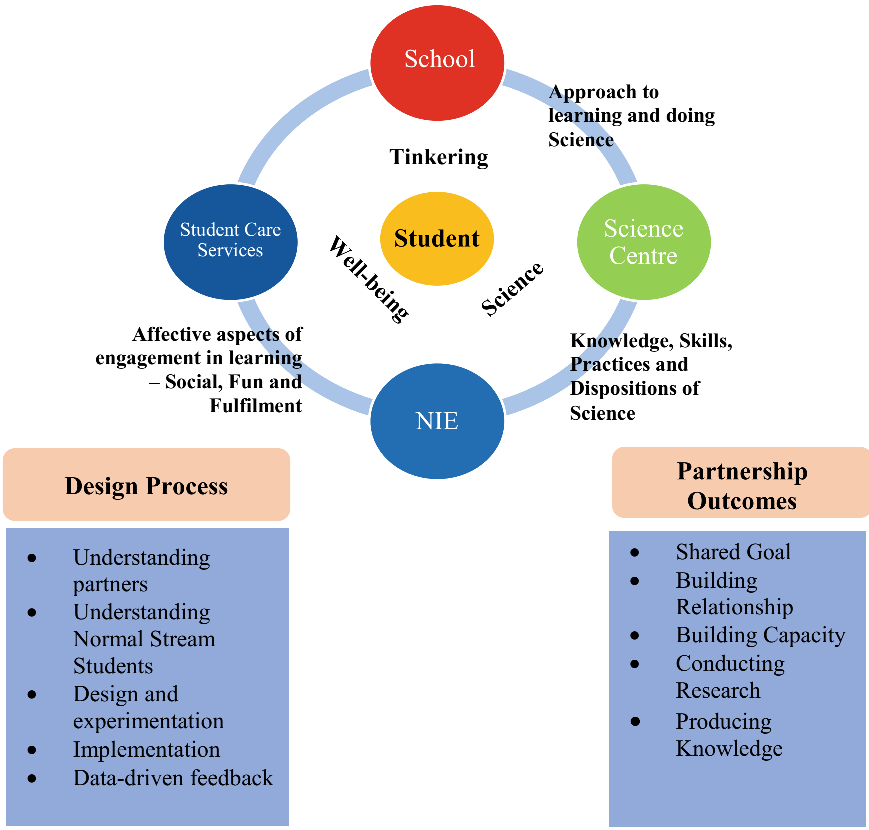

Fig. 4.5 Research-practice partnerships in the 'It Takes a Village' project

Most activities are spread across 4–5 lesson periods with plenty of opportunities for iteration, trial and testing, sourcing for ideas and collaborate with others. Subsequent iterations of the programme included opt-in tinkering programmes with the intention to mentor students created a positive learning environment for student engagement and self-directed learning. Partner-led design and implementation of tinkering activity, extension of the school syllabus and with equal emphasis on students' well-being (intentional mentoring) was planned and discussed among all members of the project team. Implementation was conducted on the classes: Sec 1NA: Basic Cardboard Automata [18 students]; Sec 1NA & 2NA: Advanced Automata (with motor and electrical components) [25 students]. 2-day workshop with 2.5 h per session were conducted by the team.

In this partnership between NIE, schools, Science Center Singapore and New Life Community Services, the partners sought to improve science learning experiences and the well-being for lower progress students in a secondary school. The design focused on how to develop students' competencies, skills and disposition to learn and

