Chapter 18
Evolution Education in Indonesia: Pre-service Biology Teachers' Knowledge, Reasoning Models, and Acceptance of Evolution

Arif Rachmatullah, Ross H. Nehm, Fenny Roshayanti and Minsu Ha

Abstract Indonesia has received little attention in the evolution education research community despite being the world's largest Muslim-majority nation and the third most populous democracy. As such, Indonesia has the potential to test generalizations and shed new light on the ways in which religion, culture, and formal education contribute to evolutionary understanding, reasoning, and acceptance levels. Here, we report on empirical studies of moderately large samples (n > 300) of Indonesian pre-service biology teachers' understanding, reasoning, and acceptance of Evolution. In the first and second study, we compare American and Indonesian student's evolutionary reasoning patterns across a range of tasks using written prompts and clinical interviews. In the third study we investigate Indonesian pre-service biology teachers' acceptance of evolution. Our first and second studies found that Indonesian participants commonly displayed: lower levels of understanding compared to American samples, mixtures of naive and normative concepts in evolutionary explanations, weak cognitive coherence across tasks, and teleological reasoning in explanations of evolutionary change. In the third study, we found that Indonesian participants, like those in other cultures, have greater acceptance of microevolution, followed by lower acceptance of macroevolution and human evolution. Taken together, our studies suggest that cognitive difficulties inherent to thinking about evolution, to a greater extent than cultural and religious influences, are shaping evolutionary reasoning patterns and acceptance levels in

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H. Deniz and L. A. Borgerding (eds.), *Evolution Education Around the Globe*, https://doi.org/10.1007/978-3-319-90939-4_18

Indonesian pre-service biology teachers. This finding is notable given the strong religious nature of Indonesian society and the prominent role of religion in Indonesian formal education.

18.1 Introduction

Indonesia has received remarkably little attention in the evolution education research community despite being the world's third most populous democracy and the world's largest Muslim-majority nation (CIA, 2016a). Although Islam is the most widely practiced religion in Indonesia (87.2%), five others are represented in the country (Christian Protestant (7%), Roman Catholic (2.9%), Hindu (1.7%) and Buddhist and Confucian (0.9%)). Choosing one of these six religions is mandatory for Indonesian citizens. Therefore, although Indonesia is a Muslim-majority nation, Parker (2017) noted that it may be more appropriate to refer to Indonesia as a religious country.

Religion is a pervasive aspect of life in Indonesia, and deeply intertwined in the cultural traditions of the more than 300 ethnic groups: Javanese (40.1%), Sundanese (15.5%), Malay (3.7%), Batak (3.6%), Betawi (2.9%), Minangkabau (2.7%), Buginese (2.7%) and Bantenese (2%) (CIA, 2016b). In addition to ethnic diversity, Indonesia has more than 700 local language dialects, with several characterizing individual ethnic groups. For these reasons—diversity of religions, ethnic groups, and languages—Indonesia is appropriately known as the most linguistically and culturally diverse country in the world (Skutnabb-Kangas, 2000). Finally, religion is a central feature of the most recent national curriculum; connections between science content and religion are expected in the classroom. As such, Indonesia provides a unique context for exploring long-standing generalizations about evolution education, such as the roles that religion and culture plan in understanding, reasoning patterns, and acceptance levels. Our study presents the first empirical investigation of moderately large samples of Indonesian pre-service biology teachers using both cognitive (knowledge and reasoning of Evolution) and affective (acceptance of Evolution) measurement instruments and accompanying interviews.

18.2 Evolutionary Theory in the School Curriculum and Biology Teacher Preparation

A brief overview of how evolution is presented in Indonesian secondary schools and teacher education programs will help to provide context for our empirical work on pre-service biology teachers. The most recent formal school curriculum was released in 2013 and modified in 2016 by the Indonesian Ministry of Education and Culture, which oversees education in the country (Mendikbud, 2016). Indonesia's placement at the bottom of international studies of scientific literacy (PISA and TIMSS) spurred the development of this new curriculum. In 2015, for example, Indonesia ranked 61st out of 69 countries on PISA (OECD, 2016), and Indonesian fourth graders ranked 44th out of 47 countries on TIMSS science (Martin et al., 2016).

The new curriculum has been implemented in most Indonesian schools, from elementary to high school. Most schools, particularly public schools, use this curriculum to organize and plan instruction. There are four core competences in Curriculum 2013, required for all school lessons, roughly translated as "spiritual/ religious, social, knowledge, and skills." The goal of including these competencies is to foster the development of Indonesian citizens who are religious, sociable, knowledgeable and skillful. Evolution is a required component of Curriculum 2013.

