Technology implementation in the VUCA era: Insights from large-scale international assessment studies

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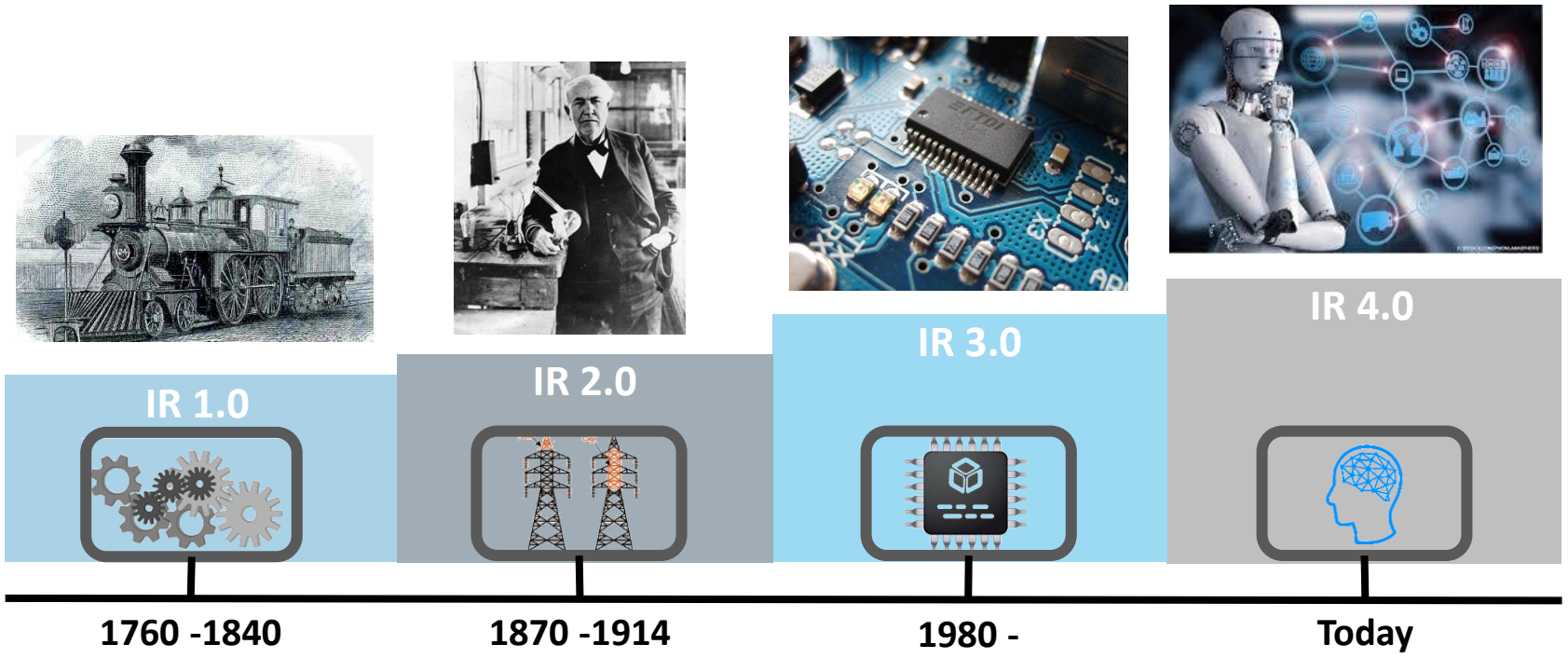
Key Questions

- Does technology really make a difference in education?
- Where are we?
- What have we learnt?

Two studies

- Study One
  - Sample: 15-year-old Hong Kong secondary students
  - Examining the relationship between students' ICT use and their academic achievements
- Study Two
  - Sample: 15-year-old secondary students from 52 countries
  - Whether the phenomena unfolded in Study One can be found in other countries
  - Examining the mediating role of students' cognitive-motivational engagement in ICT in the relationship between ICT use and their academic achievements

From Industrial Revolution to Industrial Revolution



From Industrial Revolution to Industrial Revolution

Driverless car

- Shenzhen allows fully autonomous, driverless cars on some roads (South China Morning Post, 2022)
- Baidu unveils new self-driving taxi in Shenzhen, China (BBC News, 2022)

AI generative content

- Space Opera Theater), by Jason Allen via Midjourney (an AI program), took first place in the digital category at the 2022 Colorado State Fair (The New York Times, 2022).

Symbiotic AI

- HKBU Symphony Orchestra held the Annual Gala Concert featuring AI virtual choir, AI virtual dancers, and an AI media artist (HKBU, 2022).

From Industrial Revolution to Industrial Revolution

- IR 1.0 and IR 2.0: enhancing the accessibility to education through the introduction of public schooling and broadcasting ETV
- IR 3.0 and IR 4.0: accessibility, interactivity, adaptability and symbioticity

Problem

- IRs have altered the ways we live, work, and relate to one another.
- New technology is creating more jobs (e.g., Process Automation Specialist, AI Specialist, Digital marketing, etc.)
- Prepare students for the future:
  Huge investment of information and communication technology (ICT) in schools across the world.
- However, an overall consensus about the relationship between students' ICT use and academic achievement is lacking: positive, negative, and non-significant **linear** relationships all being reported (Odell et al., 2020).

Ambivalent relationships

- PISA 2000 to 2012: students' ICT use was negatively correlated with their science and mathematics achievements (Zhang & Liu, 2016)
- PISA 2015: students' ICT use outside school for leisure correlated positively with their academic achievements. (Hu et al., 2018; Gómez-Fernández & Mediavilla, 2021)
- PISA 2015: ICT use at school and outside school for schoolwork correlate negatively with students' academic achievements (Zhang & Liu, 2016; Hu et al., 2018)
- PISA 2018: ICT use for social interaction correlates negatively with students' academic achievements (Navarro-Martinez & Peña-Acuña, 2022)

Ambivalent relationships

Table 2 Relationship between ICT interactions and scores in mathematics and science for the articles included in this scoping literature review

ICT	Math			Science		
	Positive	Negative	Null	Positive	Negative	Null
HOMSCH (use of ICT at home for schoolwork)	[1 +VE 0] UR-low	[9] -VE [17 use) EUR) [24]	[0 UR) [16]	([1 +VE oun- ch EUR- low use) [23]	[2][-VE 9] ([use) ([18] ESP) ([19 EUR) [24]	([0 FIN,
USESCH (use of ICT at school)	([4 +VE 17) [23]	[1] -VE TUR) ([16] [17 EUR-mid, high use) ([18] ESP) ([22] ESP) [24]	(0 14]	([5 +VE se EUR-	[2][-VE US) [9] ([15] ESP) ([17 EUR-mid, high use) ([18] ESP) ([22] ESP) [24] [25]	([0] CZE)
ENTUSE (use of ICT for entertainment)	([4 +VE ow es) ([6] R-low use) ([20] TUR) [23]	([1 -VE oun-) [9] ([18] QCN, KOR) ([17 EUR-high use) ([18] ESP) ([22] ESP) [24]	[0 ([17 e)	[2] +VE US, et) EUR-low use) [23] [25]	[1] -VE quent use) EUR- high use) ([18] ESP) ([22] ESP) [24]	[9 0 ([17)