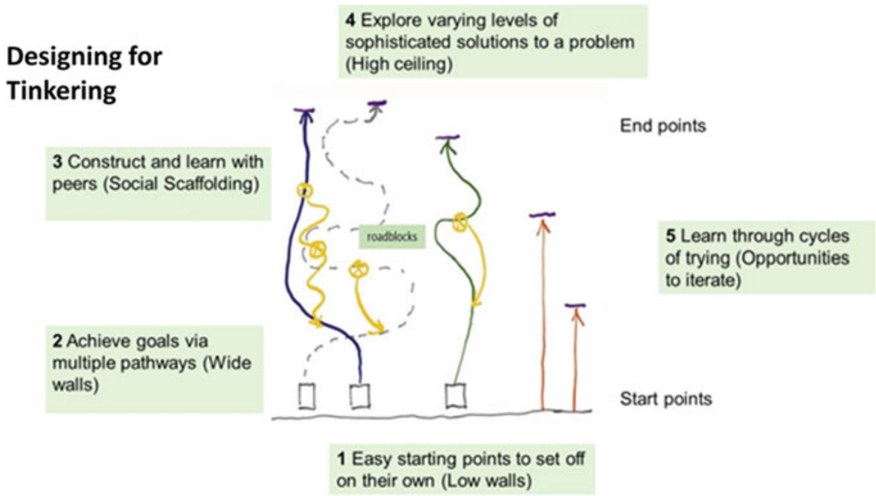

Fig. 4.6 Multiple paths encouraged through tinkering

relearn beyond the canonical knowledge required in school. We posit that designing new experiences to engage students in science learning while addressing their well-being would help them to be more responsive to learning. Drawing upon the expertise and different practices of the partners, we focused on improving the learning of lower progress students, exemplify how the 4 lives framework of Life-Long, Life-Wide, Life-Deep and Life-Wise learning can be implemented.

Life-Long We prepare students for Life-Long learning in developing knowledge and disposition, process and design skills and metacognition. The co-designed programme by the partner provided opportunities for students to learn in depth and breadth, to discover their own interest and strength. In tinkering activities, students explored ideas to solve problems and deepened their learning as they make connections between the ideas. The process of tinkering encourages students to experiment with ideas and pick up design skills to solve problems. At the end of tinkering activities, we encouraged students to reflect on their learning and experiences. This promotes the development of metacognitive skills for them to be aware of their thinking and learning. In subsequent studies in the 'It takes a village' project, we consider if our learners have developed Life-Long learning dispositions or interests or curiosity characteristics resulting from the tinkering.

Life-Wide To prepare students for Life-Wide learning, students learn from multiple perspectives and develop interdisciplinary understanding in the designed activities. Engaging tinkering activities provide learning opportunities to learn across different topics in science and provide multiple pathways of learning. Students work in pairs or groups to approach problem solving from perspectives of their peers by encouraging them to view the artifacts of other groups and sharing their ideas. Students also exercised agency to decide their path and solutions to solve the problems through integration of different science ideas from various topics. In a typical classroom, science ideas are introduced and science facts are prescribed instead of explored, and students may fail to make the connections to relevant ideas to deepen the learning through this direct instruction methods. However, with learning experiences afforded by tinkering activities such as constructing a marble machine, students have the opportunity to assimilate and connect science ideas as they integrate their knowledge. For example, they explore and learn about frictional forces, physical properties of materials that relate to motion, forms of kinetic and potential energy and motion. Students develop interdisciplinary understanding as they solve complex problems that would integrate knowledge and skills. In follow-up studies, we would consider if the depth of science concepts remains in students after the interventions in post-activities six months later, and consider how, and why students have appropriated the concepts, be they cognitive or affective aspects.

Life-Deep As students manipulate objects and materials in constructing artifacts, the abstract concepts in science are made visible for them to make sense of science. This would lead students to have deeper disciplinary and conceptual understanding of the science concepts they learn to apply. Learning is about doing science to deepen their understanding of the methods and practices of science. Students exercise autonomy when they are given a sense of control and take ownership of their created artifacts, which is what tinkering process could provide, in which students choose their materials, experiment with their ideas and decide their own pathways. The iterative processes develop persistence and practice leading to mastery. Such tinkering activities cause students to be more motivated and agentic. The depth and breadth students are exposed in tinkering activities, iterating multiple times to solve a problem, approaching from multiple perspectives, can develop them to be more flexible and creative in problem solving, leading to development of adaptive expertise to solve problems. We aim to observe how these learning outcomes from students can be ‘transferred’ to regular science class lessons.