Importantly, previous Indonesian curricula did not identify spirituality/religiosity as a core competence. Implementation of Curriculum 2013 required teachers to connect learning objectives to students' religions, and not only the dominant Islamic religion but to all religions legally recognized and represented in a class. A more diverse student body would require teachers to have a broader understanding of students' religious practices, and to foster positive connections with knowledge-related content. Thus, religion is a required component of teacher knowledge and an important aspect of the official school curriculum. Many studies of evolution education have found that religiosity and religious affiliation can be perceived to be in conflict with evolutionary theory (e.g. Deniz et al., 2008; Ha et al., 2012; Nehm & Schonfeld, 2007). A unique aspect of the Indonesian curriculum, therefore, is that evolutionary theory is delivered in the biology class while being explicitly connected to religious ideas.

In Indonesia, evolution is typically taught in the last semester of 12th grade, after students have learned other foundational biological concepts (such as genetics, development, and metabolism). In high school, four lesson hours (4×45 min), or around 6 h for two weeks, are allocated to the topic of evolutionary theory. Teachers use Curriculum 2013 to determine which concepts and theories related to evolution should be taught. These are described in the core competencies of 'knowledge' and 'skill':

> "*Memahami struktur dan fungsi enzim dan materi genetik dalam bioproses dan pewarisan sifat pada makhluk hidup, serta kelangsungan hidup organisme di bumi melalui proses mutasi dan evolusi dengan melakukan investigasi literatur dan mengkomunikasikannya secara lisan dan tulisan*." [Understanding structure and function of enzymes and genetic material in bioprocess and inheritance of living beings, as well as the viability of organisms on the Earth through a process of mutation and evolution by investigating literature and communicate it verbally and in writing]

Based on the above description, evolution should be integrated with other biological topics, such as biochemistry, genetics, and heredity.

Many teachers begin evolution instruction with the origin of life. Then the history of the emergence of evolutionary theory is discussed, including Darwin's research, with examples including finch beak evolution, and the evolution of the turtle shell. Preceding discussions of natural selection, Lamarck's ideas relating to the development of giraffe's necks, homology and analogy, comparative embryology and vestigial organs in present organisms are also included. Following lessons on the origin of life and an overview of the history of evolutionary thought, mechanisms of evolution are introduced. Natural selection, gene mutation, and geographic isolation are discussed. Students calculate gene frequencies in a population (Hardy-Weinberg's Law) and learn basic population genetics. The last section of the evolution unit focuses on fossil evidence for human evolution.

The evolution section ends with mention of ideas contrary to natural selection, including anti-evolutionary ideas, such as Michael Denton's critiques of natural selection, and Muslim writer Harun Yahya's phenomenal arguments. These ideas are contained in some Indonesian high school biology textbooks in order to show how different opinions about evolutionary theory connect with religion, which in turn align with the curricular goal of linking learning to religious and spiritual growth.

One noteworthy aspect of the Indonesian evolution curriculum is that teachers are encouraged to have students compare and contrast the relevance of evolutionary theory with Intelligent Design. The goal of this activity is to bring a spiritual dimension to the discussion of evolution. In the classroom, teachers provide examples from religious texts that are relevant to evolutionary theory. Thus, rather than avoiding religious discussions, teachers are expected to engage students to consider how evolutionary ideas relate to religious and spiritual perspectives. In terms of pedagogical practices, Indonesian teachers are given full autonomy.

18.2.1 Evolutionary Theory in Biology Teacher Preparation

Although the 2013 Curriculum changed what is taught in elementary to high schools in Indonesia, corresponding changes to biology teacher curriculum have been less dramatic; indeed, the majority of biology teacher education is the same as before the new curriculum was introduced. Of course, discussion of the new national curriculum, and associated core competencies (including the spiritual aspect), are now a part of the teacher curriculum.

Biology teacher education programs in Indonesia encompass four years (eight semesters). Similar to the high school curriculum, most biology teacher education programs in public and private universities provide an evolution course at the end of biology instruction (typically in the last three semesters). Most often, evolution is taught in the sixth or seventh semester because in the eighth semester most students are completing their teaching practicum in public or private middle or high schools. Evolution is typically offered as a one-semester class, with 16 sessions, each lasting around 100 min ($\sim$27 h).

In addition to completing an evolution course in the sixth or seventh semester, many pre-service teachers complete courses containing evolutionary content (e.g., biochemistry, taxonomy, embryology, ecology, and genetics). These courses are delivered with an evolutionary approach; for example, in the plant and animal taxonomy classes the discussion starts from lower to higher taxa, with explanations of loss and gain of traits. Overall, evolution content is widespread in biology teacher preparation coursework. Conceptual investigations and problem solving approaches are used in concert with lecturing and student presentations (Sudargo, 2009).