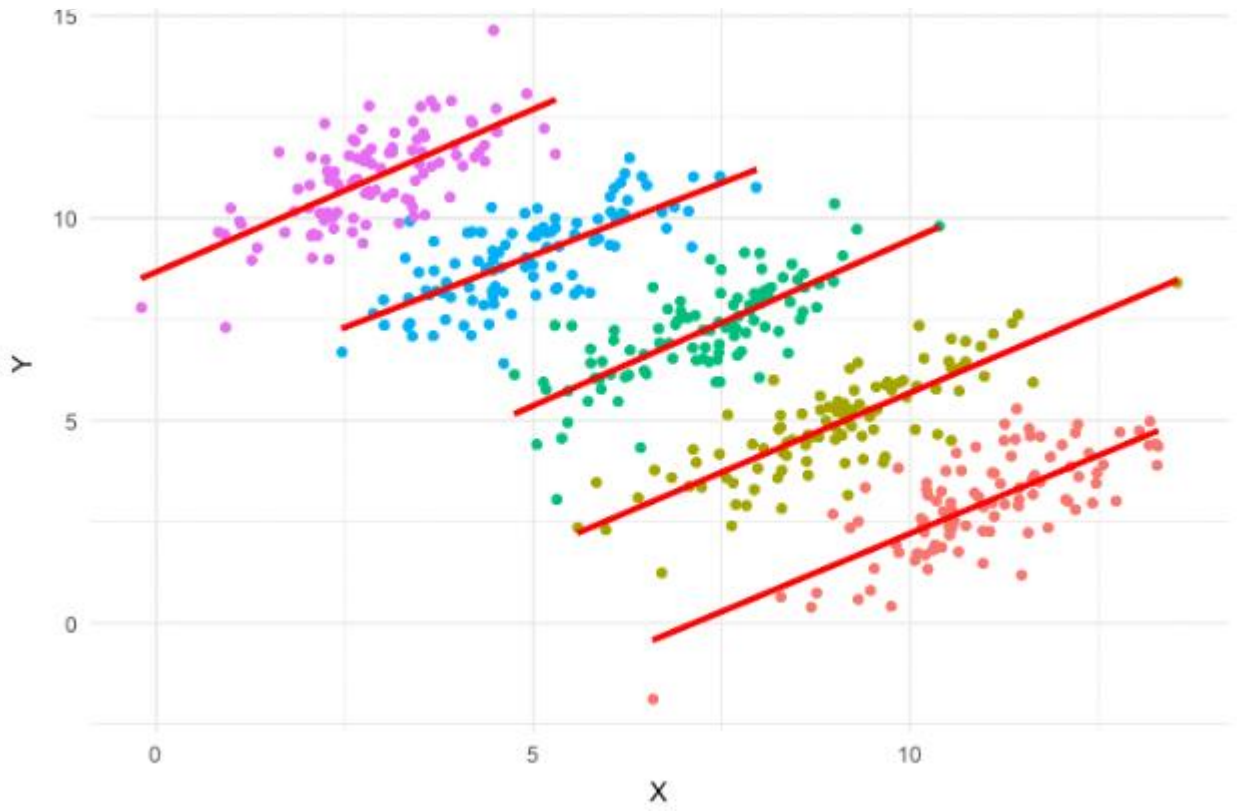
(Odell et al., 2020)

Ambivalent relationships

The ambivalent results might arise from

- imposing the assumption of a linear relationship
- neglecting the indirect effects of ICT use mediated by other ICT-related dispositions, such as, students' cognitive-motivational engagement in ICT
- neglecting the hierarchical data structure inherited in many large-scale international assessment studies.

Hierarchical data structure



Two studies

Based on PISA 2018 dataset:

- Study One
  - Sample: **15-year-old Hong Kong secondary students**
  - Examining the relationship between students' ICT use and their academic achievements
- Study Two
  - Sample: **15-year-old secondary students from 52 countries**
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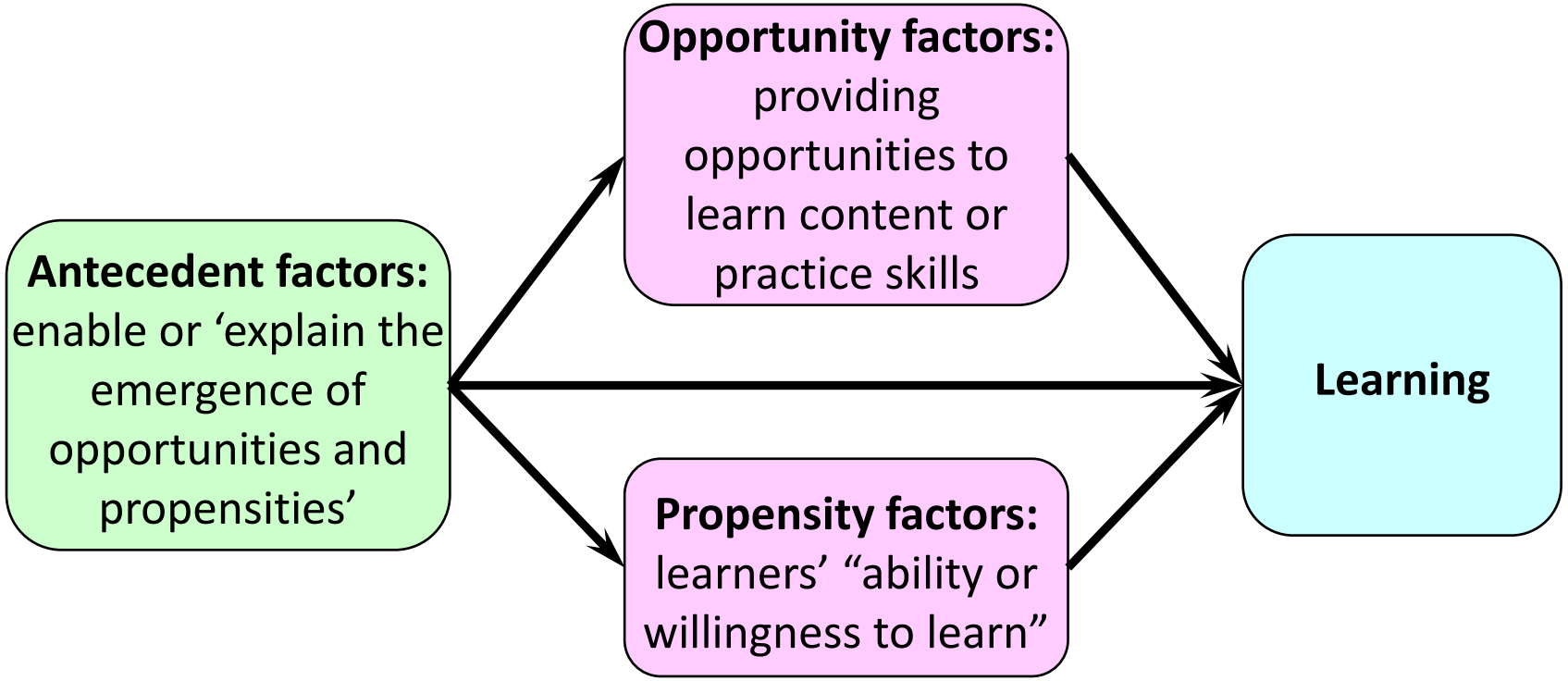
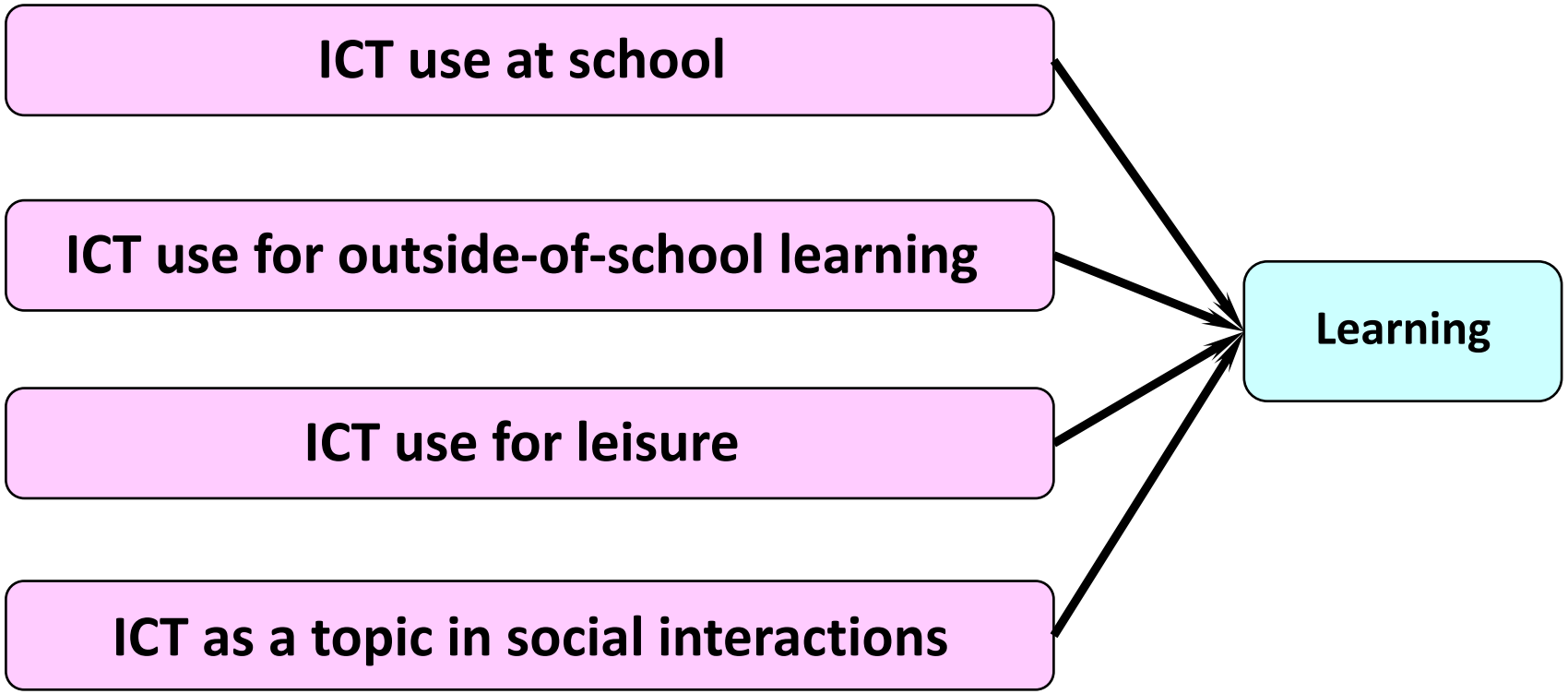
Study One: The Nonlinear Relationship