Life-Wise Students need to have their character with proper values, morals and wisdom that would enable them to make good decisions for themselves and others, and to become a responsible person who will contribute to society. In the research project, students were able to collaborate with other students, wait for their peers who were not catching up, and help their fellow students along. Students learn the value of respect through communicating, listening, negotiating and sharing with their peers. Solving problems require students to persevere and have grit as they iteratively improve their ideas. At the end, they acquire values of perseverance and hard work. With a greater awareness about themselves, experience gained from participating in tinkering activities and learning from their peers, students can use their knowledge and experience to make good judgments. They have wisdom to make the appropriate decisions in different situations. In subsequent studies, we would venture to consider if learners can sustain their learning in their motivation, engagement, and whether these transfer to regular school classroom lessons.

Social Emotional Regulation and Well-being Participating in tinkering activities in after-school programmes provide a safe and supportive learning environment for students to express themselves with the artifacts they create. The focus is on the process experienced by the students. In the process, they can fail safely—be it a wrong decision or choosing a different approach. By iterating and learning from mistakes, students can pick up from where they fail and move on. Also, students can develop self-awareness by identifying their emotions, recognizing their strengths, gaining better self-perception leading to more self-confidence. They gain social awareness when they take on different perspectives from their peers, appreciate the diversity of ideas and respecting others. Developing these competencies through the process will lead to improvement of well-being of students. Importantly, the science teachers who were involved in the tinkering activities in these after-school curricular time were part of the partnership. From these tinkering observations, we noticed that the same teachers saw a different side of their students, realizing that these low progress students had strengths which they had earlier not noticed. With a different view now of their students, they are now more able to variate their pedagogy in regular science lessons to better engage their learners. (In the Singapore school context, after-school programmes are usually conducted to external vendors, and there is minimal integration between these programmes and class lessons).

The students who were engaged in the tinkering activities exhibited evidence of the increase in motivation level before and after the programmes. Almost all participants would recommend this programme to their friends. Through the categorization of student voices in social emotional learning and creativity with the highest occurrence include:

- Openness;
  - 'To always have an open mind';
- Perseverance and resilience;
  - 'Never give up';
- Working in teams and learning from others;
  - 'it doesn't always have to be a competition'
  - Application;
  - 'How to put what I learnt in class into my life.'

Expression of ideas though different forms. Students also learn about themselves and their abilities, for example: 'I never knew I could….'; 'Do something by myself'; 'I learnt that if I think I can do it I can do it'; 'Make such things'; and 'Making object turns.'

From the post-activity interviews conducted on the student three months after the tinkering activities, these academically low achieving students were able to recount detailed experiences of their learning encounters with specification and critical thought on what they would do if they had a chance to re-do the experiments. Interestingly, the teachers who took these students in regular science lessons were surprised by their levels of engagement, recollection and criticality (which were not seemingly observed in regular science lessons). Below are some of the expressions by the students themselves:

> Yes, I do because by learning like that I could have fun and learn at the same time. Then I would have a memory of this in the future and remember the things I learned today.
>
> Yes, as I can learn more process on what I did wrong in this experience.
>
> A memorable moment is that I feel proud of our design; It was fun making design with my partner as we keep doing trial and error on our circuit.

Our findings from the study showed that students are able to learn aspects of the 4 lives in their participation with tinkering activities. They are more self-aware about themselves regarding their abilities and strengths. The opportunities to fail safely and try again developed perseverance in students. Working with others in joint-problem solving fosters social awareness and learning to respect others. We believe that the process of tinkering provided opportunities for students to develop the values, skills and knowledge for future learning.

This project has a combination of elements found in many of the interventions conducted in the last decade, from cognitive to affective process-outcomes, disciplinary content knowledge, learning in formal and informal environments and sustainability mechanisms in research-practice partnerships. The project is still on-going, and subsequent iterations include getting the teachers to practice the tinkering design principles in regular science lessons, appropriating well-being constructs to assess student holistic performances and dispositions, and whether students are able to self-regulate with interest in science. Science of learning (SoL) techniques would also be employed insofar as students' physiological responses and states, e.g., stress and motivations. Neuroscience methods can also determine how and why learners become interested and motivated, and what happens in the brain when 'transfer' of learning occurs in terms of the brain's interconnectivities in its neuronal networks. Importantly, '[n]ot only can findings from neuroscience research inform educational practices, problematizations derived from educational contexts should inform trajectories of neuroscientific investigations.' (Jamaludin et al., 2019). In essence, observable practices such as the above science tinkering contexts can give us a window into problematizations from which SoL can give us further understandings.

