

Advancing Ecological Models to Compare Scale in Multi-level Educational Change

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Education systems as units of analysis have been metaphorically likened to ecologies to model change. However, ecological models to date have been ineffective in modelling educational change that is multi-scale and occurs across multiple levels of an education system. Thus, this paper advances two innovative, ecological frameworks that improve on previous models. These models are extended to different educational contexts, specifically technology integration efforts in two private international school systems. While both models adequately compare scale of change through interactions between non-locational demographic groups on several geographic/locational levels the models are limited by their simplistic visual renderings and their application to educational contexts within the field of educational technology.

Introduction

Comparative education is a field that embraces the exchange of knowledge and learning between multiple fields and disciplines. It is heterogeneous and inclusive in terms of content, membership and purposes and, as a result, the field exemplifies “a multipolarity of centres of scholarship characterising the contemporary world and similar patterns in the different periods of the history of comparative education” (Manzon, 2015, p. 93). On these grounds, innovative methods are embraced in the field of comparative education. Bray, Adamson and Mason (2014) recognize, “one of the most important uses of comparative education research is the identification of models that are employed elsewhere and that can be imported for use in other settings” (p. 431). Thus, it is desirable for scholars in comparative education to learn from other fields and academic disciplines.

The purpose of this paper is to advance two innovative, ecological frameworks that model and compare scale of change within the field of educational technology. The paper begins with a description of two models, one proposed by Davis (2008) and the other by Law, Yuen and Lee (2015), that conceptualize change as multi-scale and education systems as complex, multi-level ecologies. Next, this paper demonstrates how these models can evolve or be translated for application to the field of educational technology, which is accomplished through a comparison of two information and communications technology-enabled innovations (ICT-enabled innovations) in the private international school context. The paper concludes with a discussion of limitations and opportunities for further research in the field of comparative education.

Multi-scale Units of Analysis

The practice of comparative education begins with the thoughtful identification of units of analysis. The Bray and Thomas cube (Bray & Thomas, 1995) is a conceptually robust

comparative education framework that can be used toward that end. This is because it allows for a holistic and comparative understanding of units of analysis along three dimensions: geographic/locational levels, non-locational demographic groups, and aspects of education and society. The geographic/locations dimension of the cube is particularly instructive because it comprises several levels that compose a cohesive, hierarchical, and multi-level social system. In this way, the cube introduces the educationalist not only to multi-dimensional analysis, but also to multi-level analysis. However, while the cube is effective in orienting an educationalist towards an appropriate unit of analysis, it does not necessarily lead the educationalist to draw multi-level comparisons (Bray, Adamson & Mason, 2014).

Despite this limitation, the Bray and Thomas cube is “crucial for a balanced and holistic understanding of educational phenomena” (Manzon, 2014, p. 126). For example, it can be used to understand the complexity of the Hong Kong education system, which comprises several categories of schools (e.g. international schools, direct subsidy scheme schools, private independent schools and aided schools) that have their own degree of operational flexibility. At one end the spectrum, international schools are allowed to raise revenue through institutionally set school fees. This is because the government does not financially support them. In contrast, direct subsidy scheme schools, which are partially funded by the government, cannot raise tuition fees above a certain level (Woo, 2013).

A closer examination of Hong Kong’s education system reveals that each school is a designed, hierarchical social organization comprised of various structures such as grade levels, classes and content areas. An international school in Hong Kong can thus be structured in many ways which allow for school self-stratification, with school structures acting as valves for change (Woo, 2014). Since there are different structural pathways in the education system, the impact of change from, for example, the enforcement of an e-learning policy is felt differently by schools categories, individual schools, and classes.

Given this picture, the emerging challenge for the educationalist becomes thoughtfully modelling and comparing change using a unit of analysis that is not only multi-level but also multi-scale. Here, scale involves a large group of learners and a wide range of stakeholders (Law, Kamylyis & Punie, 2015); multi-scale refers to the depth, spread, sustainability, ownership shift and evolution of a change within and across multiple geographic/locational levels (Law, Yuen & Lee, 2015). For example, the enforcement of a new e-learning policy impacts not only an education system’s multiple levels but also the multiple stakeholder groups vested in the change process, such as teachers, students, and vice-principals, who all hold different structural memberships. A teacher, for instance, belongs to a particular grade level and a student belongs to a particular class. Manzon (2014) suggests that the complex interplay between these different stakeholders is what makes multi-level boundaries blurred and permeable. Thus, there is a pressing need to develop robust models to delineate the boundaries between structures and different stakeholder groups.