18.3 Indonesian Evolutionary Knowledge, Reasoning Patterns, and Acceptance Levels

Many core claims in the growing field of evolution education—such as the relationships among knowledge, acceptance, and religiosity—rely on a relatively large body of work on American, Turkish, and Korean students and pre-service teachers (e.g., Ha et al., 2012; Nehm & Schonfeld, 2007), no published studies to our knowledge have explored both cognitive and affective variables in moderately large samples of Indonesian pre-service biology teachers. Cross-cultural studies can be valuable approaches for teasing apart the roles that religion, culture, and formal education play in the development of evolutionary knowledge and acceptance. Moreover, cognitive studies of evolutionary reasoning processes (that is, how cognitive resources are mobilized to solve different types and forms of evolutionary scenarios—such as the gain and loss of traits in animals and plants) are almost exclusively from American samples (Nehm & Ha, 2011). Given that most studies of evolution education have been conducted on American students and teachers (e.g. Borgerding et al., 2016; Nehm & Schonfeld, 2007) it is reasonable to ask whether these findings extend across cultures and geographic contexts.

18.3.1 Empirical Investigations of Knowledge and Acceptance

Our empirical work seeks to gain insights into Indonesians' evolutionary thinking patterns using cross-sectional sampling and mixed methods approaches. We used carefully translated and empirically validated measurement instruments to compare Indonesians' and Americans' reasoning patterns. In order to do so, we performed three studies. The first study (Study 1) was quantitative and statistically compared the composition and structure of Indonesian and American evolutionary reasoning patterns across different open-ended problem types. The second study (Study 2) was qualitative and utilized clinical oral interviews in order to provide a richer and deeper understanding of evolutionary reasoning patterns and to corroborate findings from the written tasks. The third study (Study 3) utilized three different measurement instruments in order to quantify magnitudes of evolution acceptance.

18.4 Study 1: Comparing Indonesian and American Understanding and Reasoning About Evolutionary Change

18.4.1 Methods

Our first study is a comparative, cross-sectional study of the evolutionary reasoning patterns of 529 participants (208 Indonesians and 321 Americans). In terms of Indonesian samples, we recruited the participants who were majoring in Biology Education in one University. For the American samples who were recruited from one University in the eastern United States, we studied participants of comparable ages and educational experiences to the Indonesian pre-service teachers. This sampling approach was used because in many US states, teacher preparation begins after the completion of an undergraduate degree.

In term of genders and ages, the Indonesian sample consisted of 17% males and 83% females, with an age range of 17–33 (M = 20.06). The American sample consisted of 47% males and 53% females, with an age range of 18–40 (M = 20.39). We sampled American students at three time points in their undergraduate degree programs (years 1, 2, and 4, with 106–108 students per year), and Indonesian pre-service biology teachers at four time points (years 1, 2, 3 and 4, with 52 students per year). Overall, despite similar ages, differences in gender are apparent between the two samples.

For Study 1, we used the written form of the ACORNS instrument (Assessment of COntextual Reasoning about Natural Selection; Nehm et al., 2012). The ACORNS is an open-response instrument used to document evolutionary explanations across scenarios differing in contextual features and to identify the degree of conceptual abstraction and cognitive coherence in participants' evolutionary reasoning (Nehm et al., 2012; Opfer et al., 2012). For our current study, we used four ACORNS items differing in two surface features (specifically, different taxa and polarities of trait change). Each item was otherwise isomorphic: "A species of X [plant or animal] [lacks/has] Y. How would biologists explain how a species of X [with or without] Y evolved from an ancestral X species [with or without] Y?" (For our study, X = snail/rose/penguin/elm and Y = poison/thorns/flight/winged seeds).

Two expert graders, who developed the ACORNS instrument and have experience analyzing the responses, scored participants' essays after translation into English by bilingual speakers with training in science education. Each explanation was scored for seven key concepts (KC) (variability, heritability, differential survival, competition, hyper-fecundity (no students ever used this idea, and so it is absent from our results), limited sources, and population distribution change) and four naive ideas or "misconceptions" (MIS) (e.g. needs/goals as causes of trait change, the impact of use/disuse on trait change; intentionality as a cause of trait change; and single-generation adapt/acclimation). The published rubrics of Nehm et al. (2010) were used for scoring. Since participants were given four ACORNS items, the possible score ranges were 0–28 for KCs, and 0–16 for MIS. Inter-rater scoring agreement was strong ($\kappa > 0.8$) and disagreements were resolved via deliberation.

We tabulated and quantitatively compared the concepts that participants used in their written ACORNS responses. Furthermore, statistical analyses were utilized in order to examine differences in (1) concept distributions (e.g., core key concepts, other key concepts, and misconceptions) and (2) reasoning patterns (types of explanations). Independent sample t-tests and ANOVAs were calculated using SPSS Statistics V22.