4.3.1 Macro, Meso and Micro-layers of a System (in This Case, the System of a School)

In the past research of the NIE, we realized that for sustainability to occur, teachers need to believe that inquiry practices enable students to achieve both content knowledge for the important examinations and also the twenty-first-century learning competencies required from the MOE. For sustainability, the **MACRO** (for the 'It takes a Village' project) socio-cultural environment (i.e., the context) through which innovations/academics-and-twenty-first learning occurs is the school and its leadership enablements (or otherwise) in supporting teachers in their endeavors within the research-practice partnership nexus. If this project were a system-wide adoption programme, the macro-layer would be the system, and the school or cluster of schools involved, the meso-layer. In this project, the **MESO** mechanisms are those that enable teachers to do the academic-and-twenty-first learning transformations in tandem with school cultures at the science department level within the school. The middle management leadership is in support of transformative pedagogical change process and its sustainability. This includes the supporting persons and structures that enable apprenticeship learning among teachers for epistemic change, and the alignments between pedagogy in the classrooms and the policies/leadership that enables change and sustainability. The **MICRO** layer is the supporting teaching and learning interactional mechanisms (e.g., data and analytics) that enable teachers to do what they need to for transformative classrooms as implemented by their lessons, whether formal or informal, or both.

Due to the historical propensities to responsibly teach to the test, teachers struggle as exhibited by the protocol below:

> S: the teachers are very worried, 'confirm cannot come up one' [in response to teachers' questions to students], 'what if they don't come up with what I want to hear?' …That's always their worry. So that's why, just let go. They just don't want to let go. So we show that, see, you can let go. … And then show them how we make the links. And they're like, okay it's possible. Okay let's try.

Not only is apprenticing work needed among teachers, teacher leaders are needed to align their work with the school's curriculum policies, vision and expectations. In this way, coherence in terms of school goals and pedagogical transformations become possible on the ground among teachers and students. In the process, upwards and downwards communication is needed. Upwards in terms of communications with school leaders and superintendents, and downwards in terms of convincing teachers and parents of the need to change. Making learning visible is needed and outcomes to align with multiple stakeholder concerns.

4.3.2 LIFE's Vision for Academically Challenged Students (Low Progress Students)

The following articulates a systematic or programmatic approach to leveling up academically challenged students which can be learned from the 'It takes a village' project:

Vision—to create future schools in Singapore where Low Progress Learners (LPS) (currently) can perform 'as well as' high achievers in both academics and 21st CC or future-readiness for successful outcomes.

Current problem—there is a perception among the public that elite schools enable better opportunities for success and that there is a clamor toward these schools in admission criteria based largely on exams, e.g., PSLE.

Hypothesis—schooling practices, including assessments are founded on the assumption of 'cognition in the head.' Our hypothesis to level up LPS is to adopt the paradigm of 'embodied and distributed cognition.'

Research Design—adopting a cluster/network of schools with largely LPS and bring them through an 'embodied and distributed cognition' approach(es) and compare their process-outcomes and summative outcomes with high achieving cohorts.

Multilevel Data—much of education research has focused on observable, psychological and behavioral methods situated within the learning sciences paradigm. We hypothesize that augmenting learning sciences with science of learning methodologies across multilevel analyses can bring to the fore learning that is implicit, enriched with insights into movement and emotions that are 'below the surface' of observable learning. An ecological (integrated) perspective to align and cohere multiple sources of data from ***SoL, Data analytics and Translational sciences*** will be key foci areas.

Table 4.2 summarizes on 'where we are,' the goal to achieve, and projects that can be commissioned to achieve the goal.