Ecological Metaphors and Models of Complexity

A metaphor is useful for understanding the complexity of a social phenomenon. This is because it can facilitate an understanding of a complex idea by its most essential elements, which is further helpful for guiding the interpretation of data. In this vein, a biological ecology is an appropriate metaphor for an education system because both are complex, adaptive systems, with inter-related variables in causal relationships that influence system outcomes. Additionally, a biological ecology and an educational system can be examined through the lens of complexity and systems theories, which both emerged in the early 20th century from biologists who had operated against a prevailing worldview that the world could be understood completely through analysis of the smallest components and their deducible rules (O'Connor, 2008).

Applying biological ecologies as metaphors to understand educational change is neither new to educational research nor to the comparative education field. Since the 1970s, Bronfenbrenner (1976) has likened education systems and processes to nested ecological systems and structures. This practice has continued to the present time, where scholars such as Bray and Kobakhidze (2015) have likened the private supplementary tutoring phenomenon in Hong Kong to an ecosystem. However, much of the application of biological ecology to education systems to date has been through descriptive metaphor, such as likening computer uses and teachers to species with invasive and keystone qualities, respectively (Zhao & Frank, 2003).

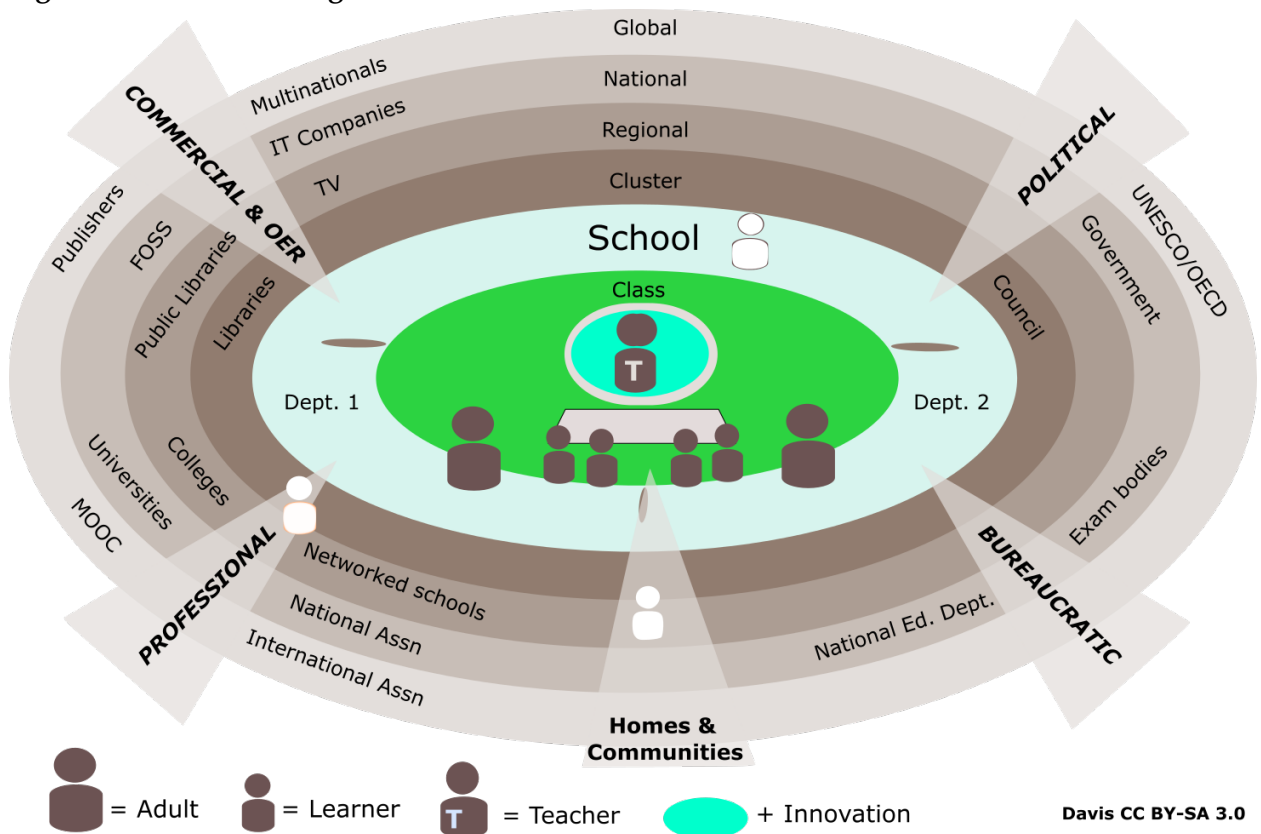
The educational technology field has not only spurred the development of ecological metaphors but also ecological models to understand multi-level, multi-scale change. Educationalists have faced the problem of not only introducing ICT-enabled innovations, but also sustaining and spreading the uptake, which go beyond the practice of an individual and are more challenging than changing pedagogical practices (Law, Yuen & Fox, 2011). This is because sustainability and scalability of ICT-enabled innovations are complex processes that require complex models of scaling that account for multiple levels, starting points, actor contributions and learning pathways, all of which impact the sustainability and scale of an innovation.