18.4.2 Findings

In their explanations of evolutionary change, American participants used significantly more core concepts of natural selection compared to Indonesian participants (Fig. 18.1). For the concept of *variation*, we found that the Indonesian sample used it significantly less often compared to the American sample, with a medium effect size ($t = -4.66$, $p < 0.01$, $d = 0.42$). Similar results were found for *heritability* ($t = -5.891$, $p < 0.01$, $d = 0.53$) and *differential survival* ($t = -17.768$, $p < 0.01$, $d = 1.58$). Both Indonesian and American participants used three additional key concepts for explaining natural selection: *competition*, *limited resources* and *changes in population distribution* (Fig. 18.1). Both American and Indonesian participants rarely used *competition* in their explanations ($M = 0.062$, $SD = 0.267$; $M = 0.048$, $SD = 0.236$, respectively), and the difference between samples was not statistically significant ($t = -0.627$, $p = 0.530$, $d = 0.06$). Indonesian participants used the concept of *limited resources* slightly more often than Americans, but the difference was not statistically significant ($t = 1.925$, $p = 0.055$, $t = 0.17$). In contrast, we found statistically significant differences in the use of *population distribution changes* ($t = -5.032$, $p < 0.01$, $d = 0.45$), with American participants using the concept more often than the Indonesian participants.

In terms of naive ideas or misconceptions, we found no significant differences between Indonesian and American participants use of teleological reasoning (frequencies of the *need/goal* concept) ($t = -0.740$, $p = 0.460$, $d = 0.07$) or in their use of the concept of *intentionality* ($t = 0.873$, $p = 0.383$, $d = 0.08$). However, *use/disuse* and *adaptation as acclimation* concepts were significantly different ($t = 6.483$, $p < 0.01$, $d = 0.58$; $t = 10.118$, $p < 0.01$, $d = 0.90$, respectively) and more common in the Indonesian sample ($M = 0.438$, $SD = 0.685$; $M = 1.178$, $SD = 1.046$) than in the American sample ($M = 0.140$, $SD = 0.365$; $M = 0.885$, $SD = 1.029$). These patterns are displayed visually in Fig. 18.2.

In addition to examining individual concepts and total concepts, it is possible to characterize the overall reasoning models used by participants across the four ACORNS items: scientifically normative (only using core or key concepts), mixed (using combinations of key concepts and misconceptions), naïve (only using misconceptions), or no model (not using any ideas relevant to the posed question).

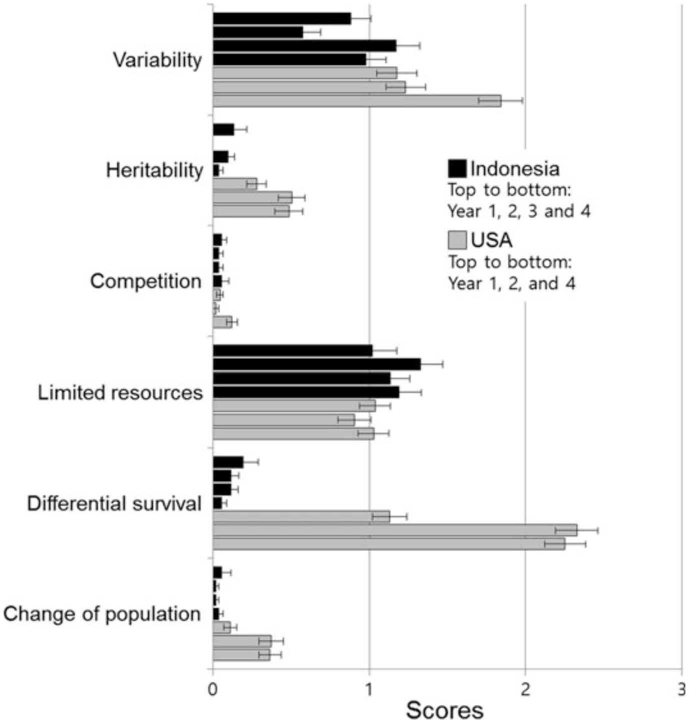

Fig. 18.1 Comparisons of the key concepts used in of Indonesian and American students' ACORNS instrument responses

Looking at Fig. 18.3, it is clear that Indonesian participants (M = 1.091, SD = 0.976; M = 0.952, SD = 0.982; M = 1.005, SD = 1.047, respectively) used significantly fewer scientific models ($t = -9.872$, $p < 0.01$, $p < 0.01$, $d = 0.88$) and significantly more naïve/no models ($t = 4.095$, $p < 0.01$, $d = 0.37$ and $t = 7.452$, $p < 0.01$, $d = 0.66$, respectively) when compared to their American counterparts (M = 2.128, SD = 1.590; M = 0.623, SD = 0.940; M = 0.399, SD = 0.847, respectively). In contrast, we did not find a significant difference between the Indonesian (M = 0.952, SD = 0.95) and American (M = 0.851, SD = 1.294) samples' uses of mixed models ($t = 1.204$, $p = 0.229$, $d = 0.11$).