Broadening or making more general the kinds of SoL (basic science studies) with the complementary translational mechanisms needed, we can focus on the following theme areas:

- Literacy (including dyslexia) and bilingual studies;
- Numeracy (including dyscalculia);
- Motivation and interest (i.e., intrinsic and extrinsic reward regions and mechanisms);
- Embodied and Distributed cognition (i.e., movement, gestures, etc.);
- Development of intuitive resources (i.e., neural correlates underpinning productive failure, for example);
- Physiology related to learning (e.g., stress and well-being, sleep, etc.);
- Metacognition and regulation (i.e., neural correlates).

When studying academically challenged students or low progress students, in order to attain the goal as stipulated in Table 4.2, we inevitably have to study accompanying factors such as literacy and numeracy that are part and parcel of their academic content learning, including aspects of well-being and metacognition (or otherwise).

LIFE™'s 'Experimental schools' are to be adopted in the programmatic effort as depicted by the following principles:

- Adopt a representative 'cluster of schools' (or network of schools);
  - Cluster needs to include kindergartens;
- Policy, socio-technical and teaching and learning mechanisms to be systematically experimented;
  - Across the different disciplinary areas;

Table 4.2 Summary of 'Where we are,' projects that can achieve this goal, and projects that can be commissioned to accomplish this goal

Where we are	Projects that can achieve this goal	Goal

• A rich historical trajectory of education research. Existing projects in key areas of:
• Learning Sciences
  • Disciplinary pedagogies
  • Academic + 21CC
• Science of Learning
  • Bilingualism
  • Numeracy
  • Working Memory
  • Early years
  • Special Educational Needs
	• Embodied Cognition
	• Neurological basis of Movement as an integral part of learning
	• Gestures and intuitive knowledge
	• Emotions and self-regulation
	• Metacognition, and regulation
	• Basic literacies and embodiment in learning
	• 21st CC and embodiment
	• Teacher translation mechanisms
	• Distributed Cognition
	• AI applications for human-and-artificial cognition partnerships
	• Creative collaborations between tools and humans
	• Creative collaborations between humans and humans
	• Assessment in creative collaborations
	• Basic literacies and distributed cognition
	• 21st CC and distributed cognition
	• Teacher translation mechanisms
	• Interest development
	• Embodied and Distributed Cognition Integrated
	• The development trajectories of academics-and-21st CC among LPS
	• Methodologies that enable embodied and distributed cognition
	• Epistemic knowledge in embodied and distributed cognition developed by learners and transfer of learning
	• AI and big data analytics supporting embodied and distributed cognition
	• Assessment practices and transformations in embodied and distributed cognition
		• To create a school-model that can enable LPS to achieve academic 'success' and future-readiness
		• Working model would include
		  • Policy mechanisms
		  • School-classroom T&L mechanisms
		  • New Assessment practices and norms
		  • Teacher learning mechanisms
		  • Human-technology mechanisms
		  • Sustainability mechanisms

- Longitudinal studies from EC to JC2 (or equivalent) based on;
  - Bio-ecological framework (from neural to social measures);
  - Data from multidata (layers and dimensions) sources;
  - Multidata synthesis;

A model of teacher learning and development (Jamaludin et al, 2019) for this programmatic effort for to include the following design principles:

- Creating a dialogical space for expanding teachers' design repertoires where teachers will have access to:
  - Video case studies of learners working on identified tasks;
  - Showing, analyzing and discussing the nature of learners' difficulties;

- Screencasts of brain images, talking through what the images mean in terms of how the brain is developing differently for different learners (perhaps in group and reporting back to the whole class);
  - Links to remediation strategies or platforms, with video explanations of the brain science and pedagogical science that underpins it;
- Debating and justifying why the use of identified remediation strategies;
  - lesson plans for how the designed interventions might be introduced into a class with different underlying reasons for learning differences, with the teacher having access to the data collected;
- Enactments of lessons plans with learners;
- Evidenced based data where teachers can report back on their SoL 'tinkering' and 'experimentations,' and compare their experiences and other teachers or groups in the class; and
- Critique on their own learning process both individually and in groups.