Davis's (2008) *Arena of Change* is one such ecological model that accounts for the multiple levels and actor contributions to sustainability and scale of change through digital technologies. Furthermore, the *Arena* is a significant ecological metaphor in the literature because it shifts ecological metaphor modality from text to images. It "aims to provide a 'satellite view' of the interconnected and embedded ecosystems that make up schooling globally," and illustrates "the chaotic and complex changes that are co-evolving with changes in the education and technology sectors" (Davis, 2015). The *Arena's* satellite view also identifies macro-ecosystem levels as regional, national and global parameters, all of which environ the school ecosystem and its sub-systems. The school ecosystem features classroom sub-systems and other sub-systems such as school departments. Teachers and students populate the classroom sub-systems and other roles – such as principal, department heads and parents – populate the other school sub-systems.

Davis (2008) originally introduced four categories of forces that influence internet technology (IT) across all levels of the ecology: bureaucratic, professional, commercial, and political. He also points out, “ensuring the essential conditions for transfer across multiple classrooms appears most challenging” (Davis, 2008, p. 516). A later Arena iteration (Davis, 2015) includes home and communities as another force influencing technology and education across all levels of the ecology. Institutions and organizations associated with these forces populate various ecosystems levels in the Arena of Change.

Davis (2008) states that though the model can be “somewhat different across countries...the multilevel ecological hierarchy still applies” (p. 508). For instance, the Arena has been used to map influential factors on the design of a university postgraduate course and the influence of that course on wider ecosystems (Davis, 2015). Figure 1 illustrates the latest iteration of Davis’s Arena of Change.

Figure 1. Arena of Change.



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Davis’s Arena of Change is an appealing, visual map of non-locational demographic groups and geographic/locational levels, and it acknowledges select aspects of education and society as forces acting on these actors and levels. However, it only begins to address the specific alignment of these levels, actors and their focused interactions,

which impact scale.

Thus, Law, Yuen and Lee (2015) developed a multi-level, multi-scale model of scalability that addresses issues of sustainability and scalability, particularly at each level of the multi-level ecosystem. The model recognizes multiple levels in an education system and facilitates descriptive mapping of within-level and across-level interactions, either within a unique instance of a unit of analysis or across another instance of the unit of analysis. Within-level, within unit refers to interactions within a specific ecological level within a unique instance of a unit of analysis. A meeting among teachers of the same grade (i.e., ecological level) and school (i.e., multi-level unit of analysis), for example, is an instance of a within-level, within unit interaction. Across-level, within unit refers to interactions across specific ecological levels within a unique instance of a unit of analysis. In this case, a meeting between a principal (i.e., school-level role) and a teacher (i.e., grade-level role) of the same school could be considered an across-level, within unit interaction. While the interactions described thus far occur within one school, across unit interactions involve two or more schools. Thus, students from a class in school A collaborating with students from another class in school B could be considered an across unit interaction. An across-level, across unit interaction could be defined as teachers (i.e., grade-level) of school A meeting the principal of school B (i.e., school-level).

Furthermore, Law, Yuen and Lee's (2015) model draws attention to outcomes and breakdowns from these interactions at each ecological level. Like Davis's Arena, this multi-level, multi-scale model has been used to analyze multi-scale change amongst non-locational demographic groups and geographic/locational levels in educational systems comprising various structures (Laferriere & Breuleux, 2015). However, despite the model's effectiveness in capturing within-level and across-level interactions, within unit and across unit interactions, and interaction breakdowns and outcomes at each ecological level, it does not provide a striking visual of the ecology and its actors at each ecological level. Table 1 is a representation of Law, Yuen and Lee's (2015) multi-level, multi-scale model of scalability.

Table 1. Schematic representation of the multilevel multiscale analysis of the architecture for learning within and across different contextual units of the hierarchical nested education system, and their effect on scalability.