Theoretical framework: the Opportunity-Propensity (O-P) framework (Byrnes & Miller, 2007)

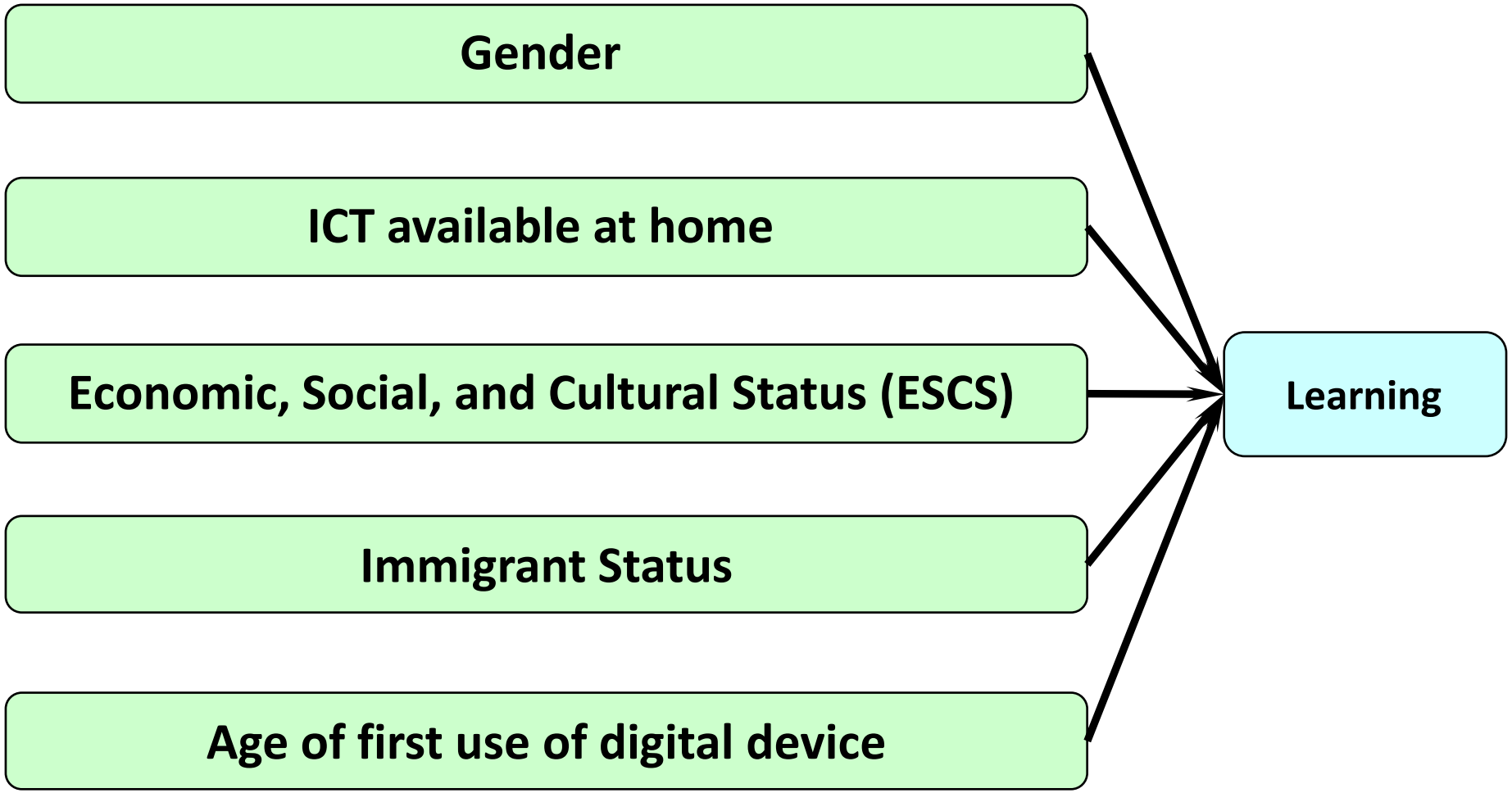


Byrnes, J. P., & Miller, D. C. (2007). The relative importance of predictors of math and science achievement: An opportunity-propensity analysis. *Contemporary Educational Psychology*, *32*(4), 599–629. doi:10.1016/j.cedpsych.2006.09.002