4.3.3 Data Analytics, AI and Assessment

Going forward besides SoL, complementary work in artificial intelligence (AI) in enabling learning applications with machine learning and diagnostics would be useful in supporting academically challenged students. The data that is generated of these students across the system would also aid in constructing a system profiling understanding of these learners accompanying the design-interventions be they in cognitive, emotional, or well-being outcomes. With the adoption of these AI techniques, human cognition can be shared with tools and machines instead of an over reliance on the human. A shared creative collaborative relationship between human and machines as a whole unit of analysis in a distributed manner has significant implications on assessment and its current practices. Transformative pedagogy and assessments in line with embodied and distributed cognition principles need to radically question the status quo and spur work toward future outcomes. With machines doing what they are good at, humans can focus on higher order functions, in particular metacognition and cross-boundary cognition and transfer.

4.4 Conclusion

The process of applying findings from 'laboratories to learning' includes iterative steps of identifying foundational learning principles that would aid student learning (Jamaludin et al, 2019). This includes cognitive mechanisms, e.g., working memory and also affective mechanisms, e.g., emotions and regulation.

It is also important to systematically engage in correlating prevailing classroom practices with learning principles identified with a view to probing and deepening explanatory foundations for successfully situating and implementing learning strategies. Developing *original, effective and specific* teaching and learning strategies; grappling with inherently contextual, dynamic and multiple classroom variables is a necessity (Jamaludin et al, 2019) for impactful educational research insofar as LIFE is concerned.

Finally, developing evidence-based practices through iterating principles and designs; and sustaining these practices and designs through a community of teachers who deeply understand foundational principles and translational mechanisms are ways for effective translation. Working across institutional agencies within the system to scale and sustain improvement practices with teacher professional development (and epistemic change) at heart is the crux to reform efforts (Jamaludin et al, 2019). These mechanisms, when put in place, could very well be the 'pillar' that joins neuroscience and education, where bringing SoL to the classroom may be a bridge that is *not that far*. In the meantime, neuroscientists and educators should develop common goals, establish common language and methodologies, and importantly trust. Building research-practice partnerships with schools and industry to provide evidenced based interventions mitigating the risks across the life-span that can leverage on research to commercial applicational outcomes becomes a possibility in reality.

Tangibly, NIE can lead in the development of a comprehensive evidenced based developmental framework of *risks and opportunities* for SoL in Life-long learning, in collaboration with the universities in Singapore. This developmental framework would consist of 4 age-bins: K to 12 learning; tertiary and adult learning; post-career learning; and elderly learning. A coherent interoperable data infrastructure of cohort data over time of the above comprehensive across the age-bins which can be mined for policy purposes with a view to translating basic research to practice-policy outcomes. Through this, it can begin to build a pillar to join the bridge between SoL basic research and its translational outcomes (forging a bridge between neuroscience and education which was formerly a bridge too far). This creates the opportunity for NTU's multidisciplinary community to come together toward this common goal. With this goal, NIE/NTU can potentially attract the best researchers and practitioners across the world to converge in the 'living lab' in Singapore to bring SoL into practical realities across the life-span through this initiative. With the demographics among Singaporeans suggesting longer lifespans, NTU can be a forerunner in post-career learning and elderly care learning. We hope that LIFE and its endeavors would propel us to new and transformative change that would put our children at the center of why we do what we do.

Finally, fostering collaborative partnerships similar to the 'It takes a Village' project is needed to fulfill the research-practice nexus goals of NIE. See Fig. 4.7.

The present and future NIE research centers (left side of Fig. 4.7) would need to consider how nexus goals are met through partnerships that have sustainability and follow through in the situated context where innovations occur (see center of Figure) with further translations and implications for new assessment modalities and learning