Level	Within level		Cross level		Effect on scalability (depth, spread, sustainability, shift & evolution)		Breakdown
	Within unit	Cross unit	Within unit	Cross unit	For itself	For other units	
International							
System							
Project							
District / multi-school organization							
School (leadership)							
Teacher							
Student							
Technology							

Source: Law, Yuen and Lee (2015).

Research Design and Analytical Method for Adapted Ecological Models

This section describes the translation of Davis’s (2008) and Law, Yuen and Lee’s (2015) ecological conceptual frameworks into innovative models that can more effectively map multi-level, multi-scale educational change. This section also includes a description of the research context and the coding process by which data were mapped to the ecological models.

These adapted ecological models are grounded in a research project featuring two cases of ICT-enabled innovation in private international school systems. The unit of analysis is one ICT-enabled innovation facilitated by a technologist in one private international school during one school year. In multi-level, multi-scale learning, technologists act as brokers to create teacher learning opportunities and align learning within and across levels in a school system. The technological innovations of iPads and digital storytelling were the most frequently mentioned innovations for the ICT Facilitator in School A and the Head of Teaching and Learning Technologies in School B, respectively. Data to be mapped onto these ecological models came from iterative interviews with the selected technologists and their colleagues. Data also included notes taken from observations of

technologist interactions and digital artifacts such as blog posts.

The scale of educational change through each ICT-enabled innovation is evidenced through technologists' interactions. Therefore, data related to technologist interactions for the selected innovation were coded descriptively to identify their structure, which included identifying structural membership for each role at each unique interaction. Based on the structural membership of roles at an interaction, each interaction was positioned at a specific level and categorized as either a within-level interaction or an across-level interaction. Each unique interaction was further analyzed to identify formality in terms of regularity and compulsion, and whether the interaction was emergent or pre-existing to the innovation. In addition, data for each unique interaction were analysed for any explicit mention of outcomes, including any connections to other unique interactions. Finally, they were analyzed for breakdowns, tension or conflict in the interaction. The directionality of each interaction was determined based on the structural membership of participating roles, the outcomes of the interaction and whether the interaction was emergent or pre-existing.

Tables 2 and 3 (below) are adapted from Law, Yuen and Lee's (2015) multi-scale, multi-level model of scalability. Table 2 is a diagrammatic representation of the scale of educational change portraying an ICT Facilitator's interactions with multi-level, multi scale stakeholders to integrate iPads in School A. Similarly, Table 3 is a diagrammatic representation of the scale of educational change portraying a Head of Teaching and Learning Technologies' interactions to integrate digital storytelling in School B. Interactions are plotted in each table. These adapted models feature ecological levels, but focus particularly on within unit interactions, that is interactions within the school. Therefore, unlike the original Law, Yuen and Lee (2015) model, these translated models do not have across unit columns for within level and across level interactions. Table 3 features an extra-school ecological level because extra-school interactions related to the selected ICT-enabled innovation were identified in the data. Since the focus of the research is interactions within a school, only one column for outcomes is used in these adapted models. Interactions are described using emic labels if available from the data. Similarly, the different stakeholder group memberships, if available from the data, are stated in the description of each interaction.

Table 2. Schematic representation of the multilevel multiscale analysis of an ICT Facilitator’s interactions to integrate iPads in School A

PT Interactions	Within level	Across level	Outcome	Breakdown
School-level		School Head meetings	Approval for Samsung TV and Apple TV purchase	
Campus-level				
School section-level	P Principal meetings; P parent meetings	P religious studies curriculum team meetings	iPads and project goals; Samsung and Apple TV opportunity; meetings with School Head; P parent meetings; plans for whole-school iPad deployment and financing; professional development structure; 21CLHK; P iPad policies; curriculum mapping for K, P2, P4 teacher meetings; language support for P religious studies curriculum team	P principal has no authority to approve purchases
Grade-level		K, P2, P4 teacher meetings	Specific iPad app interaction focus for K, P2, P4 lessons; agreements for Scarlett to drop in and teach K, P2, P4 lessons	Disagreement between PT and teacher
Class-level		K, P2, P4 lessons	Learning artifacts	Disagreement between PT and teacher
Individual-level				