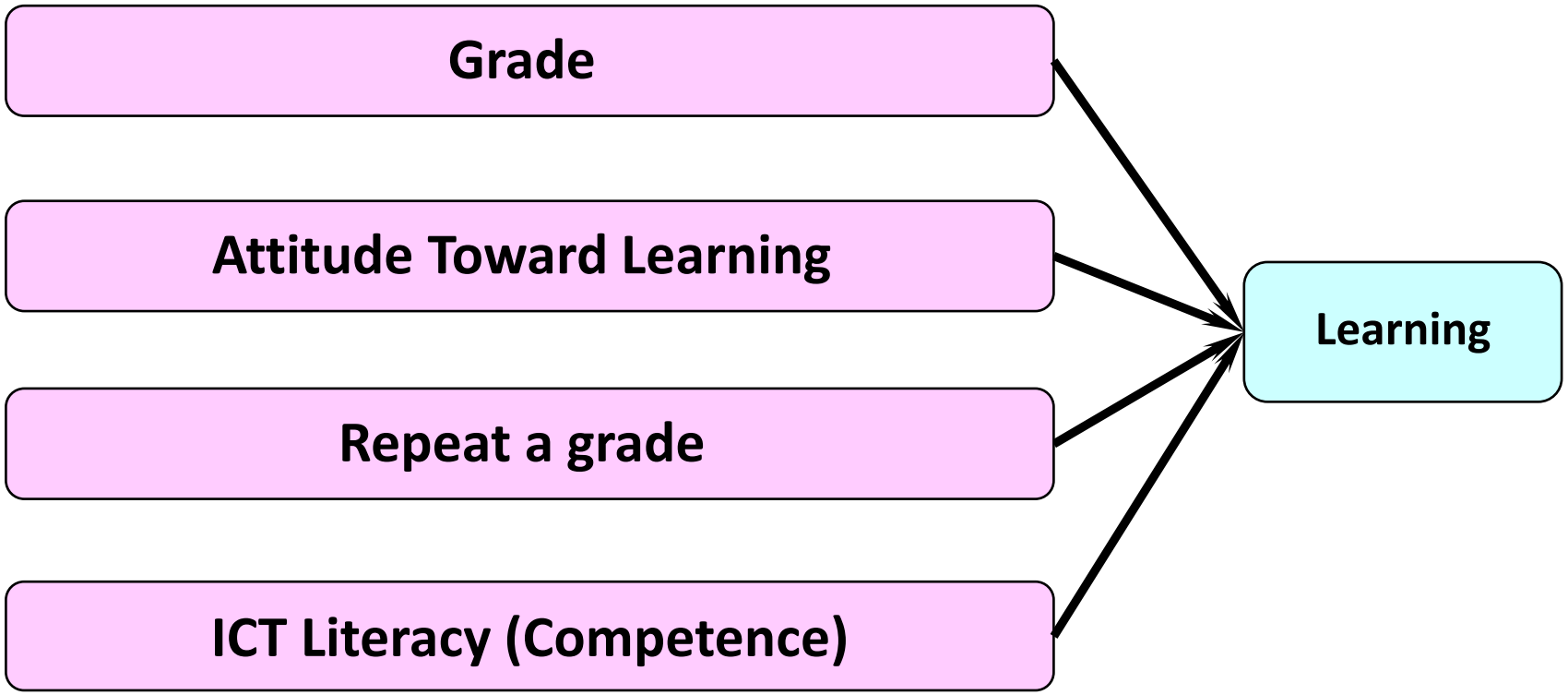
ICT Use as Opportunity Factors



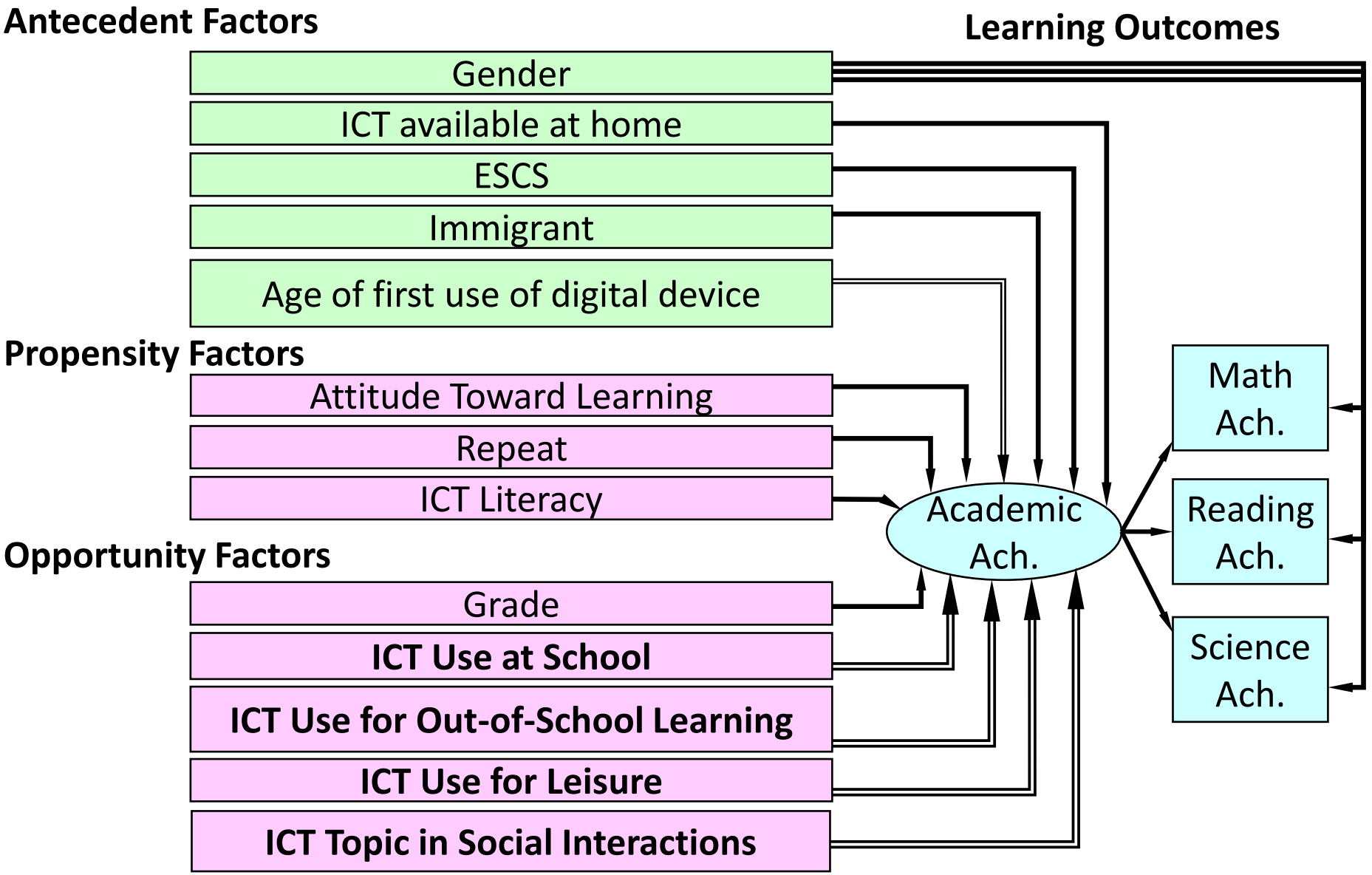
Control Variables: Antecedent Factors



Control Variables: Other Opportunity Factors and Propensity Factors



Theoretical Framework



The single line signifies the linear hypothesis; the double line signifies the non-linear hypothesis.

Method: Sample

- Secondary data from 2018 cohort of Programme for International Student Assessment (PISA)
- 15-year-old secondary students (enrolled in Grade 7 or above)
- A two-stage stratified random sampling design
  - At least 150 schools were selected in proportion to their number of PISA-eligible 15-year-old students,
  - A list of 42 students (or all 15-year-old students if fewer than 42 were enrolled) were selected with equal probability.
- The target Hong Kong population: 51,328 students
- Representative Sample: 6,037 students from 152 schools

Demographic Information of the Sample

Student age	Years
Mean	15.73
Minimum	15.25
Maximum	16.25

Grades	N (%)
7	56 (0.9%)
8	315 (5.2%)
9	1,507 (25%)
10	4,108 (68.0%)
11	51 (0.8%)
Total	**6,037**

Instrument: ICT Use at School

How often do you use digital devices for the following activities <u>at school</u>?

(Please select one response in each row.)

Cronbach's α = .94; N =10

	Never or hardly ever	*Once or twice a month*	*Once or twice a week*	*Almost every day*	*Every day*
Chatting online at school.	☐01	☐02	☐03	☐04	☐05
Using email at school.	☐01	☐02	☐03	☐04	☐05
Browsing the Internet for schoolwork.	☐01	☐02	☐03	☐04	☐05
Downloading, uploading or browsing material from the school's website (e.g. intranet).	☐01	☐02	☐03	☐04	☐05
Posting my work on the school's website.	☐01	☐02	☐03	☐04	☐05
Playing simulations at school.	☐01	☐02	☐03	☐04	☐05
Practicing and drilling, such as for foreign language learning or mathematics.	☐01	☐02	☐03	☐04	☐05
Doing homework on a school computer.	☐01	☐02	☐03	☐04	☐05
Using school computers for group work and communication with other students.	☐01	☐02	☐03	☐04	☐05
Using learning apps or learning websites.	☐01	☐02	☐03	☐04	☐05

Instrument: ICT Use for Outside-of-school Learning

How often do you use digital devices for the following activities <u>outside of school</u>?