Finally, we compared the impact that different surface features (plant vs. animal, trait gain vs. loss) had on participants' evolutionary reasoning (Fig. 18.4). In contrast to novices, evolution experts are not impacted by such context effects, and so context sensitivity provides a measure of expertise (Nehm & Ridgway, 2011). The ANOVA revealed different patterns of context effects in the American and Indonesian samples. For the American sample, there were significant effects of trait polarity (gain/loss) and an interaction effect for key concept use patterns (US: Taxa: $F = 1.1$, $p = 0.29$, $\eta_p^2 = 0.00$, Trait: $F = 75.9$, $p < 0.01$, $\eta_p^2 = 0.19$, Interaction: $F = 40.1$, $p < 0.01$, $\eta_p^2 = 0.11$). In contrast, the Indonesian sample showed a

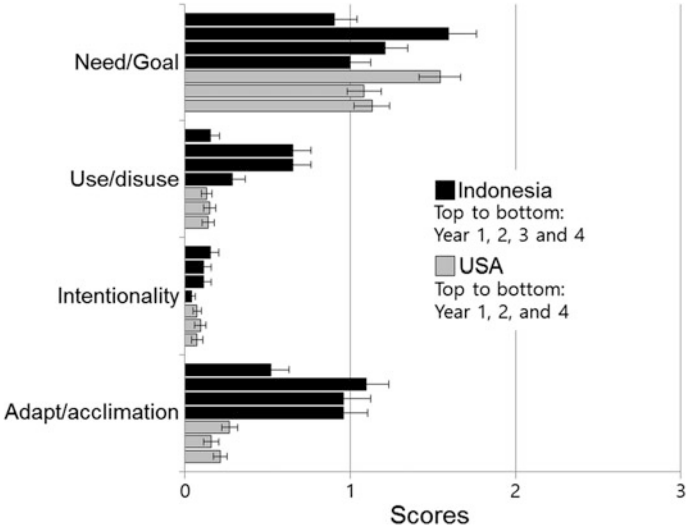

Fig. 18.2 Comparisons of misconception use in the ACORNS responses

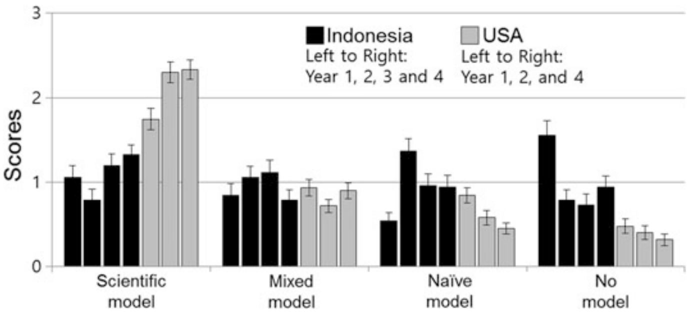

Fig. 18.3 Comparisons of model types by Indonesian and American participants

significant effect of taxon and interaction, but not a significant effect of trait polarity (Taxa: $F = 5.2$, $p = 0.02$, $\eta_p^2 = 0.02$, Trait: $F = 0.0$, $p = 0.95$, $\eta_p^2 = 0.00$, Interaction: $F = 16.3$, $p < 0.01$, $\eta_p^2 = 0.07$). It is worth noting that KC use was very low for both gain and loss contexts in the Indonesian sample compared to the American sample.

Examining misconception use patterns by context across the two countries revealed slightly similar patterns for the US and Indonesia. There was a significant effect for both taxa and trait polarity (gain/loss), but no interaction effect (US: Taxa: $F = 49.1$, $p < 0.01$, $\eta_p^2 = 0.13$, Trait: $F = 64.2$, $p < 0.01$, $\eta_p^2 = 0.17$, Interaction: $F = 3.6$, $p = 0.06$, $\eta_p^2 = 0.01$. The Indonesian sample showed significant effects of taxon (animal/plant) and interaction (Taxa: $F = 79.3$, $p < 0.01$, $\eta_p^2 = 0.28$, Trait:

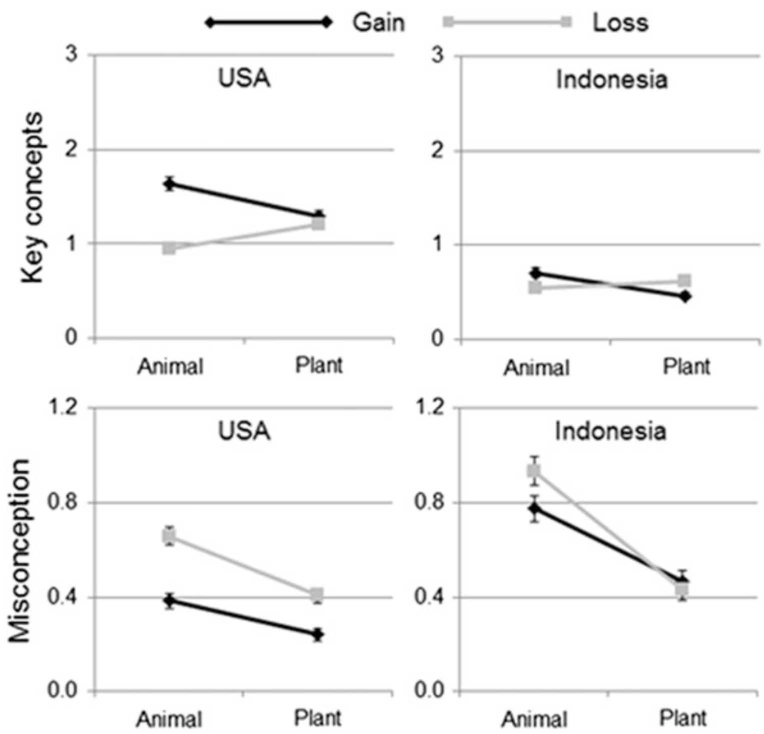

Fig. 18.4 Two-way ANOVAs examining the interactions of animal, plant, gain, and loss contexts on Indonesian participants reasoning

$F = 1.6$, $p = 0.21$, $\eta_p^2 = 0.01$, Interaction: $F = 3.8$, $p = 0.05$, $\eta_p^2 = 0.02$). Overall, it is clear that context is having an impact on some aspects of evolutionary reasoning in both samples (Fig. 18.4).

18.5 Study 2: Clinical Interviews

18.5.1 Methods

In our second study, we performed clinical interviews in order to corroborate findings documented with the written tasks, and to gain deeper insights into Indonesian pre-service biology teachers' understandings and reasoning patterns. Comparable types of studies have been conducted with American samples and have shown that written ACORNS tasks align with oral interviews (Beggrow et al., 2014). However, it is important to confirm this finding with our new sample. 22 Indonesian pre-service biology teachers were randomly chosen from our larger sample. The 22 participants were in their fourth year of the biology teacher preparation program and had completed a course in evolution. Mirroring the demographics of the larger sample, five males and seventeen females participated in the clinical interviews.

Similar to the written tasks, we utilized four ACORNS items in the interview tasks, but varied the surface features (i.e. Snail, Cactus, opossum and lily as taxa, and teeth, thorns, tail, and petals as traits). The interviews lasted between eight and 15 min. Participants' responses were coded similarly to those in Study 1.

18.5.2 Findings

Similar to the written tasks, we found that participants displayed a wide array of reasoning models, ranging from normative to naive, in their clinical interviews. Below we provide two quotes representing a normative scientific model and a naive reasoning model:

> **Normative**: [*translated from Indonesian*] Perhaps, at first there were two variations of opossums, with tail and without tails. Then, unfortunately tailed opossums were more able to survive than opossums without tails. Thus, tailed opossums keep breeding and produced more tailed opossums, while opossum without tail by the time could not survive and finally reached extinction (F17)

> **Naive**: [*translated from Indonesian*] Perhaps, the lily did not need petals to attract insects, so lilies reduced petals because there was no benefit for the life of lily (F12).

As shown in Fig. 18.5, we found that about half of the Indonesian pre-service biology teachers explained evolutionary change using the *need/goal* concept (around 46%) and the *resources* concept (42%). In addition, about 18% of participants used the concept of *use/disuse,* and about 17% used *environmental effects*, *adaptation/acclimation* and *variation* concepts (Fig. 18.5). Here we also found that participants' thinking about environmental factors was often associated with use-disuse and acclimation misconceptions. Quotes from two participants (F1 and F10) illustrate this point:

> [*translated from Indonesian*] "Perhaps it is influenced by the environment where the opossum lives. It might demand the opossum to not use its tail when they do their activities, thus the tail is gone" (F1)

> [*translated from Indonesian*] "When at first, snail could find the food that easily can be eaten, suddenly the environment where the snail lives was changed and it made the snail's food gone and just remains the food that need more effort for snail to be chewed. Thus, continuously eating that kind of food, over time the teeth, one by one, are grown and it is passed down to their descendants" (F10)

Very few participants discussed *changes in population distribution*, *differential survival,* and *intentionality* concepts (each about 3–4%). Remarkably, none of the participants used the concepts of *hyperfecundity/over-production of offspring*, *competition* or *heredity*. Clinical interview findings generally aligned with written tasks in terms of the relative frequencies of concepts (e.g. teleology being the most