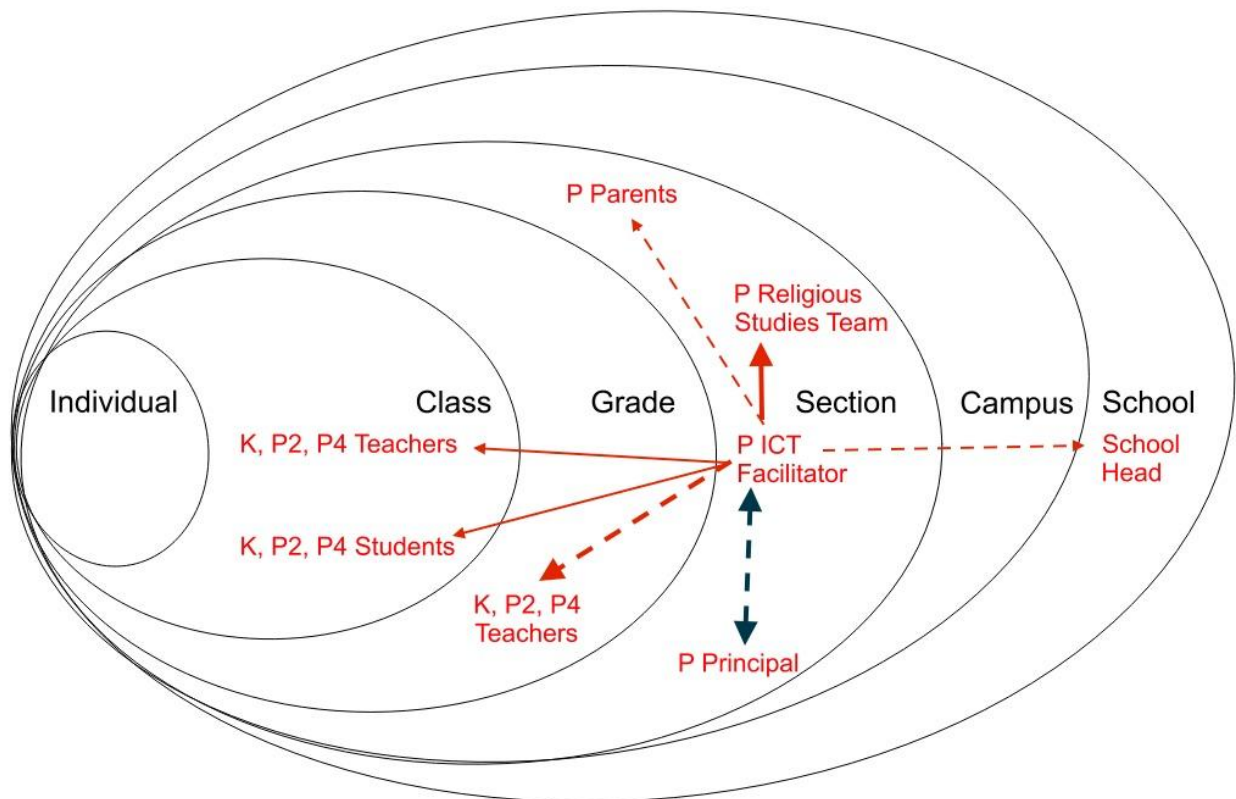
Table 3. Schematic representation of the multilevel multiscale analysis of a Head of Teaching and Learning Technology's interactions to integrate digital storytelling in School B

PT Interactions	Within level	Across level	Outcome	Breakdown
Extra-school		Conference presentations; university course teaching; commercial course	Digital storytelling practice; arrangement with E S9 biology teacher to team teach	
School-level		Afterschool Activity	ICT teacher, ICT technician and E P5 teacher drop in; digital storytelling artifacts; commercial course	Daniel leaves school
Campus-level				
School section-level				
Grade-level				
Class-level		E S9 biology teacher meeting; E S9 biology lessons	Pollution curriculum map and artifacts; P ICT teacher and E S Biology Head drop into lessons; commercial course; conference presentations; year-end assembly	Curriculum unit finishes; no biology teacher workshop on digital storytelling
Individual-level		E P ICT teacher meeting; E P5 teacher meeting; technician meeting; E S Biology Head drop in	Conference presentations	

Figures 2 and 3 (below) are adapted from Davis's (2008) Arena of Change model. Figure 2 is a diagrammatic representation of the scale of educational change through an ICT Facilitator's interactions to integrate iPads in School A. Similarly, Figure 3 is a diagrammatic representation of the scale of educational change through a Head of Teaching and Learning Technologies' interactions to integrate digital storytelling in