(Please select one response in each row.)

Cronbach's α = .94; (N = 11)

	Never or hardly ever	*Once or twice a month*	*Once or twice a week*	*Almost every day*	*Every day*
• Browsing the Internet for schoolwork	☐01	☐02	☐03	☐04	☐05
• Browsing the Internet to follow up lessons	☐01	☐02	☐03	☐04	☐05
• Using email for communication with other students about schoolwork.	☐01	☐02	☐03	☐04	☐05
• Using email for communication with teachers and submission of homework or other schoolwork.	☐01	☐02	☐03	☐04	☐05
• Using social networks for communication with teachers.	☐01	☐02	☐03	☐04	☐05
• Downloading, uploading or browsing material from my school's website.	☐01	☐02	☐03	☐04	☐05
• Checking the school's website for announcements	☐01	☐02	☐03	☐04	☐05
• Doing homework on a computer / mobile device.	☐01	☐02	☐03	☐04	☐05
• Using learning apps or learning websites on a computer.	☐01	☐02	☐03	☐04	☐05
• Using learning apps or learning websites on a mobile device.	☐01	☐02	☐03	☐04	☐05

Instrument: ICT Use for Leisure

How often do you use digital devices for the following activities <u>outside of school</u>?
(Please select one response in each row.)

Cronbach's α = .84; (N = 12)

	Never or hardly ever	*Once or twice a month*	*Once or twice a week*	*Almost every day*	*Every day*
Playing one-player games.	☐01	☐02	☐03	☐04	☐05
Playing collaborative online games.	☐01	☐02	☐03	☐04	☐05
Using email.	☐01	☐02	☐03	☐04	☐05
Chatting online (e.g. Whatsapp).	☐01	☐02	☐03	☐04	☐05
Participating in social networks	☐01	☐02	☐03	☐04	☐05
Playing online games via social networks .	☐01	☐02	☐03	☐04	☐05
Browsing the Internet for fun (such as watching videos,	☐01	☐02	☐03	☐04	☐05
Reading news on the Internet (e.g. current affairs).	☐01	☐02	☐03	☐04	☐05
Obtaining practical information from the Internet.	☐01	☐02	☐03	☐04	☐05
Downloading music, films, games or software from the Internet.	☐01	☐02	☐03	☐04	☐05
Uploading your own created contents for sharing.	☐01	☐02	☐03	☐04	☐05
Downloading new apps on a mobile device.	☐01	☐02	☐03	☐04	☐05

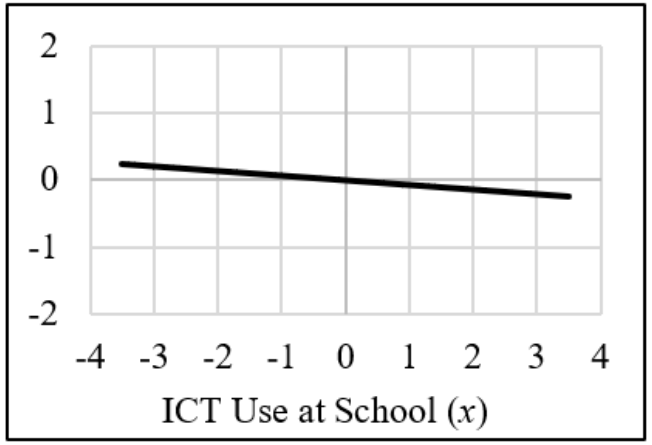
Instrument: Using ICT as a Topic in Social Interactions

Thinking about your experience with digital media and digital devices: to what extent do you disagree or agree with the following statements?
(Please select one response in each row.)

Cronbach's α = .89; N = 5

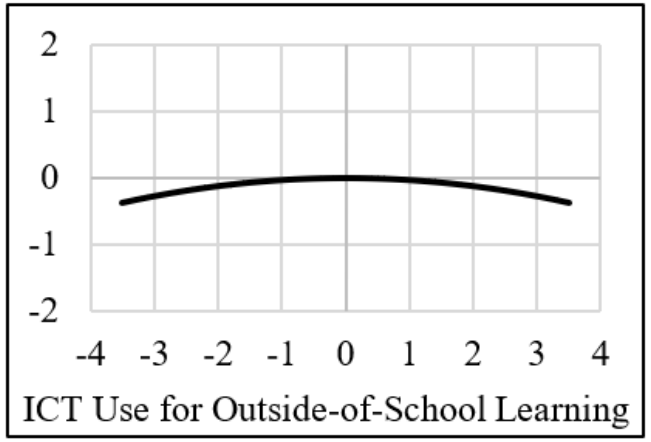
	Strongly disagree	*Disagree*	*Agree*	*Strongly agree*
To learn something new about digital devices, I like to talk about them with my friends.	☐01	☐02	☐03	☐04
I like to exchange solutions to problems with digital devices with others on the Internet.	☐01	☐02	☐03	☐04
I like to meet friends and play computer and video games with them.	☐01	☐02	☐03	☐04
I like to share information about digital devices with my friends.	☐01	☐02	☐03	☐04
I learn a lot about digital media by discussing with my friends and relatives.	☐01	☐02	☐03	☐04

Achievements and ICT use (Student Level)