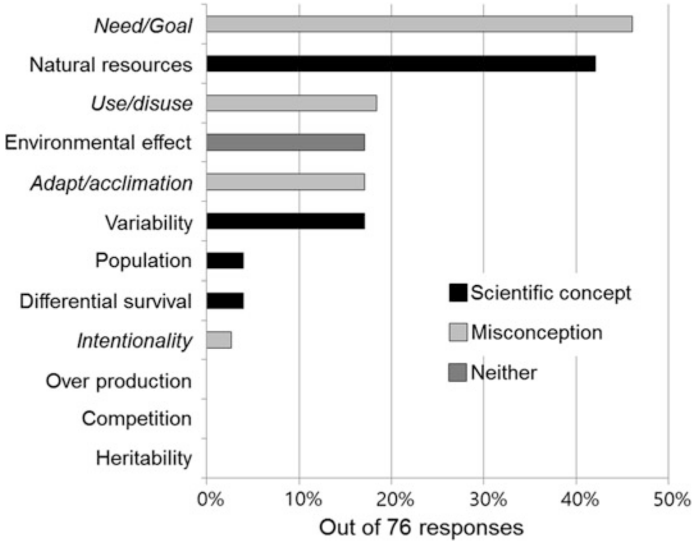

Fig. 18.5 Concept frequencies from the clinical interviews

common naive idea), but the magnitudes of particular ideas differed to some degree (e.g. variation vs. resources). In addition, similar to study 1, in the study 2 we also found that mixtures of normative and non-normative ideas were common.

18.6 Study 3: Acceptance of Evolutionary Theory

18.6.1 Methods

In order to investigate Indonesian pre-service biology teacher's acceptance of evolutionary theory, we employed three different instruments designed to measure the construct of "evolution acceptance." The first instrument, the MATE (Measure of Acceptance of the Theory of Evolution), was developed by Rutledge and Warden (1999) and has been widely used in evolution education research. It was administered to 208 Indonesian pre-service biology teachers early in our study, prior to the availability and translation of two newer instruments, namely the I-SEA (Inventory of Student Evolution Acceptance; developed by Nadelson and Southerland, 2012) and the GAENE 2.1 (Generalized Acceptance of EvolutioN Evaluation version 2.1; developed by Smith et al., 2016). The latter two instruments were translated, checked, and administered to a second sample of 340 Indonesian pre-service biology teachers. Thus, two different participant samples were used in our studies of acceptance.

Demographically, the first sample was comprised of equal numbers of pre-service teacher participants from their first, second, third, and fourth years. In term of genders and ages, the sample was 17% male and 83% female, with an age range of 17–33 years (M = 20.06). The second sample was gathered after the first sample, and also contained equal numbers of pre-service teacher participants from their first, second, third, and fourth years. In terms of genders and ages, the second sample contained 13% males and 87% females, with an age range of 17–23 years (M = 19.40).

We calculated raw means for the MATE so that we could compare our findings to prior MATE work, which has not employed Rasch methods. In contrast, we used ConQuest v.4 to perform raw and Rasch (Partial Credit Model) measures for the GAENE and I-SEA. The Rasch fit-indices for all I-SEA and GAENE items met the suggested cutoffs of 0.6–1.40 (Boone et al., 2014). The internal consistency (Cronbach's alpha and Plausible Value Reliability) were, respectively, 0.839 and 0.795 for the GAENE and 0.831 and 0.727 for the I-SEA.

Unlike the MATE and GAENE, the I-SEA consisted of three different subscales (human evolution, microevolution and macroevolution). Consequently, we tested whether the I-SEA best fit a one-dimensional or three-dimensional model. We used what has been suggested by Bond and Fox (2013) regarding the best model of the data using Rasch analysis. Based on the same data set, we used the value of Deviance and AIC for comparing the I-SEA and GAENE data. We found that the three-dimensional model had lower Final Deviance and AIC (19438.08 and 19638.08) and higher chi-square ($\chi^2 = 1271.48$, df = 21, $p < 0.01$) compared to one-dimension (19523.55 and 19713.55) and with a lower chi-square value ($\chi^2 = 279.13$, df = 23, $p < 0.01$). Consequently, we used a three dimensional model to describe the I-SEA results. Recent empirical work on American undergraduates also suggests that the I-SEA is best modeled as a multidimensional instrument (Sbeglia & Nehm, 2017).

18.6.2 Findings: MATE

The average MATE score was 65.06 (SD = 6.76). Based on Rutledge (1996), this score is considered "moderate acceptance" of evolutionary theory, although this average is near the border between moderate and low acceptance. Analyzing the results individually, only 5% of the Indonesian participants had "high acceptance" of evolutionary theory, and more than 40% had "moderate" to "low acceptance" (48% and 45%, respectively). In addition, only 2% of the sample had very low acceptance, and not a single participant had very high acceptance.