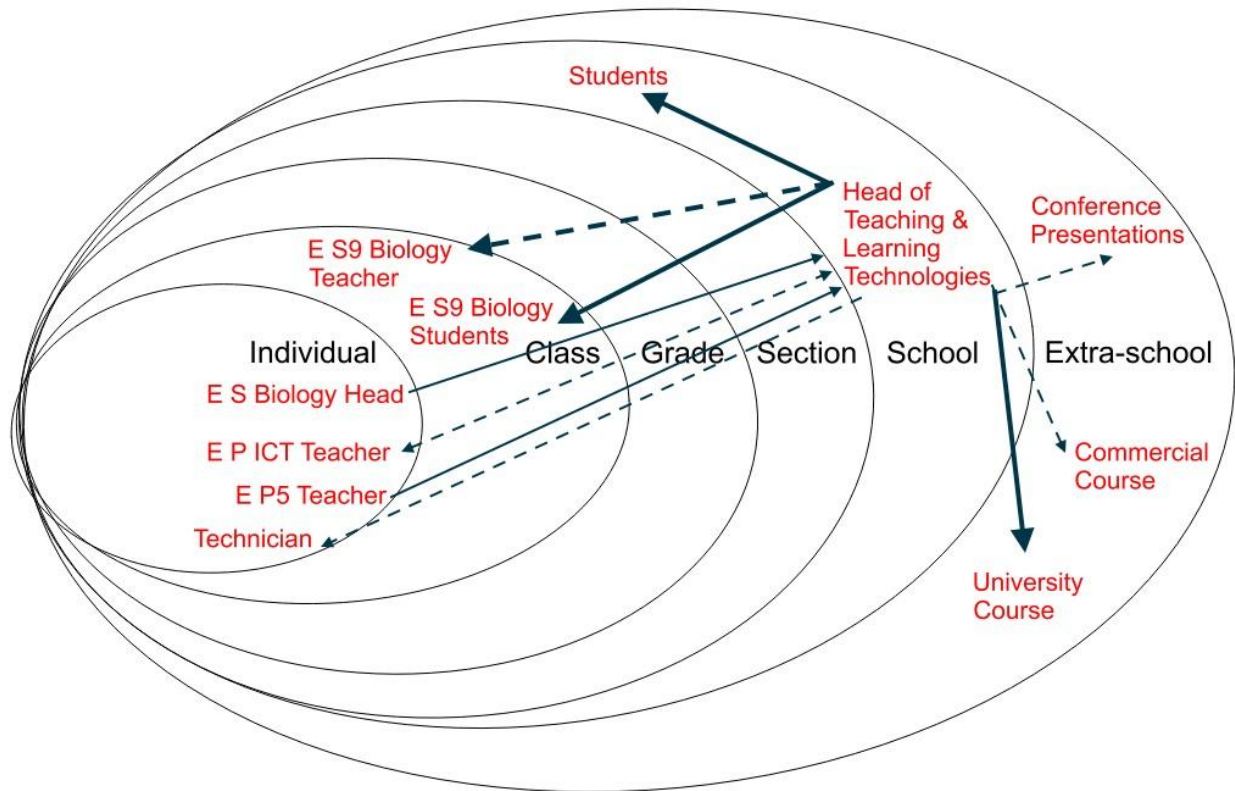
School B. Like Davis's original model, these adapted models feature ecological levels, roles and structures, with ecological levels highlighted in black and school roles and other structures highlighted in red. The models feature standardized fonts and colors. They also resemble Law, Yuen and Lee's (2015) multi-scale, multi-level model of scalability in that they visualize within and across level interactions (see Figures 2 and 3). However, the resemblance diverges in their emphasis of plotting various stakeholder groups at various ecological levels over plotting interactions, which is more of an element of Davis's model. Figure 3 features an extra-school ecological level because extra-school interactions related to the selected ICT-enabled innovation were identified in the data. These adapted models of the Arena of Change do not feature any political, professional, commercial or bureaucratic forces. This is because categorizing intra-school roles as being either mainly political, professional, commercial or bureaucratic was too subjective and superfluous to the research project.

Figure 2. Diagrammatic Arena representation of the multi-level, multi-scale analysis of an ICT Facilitator's interactions to integrate iPads in School. Creative Commons Attribution-ShareAlike 3.0 Unported (CC BY-SA 3.0)



Source: David Woo.

Figure 3. Diagrammatic Arena representation of the multi-level, multi-scale analysis of a Head of Teaching and Learning Technologies interactions to integrate digital storytelling. Creative Commons Attribution-ShareAlike 3.0 Unported (CC BY-SA 3.0).



Source: David Woo.

Figures 2 and 3 feature arrows from the technologist role to other school roles, which represent across-level and within-level interactions. These arrows should be interpreted as follows: arrows by their points convey directionality; thicker arrows convey routine interactions while thinner arrows convey ad hoc interactions; red arrows convey conflict while black arrows do not; dashed arrows are emergent interactions created in the target school year while solid arrows convey pre-existing routines.