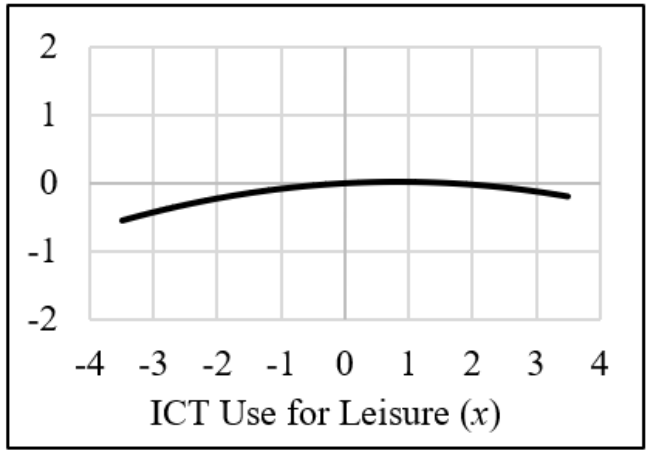
a. Achi = $-0.01x^2 - 0.07^*x + e$

$\overset{\#}{\approx} \quad - 0.07^*x + e$



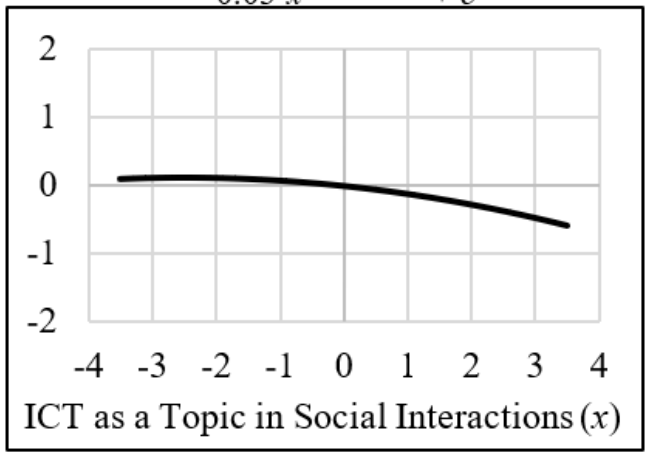
b. Achi = $-0.03^*x^2 + 0.02x + e$

$\overset{\#}{\approx} -0.03^*x^2 \quad + e$



c. Achi = $-0.03^*x^2 + 0.05^*x + e$

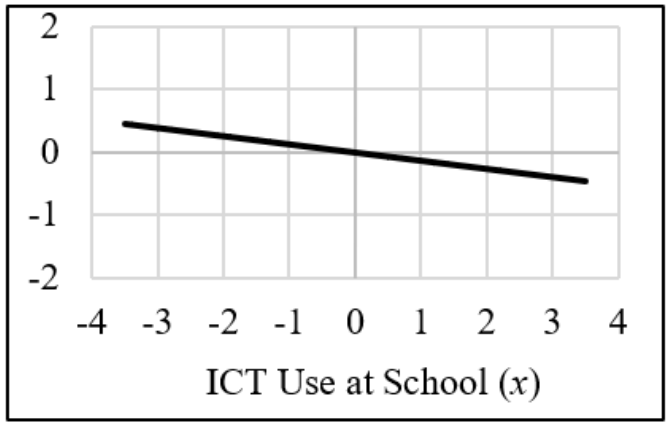
$\approx -0.03^* (x - 0.83)^2 + e'$



c. Achi = $-0.02^*x^2 - 0.10^*x + e$

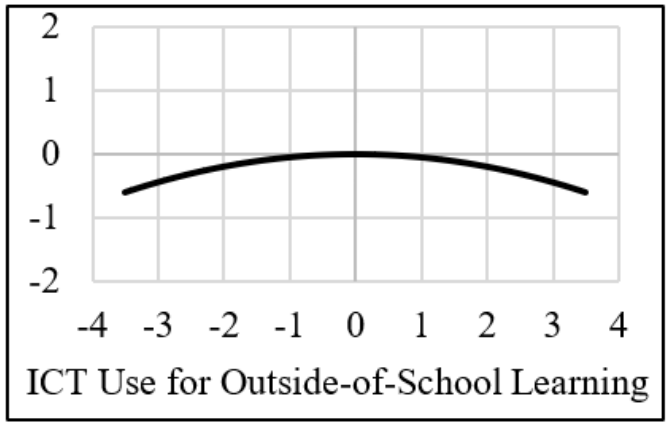
$\approx -0.02^* (x + 2.50)^2 + e'$

Achievement and ICT use (School Level)



a. $\text{Achi} = 0.00x^2 - 0.13^{*}x + e$

$\overset{\#}{\approx} \quad - 0.13^{*}x + e$



b. $\text{Achi} = -0.05^{*}x^2 + 0.01x + e$

$\overset{\#}{\approx} -0.05^{*}x^2 \quad + e$

Brief Summary

The Hong Kong dataset of PISA 2018:

- Non-linear, non-positive effects of ICT use on academic achievements
- In particular, ICT use at school has a negative effect on academic achievements at the student and school levels.
- ICT use outside school for schoolwork, leisure and social interaction have an inverted-U shaped relationship with academic achievements.

Study Two

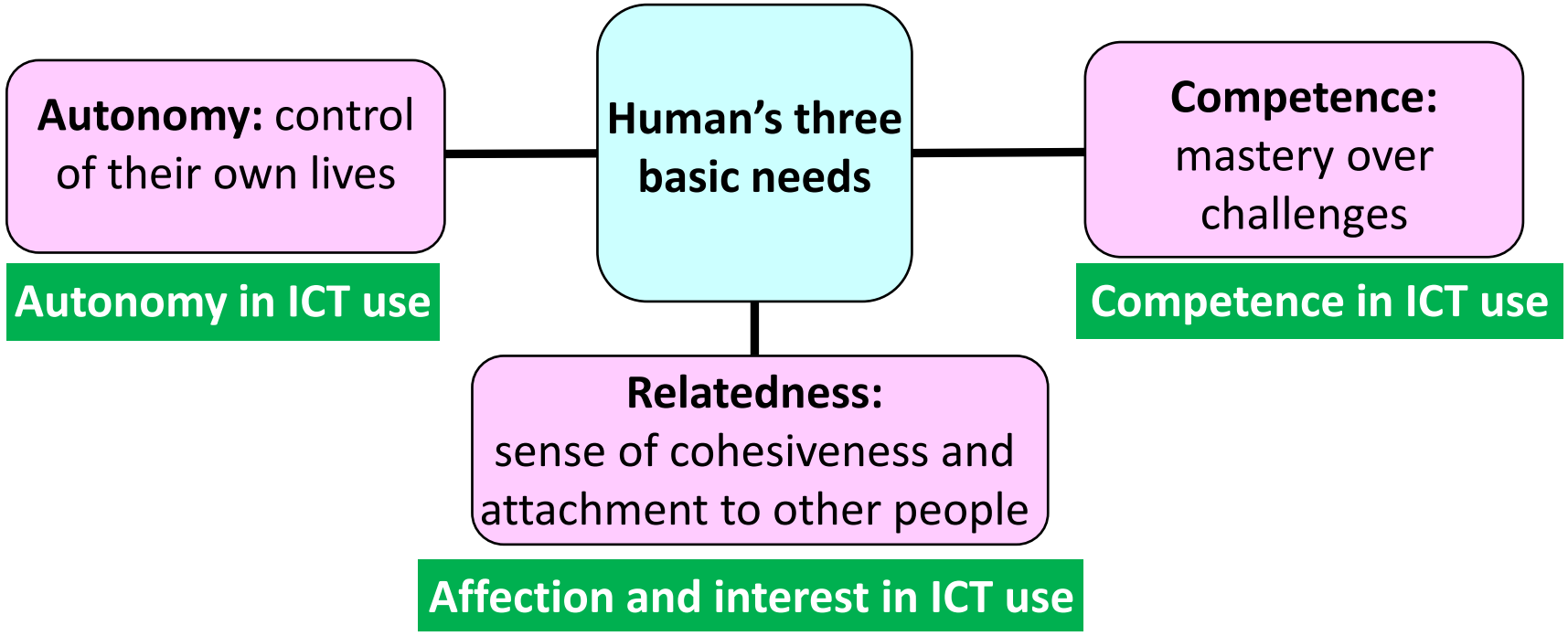
Overarching Research Questions:

- Are the non-linear relationships between ICT use and academic achievements **consistent across different countries**?
- Does ICT use affect students' academic achievements indirectly via ***cognitive-motivational engagement (CME) in ICT***, that is **perceived autonomy**, **competence**, and **interest in ICT use**?