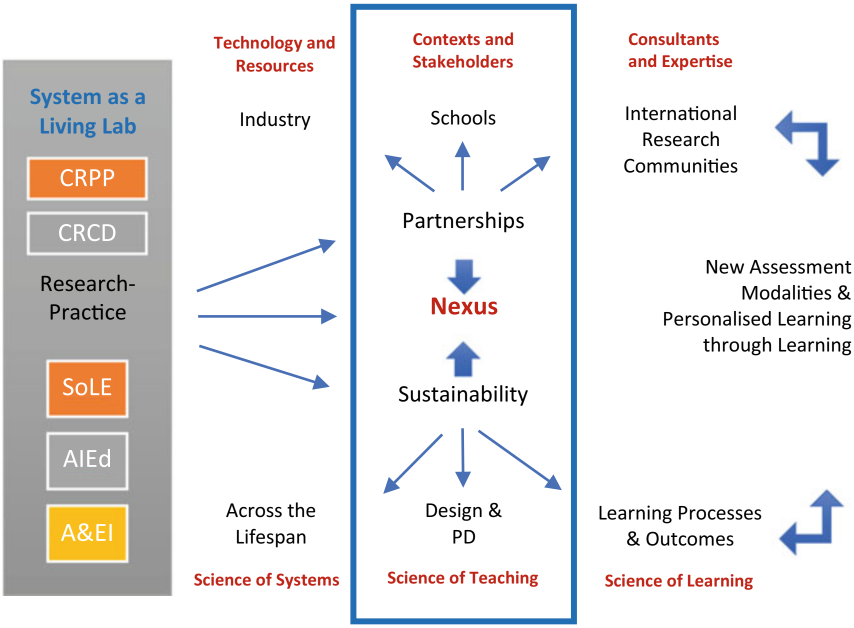

Fig. 4.7 Partnerships toward research-practice nexus

outcomes (see right side of Fig. 4.7). The 'It takes a Village' project delves into details on how 'tinkering' as a process can be embedded into the research-practice nexus partnership design and approach.

Going forward, the Office of Education Research with its LIFE's efforts intends to bring into convergence different sources of data (from neural to social) and various techniques, including AI and other augmented technologies to enable leading in all its varied dimensions socially, emotionally and cognitively.

References

Abry, T., Rimm-Kaufman, S. E., Larsen, R. A., & Brewer, A. J. (2013). The influence of fidelity of implementation on teacher-student interaction quality in the context of a randomized controlled trial of the responsive classroom approach. *Journal of School Psychology, 51*(4), 437–453. https://doi.org/10.1016/j.jsp.2013.03.001

Jamaludin, A., Hung, D., & Lim, P. (2019). Developments in educational neuroscience: Implications for the art and science of learning. *Learning, Research and Practice, 5*(2), 201–213.

Koh, T. S., Hung, D., Ho, J.-M., Raveendaran, S., Toh, Y., Jamaludin, A., Tan, K. C. K. (2018). *Leadership for change: the Singapore schools' experience*. World Scientific.

Larsen, S. A., Byrne, B., Little, C. W., Coventry, W. L., Ho, C. S., Olson, R. K., & Stevenson, A. (2019). Identical genes, unique environments: A qualitative exploration of persistent monozygotic-twin discordance in literacy and numeracy. *Frontiers in Education, 4*, 21. https://doi.org/10.3389/feduc.2019.00021

NIE (2020). *2020 NIE strategic vision.* https://www.nie.edu.sg/docs/default-source/spaq/nie-2022_6pp_softcopy-final-editsp2020.pdf?sfvrsn=cbb06543_2

Ong, Y. K. (Mar 26, 2018a) *Speech by Mr Ong Ye Kung, Minister for Education (higher education and skills), at APAIE 2018 conference and exhibition.* https://www.moe.gov.sg/news/speeches/speech-by-mr-ong-ye-kung--minister-for-education-higher-education-and-skills--at-apaie-2018-conference-and-exhibition

Ong, Y. K. (June 7, 2018b) *Keynote address by Mr Ong Ye Kung, Minister for Education, at the 3rd International congress on vocational and professional education and training, Winterthur, Switzerland*. https://www.moe.gov.sg/news/speeches/keynote-address-by-mr-ong-ye-kung--minister-for-education--at-the-3rd-international-congress-on-vocational-and-professional-education-and-training--winterthur--switzerland

Ong, Y. K. (March 5, 2019). *No more streaming for students: Full transcript of speech by Education Minister Ong Ye Kung.* https://www.straitstimes.com/singapore/education/no-more-streaming-for-students-full-transcript-of-speech-by-education-minister

Quacquarelli Symonds Rankings. (2018). *QS World University rankings by subject 2018: Education.* https://www.topuniversities.com/university-rankings/university-subject-rankings/2018/education-training