The translations of Law, Yuen and Lee's (2015) model and Davis's (2008) model demonstrate different approaches to modelling scale from the same data set. They also emphasize the complex interplay between roles, school levels and qualities of interactions, all of which influence the scale of an ICT-enabled innovation. For schools A and B, the result of such complex interplay is different pathways for ICT-enabled innovation. In the case of school B, the ICT Facilitator worked with a larger and more diverse group of stakeholders to scale change. Thus, the interactions among the diverse stakeholder group impacted individual and class-levels of the school, or had impact outside the school. Also, there was an absence of conflict between the ICT Facilitator

and the stakeholders of school B. In contrast, the ICT Facilitator in School A worked with a smaller and less diverse group of stakeholders on mainly three levels: school section, grade level and class level. Also, while school B experienced an absence of conflict, school A experienced an abundance of conflict in the ICT Facilitator's interactions in School A. Although these specific pathways do not guarantee impact for an innovation in classroom practice, the findings suggest interactions at selected levels are correlated with other selected qualities that ultimately impact the influence of innovation on classroom-level practice. This supports Law, Yuen and Lee's (2015) argument that the value of good practices is not necessarily about the "what" and "how" of innovation, but the strategic alignment and development of learning across levels.

Discussion and Conclusion

This paper advanced two innovative, multi-level ecological frameworks that are based on ecological models proposed by Davis (2008) and Law, Yuen and Lee (2015). This section offers reflections on changing ecological models by identifying limitations to the models found in this paper, and by suggesting how comparative education researchers and practitioners can continue to advance models of ecology to compare scale of multi-level systems change.

Visualizations of metaphorical school ecologies are scarce and under-valued in both research and practice. Thus, there is a great opportunity and a need to develop new and improve existing ecological models that utilize visualizations to map educational change. This study sought to fill this need by advancing two innovative, multi-level ecological frameworks adapted from Davis (2008) and Law, Yuen and Lee (2015). While these models adequately compare scale of change through interactions between non-locational demographic groups on several geographic/locational levels, they are limited in several ways. At present, these models cannot visualize and compare breakdown of interactions within ecological levels in a system. In addition, while the models can adequately illustrate isolated interactions related specifically to an ICT-enabled innovation, they are unable to illustrate and facilitate comparison of secondary interactions that result from previous interactions. In other words, a challenge to the Arena of Change model is clearly illustrating a sequence of interactions, which is difficult because of the amount of detail required to map sequential interactions. The additional arrows and stakeholder groups would only clutter the visual model and render it unreadable. In brief, these models would be more robust could they convey more information about interactions in a clear manner.

Furthermore, drawing interaction arrows for Arena models using Sketchup Layout was very difficult and time-intensive. Also, learning how to use QCAD, which was used to create Figures 2 and 3, was equally time-intensive. Thus, while these technologies can spur the creation and diffusion of knowledge, the high learning curve associated with computer-assisted drawing software are constraints for educationalists.

Finally, any visualization will only be as valid as the coding of data for the visualization. To illustrate, a coding challenge arose when classifying eclectic groups of stakeholders such as the types of students that attend the Head of Teaching and Learning

Technologies's extra-curricular activities. After much deliberation, the interactions of these eclectic groups of stakeholders were categorized as school-level interactions; the interactions of individual teachers and eclectic, individual school stakeholders were categorized as individual level interactions. In the end, it was clear that impressive visuals do not mitigate loose constructs. In general, ecological metaphors are too theoretical because they are rarely applied to and grounded through research data.

School systems will continue to change just as biological ecologies and societies change over time. In view of this, models are necessary to "guide different trajectories of change observed under different contexts and stimulate further research" (Punie, Law & Kamylyis, 2013, p. 8). Since these models were developed within the field of educational technology and have advanced understanding of educational change in that field, their exclusivity to that field has limited their application to other educational contexts and units of analysis: the scope of educational technology and ecological research undervalues certain countries, school organizational types and school roles. Therefore, just as educational technology researchers have overlooked school-based levels and non-mainstream school systems as areas for scale, they have also overlooked these areas for the application of ecological models in the field of education. The field of comparative education may assemble a greater cross section of researchers from diverse educational contexts and disciplines than the field of educational technology. Comparative educationalists from these diverse educational contexts and disciplines have the opportunity not only to advance comparative education and educational technology field but also the ecological models shared between these fields.