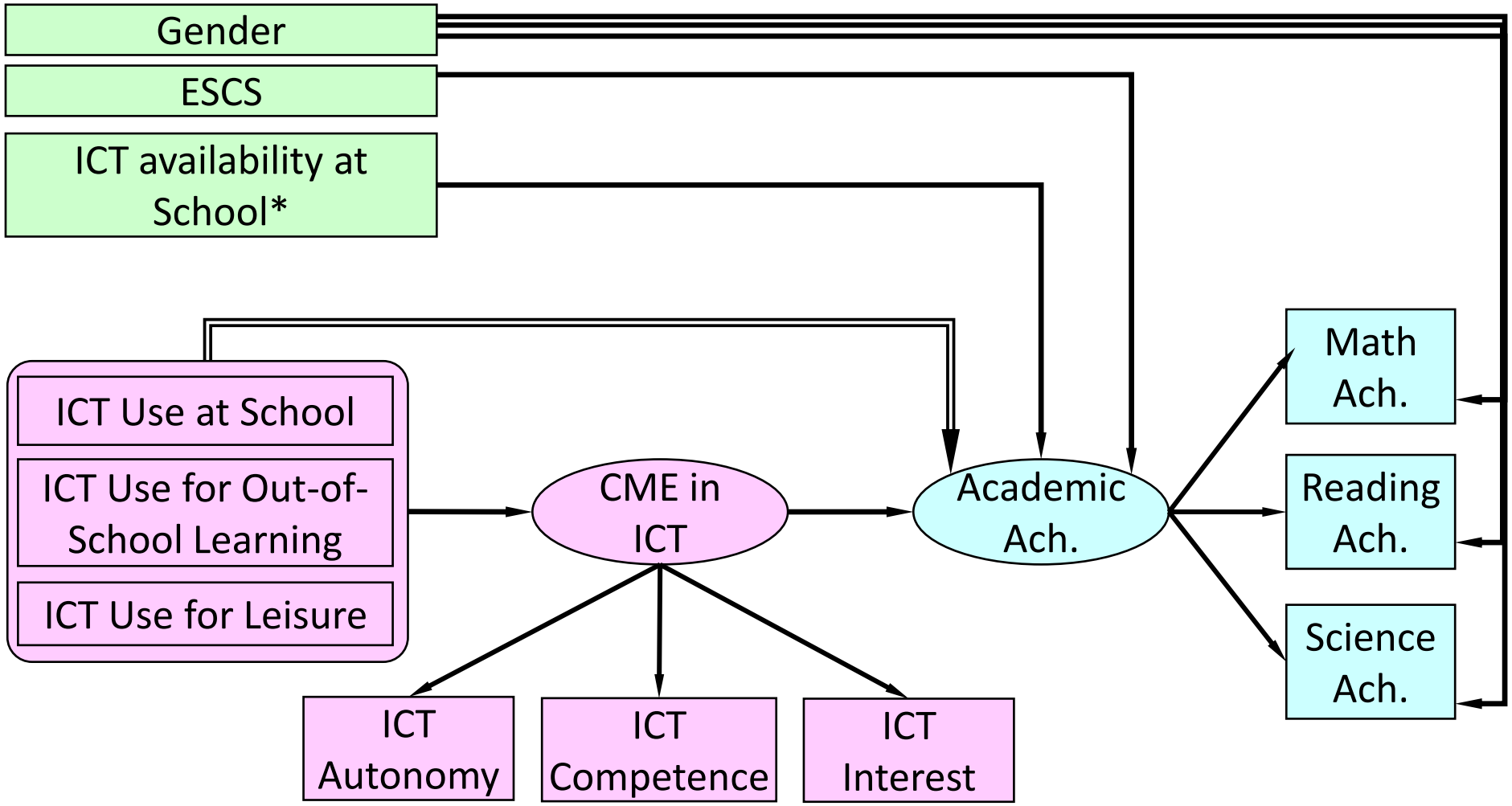
Study Two: Indirect Effect of ICT Use

Guiding theory: Self-determination theory (SDT; Ryan & Deci, 2017).

Satisfaction of these needs is essential for individuals' optimal functioning and growth.



Theoretical Framework



*: school and country levels only. Ach. = Achievement

Method: Sample

- Secondary data from PISA 2018
- 250,163 PISA-eligible 15-year-old secondary students
- 11,403 schools
- 52 countries or economies

Instrument (Study 2): ICT Autonomy

Thinking about your experience with digital media and digital devices: to what extent do you disagree or agree with the following statements?

(Please select one response in each row.)

	Strongly disagree	*Disagree*	*Agree*	*Strongly agree*
If I need new software, I install it by myself.	☐ 01	☐ 02	☐ 03	☐ 04
I read information about digital devices to be independent.	☐ 01	☐ 02	☐ 03	☐ 04
I use digital devices as I want to use them.	☐ 01	☐ 02	☐ 03	☐ 04
If I have a problem with digital devices I start to solve it on my own.	☐ 01	☐ 02	☐ 03	☐ 04
If I need a new application, I choose it by myself.	☐ 01	☐ 02	☐ 03	☐ 04

Instrument: ICT Competency

Thinking about your experience with digital media and digital devices: to what extent do you disagree or agree with the following statements?

(Please select one response in each row.)

Cronbach's α = .92; N =5

	Strongly disagree	*Disagree*	*Agree*	*Strongly agree*
I feel comfortable using digital devices that I am less familiar with.	☐01	☐02	☐03	☐04
If my friends and relatives want to buy new digital devices or applications, I can give them advice.	☐01	☐02	☐03	☐04
I feel comfortable using my digital devices at home.	☐01	☐02	☐03	☐04
When I come across problems with digital devices, I think I can solve them.	☐01	☐02	☐03	☐04
If my friends and relatives have a problem with digital devices, I can help them.	☐01	☐02	☐03	☐04

Instrument (Study 2): ICT Interest

Thinking about your experience with digital media and digital devices: to what extent do you disagree or agree with the following statements?

(Please select one response in each row.)

	Strongly disagree	*Disagree*	*Agree*	*Strongly agree*
I forget about time when I'm using digital devices.	☐ 01	☐ 02	☐ 03	☐ 04
The Internet is a great resource for obtaining information I am interested in (e.g. news, sports, dictionary).	☐ 01	☐ 02	☐ 03	☐ 04
It is very useful to have social networks on the Internet.	☐ 01	☐ 02	☐ 03	☐ 04
I am really excited discovering new digital devices or applications.	☐ 01	☐ 02	☐ 03	☐ 04
I really feel bad if no Internet connection is possible.	☐ 01	☐ 02	☐ 03	☐ 04
I like using digital devices.	☐ 01	☐ 02	☐ 03	☐ 04

Instrument (Study 2): ICT available at school

- The number of available computers per student for educational purposes (N Computer / S)
- The proportion of Internet-connected computers at school available to students (% IC Computer)

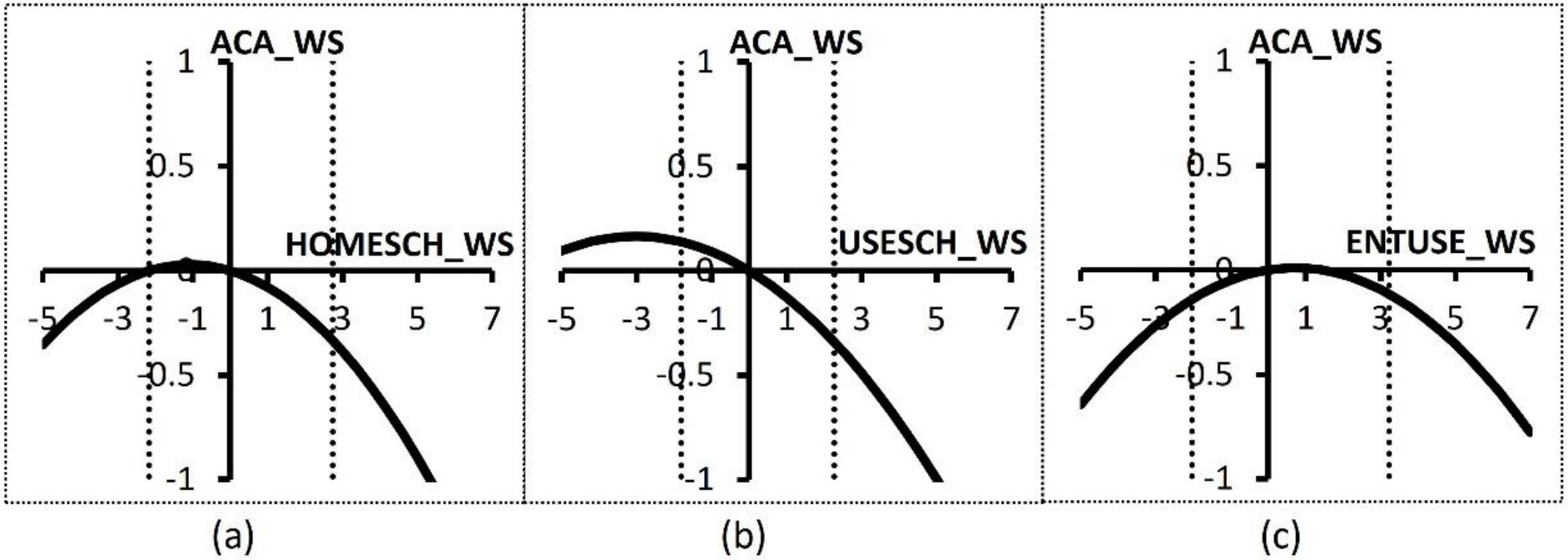
Result (Student Level; Standardized)

		Quadratic	Linear	Baseline
Measurement part				
CME in ICT	→ICT Autonomy	0.755*	0.755*	0.746*
	→ICT Competence	0.614*	0.614*	0.599*
	→ICT Interest	0.812*	0.812*	0.841*
Academic Achi.	→Science Achi.	0.901*	0.902*	0.902*
	→Math Achi.	0.812*	0.812*	0.813*
	→Reading Achi.	0.893*	0.891*	0.890*
Regression part				
CME in ICT	→**Academic Achievements**	0.191*	0.192*	-
ICT use outside of School		-0.074*	-0.096*	-
^2		-0.070*	-	-
Use at school		-0.143*	-0.150*	-
^2		-0.042*	-	-
ICT use for leisure		0.043*	0.010	-
^2		-0.089*	-	-
ESCS		0.173*	0.177*	0.181*
ICT use outside of School	→**CME in ICT**	0.070*	0.070*	-
Use at school		0.065*	0.065*	-
ICT use for leisure		0.344*	0.344*	-
ESCS		0.068*	0.068*	0.106*
Gender		0.099*	0.099*	0.146*
Gender	→**Science Achi.**	0.014*	0.004	0.021*
Gender	→**Math Achi.**	0.059*	0.049*	0.064*
Gender	→**Reading Achi.**	-0.138*	-0.148*	-0.132*

Note: (1) ^2 represents the quadratic term of the associated variable; (2) *p < .05

Result (Student Level; Unstandardized)

The quadratic relationships between ICT use and academic achievements



Note: The two vertical dotted lines on the left and right of the y-axis represent respectively 2.5 percentile and 97.5 percentile of the variable on the x-axis).

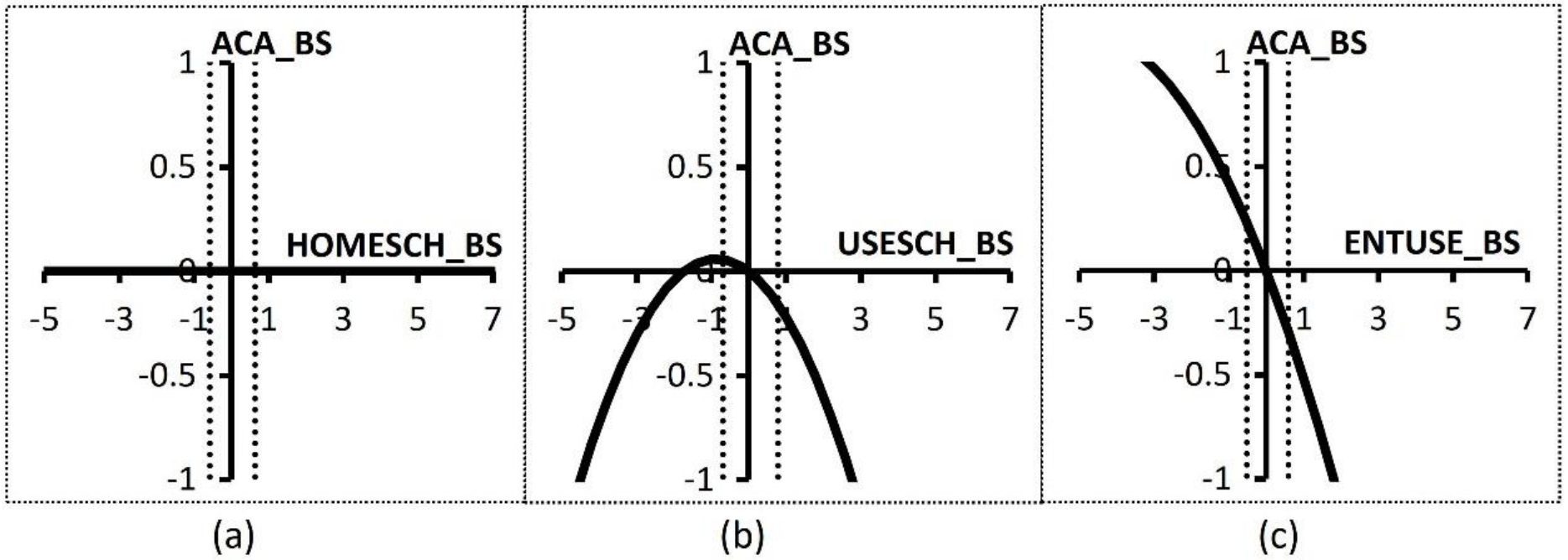
Result (School Level; Standardized)

		Quadratic	Linear	Baseline
Measurement part				
CME in ICT	→ICT Autonomy	0.925*	0.925*	0.876*
	→ICT Competence	0.912*	0.914*	0.863*
	→ICT Interest	0.990*	0.989*	0.998*
Academic Achi.	→Science Achi.	0.987*	0.987*	0.984*
	→Math Achi.	0.967*	0.968*	0.966*
	→Reading Achi.	0.974*	0.972*	0.966*
Regression part				
CME in ICT	→ **Academic Achievements**	0.559*	0.576*	-
ICT use outside of School		-0.022	-0.044	-
^2		-0.037	-	-
Use at school		-0.137*	-0.133*	-
^2		-0.074*	-	-
ICT use for leisure		-0.440*	-0.470*	-
^2		-0.065*	-	-
N Computer / S		-0.033*	-0.033*	-
% IC Computer		0.019	0.020	-
ESCS		0.570*	0.571*	0.765*
ICT use outside of School	→**CME in ICT**	-0.010	-0.010	-
Use at school		-0.066*	-0.066*	-
ICT use for leisure		0.832*	0.832*	-
ESCS		0.007	0.007	-
Gender		0.007	0.006	-
Gender		0.328*	0.329*	0.615*
Gender		-0.053	-0.054	0.035
Gender	→**Math Achi.**	-0.022	-0.039	-0.096*
ESCS	→**Reading Achi.**	0.012	-0.004	-0.059*
ICT use outside of School	→**Math Achi.**	-0.132*	-0.145*	-0.203*

Note: (1) ^2 represents the quadratic term of the associated variable; (2) *p < .05

Result (School Level; Unstandardized)

The quadratic relationships between ICT use and academic achievements



Note: The two vertical dotted lines on the left and right of the y-axis represent respectively 2.5 percentile and 97.5 percentile of the variable on the x-axis).

Result (Country Level; Standardized)

		Quadratic	Linear	Baseline
Measurement part				
CME in ICT	→ICT Autonomy	0.739*	0.738*	0.732*
	→ICT Competence	0.873*	0.876*	0.899*
	→ICT Interest	0.704*	0.703*	0.718*
Academic Achi.	→Science Achi.	0.959*	0.945*	0.920*
	→Math Achi.	0.936*	0.928*	0.926*
	→Reading Achi.	0.920*	0.912*	0.897*
Regression part				
CME in ICT	→**Academic**	0.204	0.173	-
ICT use outside of School	**Achievements**	-0.183*	-0.224*	-
^2		0.089	-	-
N Computer / S		0.146	0.166	-
% IC Computer		0.340*	0.342*	-
ESCS		0.410*	0.421*	0.741*
ICT use outside of School	→**ICT**	0.009	0.006	-
N Computer / S	**CME in ICT**	0.155	0.154	-
% IC Computer		0.138	0.139	-
ESCS		0.321	0.319	0.418*
Gender		-0.099	-0.097	-0.230
Gender	→Science Achi.	-0.265	-0.310*	-0.392*
Gender	→Math Achi.	-0.142	-0.195	-0.272
Gender	→Reading Achi.	-0.265*	-0.302*	-0.380*

Note: (1) ^2 represents the quadratic term of the associated variable; (2) *p < .05

Discussion & Conclusion

- Satisfaction of students' basic psychological needs in a specific area such as ICT is likely to promote their optimal functioning in other areas such as learning.
- Providing students with more opportunities to orchestrate technologies in formal and informal contexts helps develop their CME and self-regulatory use of ICT for learning.
- Non-linear, non-positive effects of ICT use on academic achievement (consistent across countries).
- The negative relationship between ICT use at school and academic achievements suggests that schools, in general, lack the full capacity to unleash the potential of technology in promoting learning and teaching.

Discussion & Conclusion

- At the country level, building a robust ICT infrastructure and ensuring students' access to online ICT resources at schools are conducive to promoting students' performance.

Thank you!

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