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References

- Bray, M., & Thomas, R. M. (1995). Levels of comparison in educational studies: Different insights from different literatures and the value of multilevel analyses. *Harvard Educational Review*, 65(3), 472-491.
- Bray, M., Adamson, B., & Mason, M. (2014). Different Models, Different Emphases, Different Insights. In M. Bray, B. Adamson, & M. Mason (Eds.), *Comparative education research approaches and methods* (Second ed., pp. 417-436). Hong Kong: Comparative Education Research Centre University of Hong Kong.
- Bray, M., & Kobakhidze, M. (2015). Evolving ecosystems in education: The nature and implications of private supplementary tutoring in Hong Kong. *PROSPECTS*, 1-17. doi:10.1007/s11125-015-9353-2.
- Bronfenbrenner, U. (1976). The Experimental Ecology of Education. *Educational Researcher*, 5(9), 5-15. Retrieved from <http://www.jstor.org/stable/1174755>
- Davis, N. (2008). How May Teacher Learning Be Promoted for Educational Renewal with IT? In J. Voogt & G. Knezek (Eds.), *International Handbook of Information Technology in Primary and Secondary Education* (Vol. 20, pp. 507-519): Springer.

- Davis, N. (2015, June 20). The arena of change - an example for and with EDEM630. Retrieved from <http://davisarena.blogspot.hk/2015/06/the-arena-of-change-example-for-and.html>
- Davis, N. (2015, September 12). The Arena of change for EDUsummit on 14-15 Sept 2015. Retrieved from <http://davisarena.blogspot.hk/2015/09/the-arena-of-change-edusummit-in-14-15.html>
- Law, N., Kamylyis, P., & Punie, Y. (2015). Pathways to Enhance Multilevel Learning for Scaling Up Systemic ICT-Enables Learning Innovations: Lessons from 7 European and Asian Cases. In C. K. Looi & L. W. Teh (Eds.), *Scaling Educational Innovations* (pp. 197-223): Springer Singapore.
- Law, N., Yuen, A., & Fox, R. (2011). Educational innovations beyond technology: nurturing leadership and establishing learning organizations. New York: Springer.
- Law, N., Yuen, J. K. L., & Lee, Y. (2015). *Precarious School Level Scalability Amid Network Level Resilience: Insights from a multilevel multiscale model of scalability*. Paper presented at the American Educational Research Association Conference, Chicago.
- Manzon, M. (2014). Comparing Places. In M. Bray, B. Adamson, & M. Mason (Eds.), *Comparative education research approaches and methods* (Second ed., pp. 97-138). Hong Kong: Comparative Education Research Centre University of Hong Kong ; Springer.
- Manzon, M. (2015). CERC: An Intellectual Field in Microcosm. In M. Manzon (Ed.), *Changing Times, Changing Territories: Reflections on CERC and the Field of Comparative Education* (First ed., Vol. 11, pp. 76-102). Hong Kong: Comparative Education Research Centre (CERC).
- O'Connor, G. C. (2008). Major Innovation as a Dynamic Capability: A Systems Approach*. *Journal of Product Innovation Management*, 25(4), 313-330. doi:10.1111/j.1540-5885.2008.00304.x
- Punie, Y., Law, N. W. Y., & Kamylyis, P. (2013). ICT-enabled Innovation for Learning in Europe and Asia: Exploring Conditions for Sustainability, Scalability and Impact at System Level. Luxembourg: Publications Office of the European Union.
- Spillane, J. P., Parise, L. M., & Sherer, J. Z. (2011). Organizational Routines as Coupling Mechanisms: Policy, School Administration, and the Technical Core. *American Educational Research Journal*, 48(3), 586-619. doi:10.2307/27975303.

- Woo, D. (2013). Neoliberalism in Two Hong Kong School Categories. *Current Issues in Comparative Education*, 16(1), 37-48. Retrieved from <http://www.tc.columbia.edu/cice/index.asp?Id=Current+Issue&Info=Volume+16%2c+Issue+1>
- Woo, D. J. (2014). Exploring organisational stratification and technological pedagogical change: cases of technology integration specialists in Hong Kong international schools. *Globalisation, Societies and Education*, 1-16. doi:10.1080/14767724.2014.965010
- Zellermayer, M., & Margolin, I. (2005). Teacher educators' professional learning described through the lens of complexity theory. *The Teachers College Record*, 107(6), 1275-1304.
- Zhao, Y., & Frank, K. A. (2003). Factors Affecting Technology Uses in Schools: An Ecological Perspective. *American Educational Research Journal*, 40(4), 807-840. doi:10.3102/00028312040004807