Figure 18.6 depicts Indonesian pre-service biology teachers' MATE scores compared to previous studies. The most similar acceptance levels are from Turkish participants studied by Deniz et al. (2008) and Korean pre-service biology teachers in their fourth year (Ha et al., 2012). Indonesian MATE scores are higher than the Turkish scores (N = 132, M = 63.69, SD = 12.2), although the difference is not

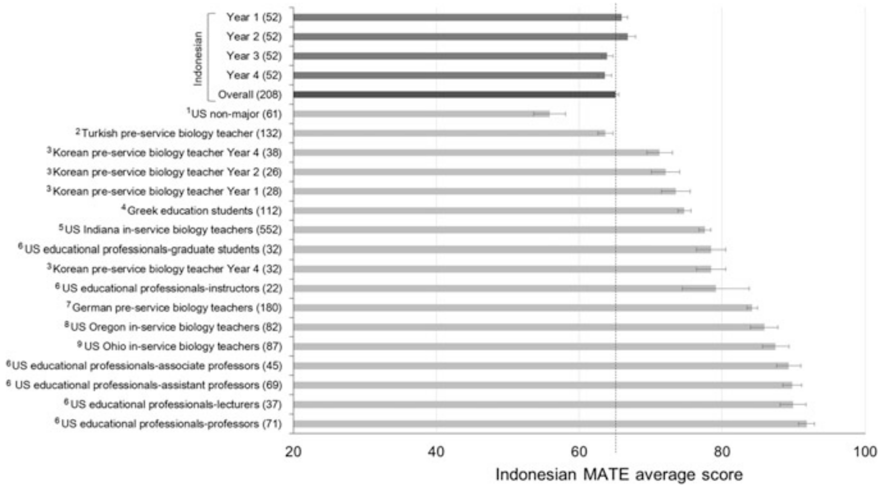

Fig. 18.6 Average scores for MATE ([1]Rutledge and Sadler (2007); [2]Deniz et al. (2008); [3]Ha et al. (2012); [4]Athanasiou and Papadopoulou (2012); [5]Rutledge and Warden (2000); [6]Nadelson & Sinatra (2008); [7]Großschedl et al., (2014); [8]Trani (2004); [9]Korte (2003)). Indonesian = the current study

statistically significant (t = 1.33, p = 0.18, d = 0.15). In contrast, the Indonesian sample has significantly lower scores (t = 4.64, p < 0.01, d = 0.82) than Korean pre-service biology teachers in year 4 (N = 38, M = 71.26, SD = 11.10).

18.6.3 Findings: I-SEA and GAENE

The raw mean of I-SEA scores was 3.27 (N = 340, SD = 0.33) which is significantly lower (t = 7.60, p < 0.001, d = 0.73) than an American sample studied by Nadelson and Hardy (2015; N = 159, M = 3.61, SD = 0.67). Indonesians' acceptance of macroevolution, microevolution and human evolution were, respectively, 3.42 (SD = 0.42), 3.44 (SD = 0.43) and 2.97 (SD = 0.48). Compared to the American sample (N = 159), we found that the Indonesian sample was significantly less likely to accept macroevolution (t = 10.65, p < 0.001, d = 1.04), microevolution (t = 2.51, p = 0.012, d = 0.24) and human evolution (t = 5.78, p < 0.001, d = 0.56), with large, small, and medium effect sizes, respectively (macroevolution, M = 3.92, SD = 0.61; microevolution, M = 3.57, SD = 0.72 and human evolution, M = 3.33, SD = 0.91).

For the GAENE, the raw mean for our sample was 2.96 (N = 340; SD = 0.31). There is only one previously published study using the GAENE (Smith et al., 2016). In this study, 671 American high school students and undergraduates (*M* = 3.74; SD = 0.35) were given a five point scale (in contrast, we used a four-point scale). In order to make the findings between the two studies comparable, we converted our four-scale data to five scales with the methods suggested by IBM Support (http://www-01.ibm.com/support/docview.wss?uid=swg21482329) and it fell to $M = 3.62$ (SD = 0.40). Indonesians have significantly lower acceptance than documented in the American sample ($t = 4.90$, $p < 0.01$, $d = 0.33$).

In addition to using raw scores, we utilized Rasch person measures from the I-SEA and GAENE to analyze acceptance of evolutionary theory. Based on GAENE scores, we found that the mean person measure was 1.24 (SD = 0.98), indicating a generally positive attitude. Approximately 91% of the sample had positive person values; most individuals were above the zero point. Analysis of the I-SEA scores generally produced similar findings. The average person measure was 0.21 (SD = 0.37), indicating a generally positive acceptance level. Nevertheless, approximately 24% had negative person measures. In addition more than a fifth of the sample (~23%) had scores near zero.

Looking at the different dimensions of acceptance in Fig. 18.7, it is apparent that the sample is most accepting of microevolution, and less accepting of macroevolution and human evolution. Average person values were positive for macroevolution and microevolution ($M = 0.25$, SD = 0.46 and $M = 0.52$, SD = 0.52 respectively) and negative for human evolution ($M = -0.08$, SD = 0.31). Less than half of the sample (40%) is above the zero point for human evolution. In contrast, only 13% had negative values for microevolution.

The three measurement instruments illustrate somewhat different perspectives on Indonesian pre-service teachers' acceptance of evolution, which is not surprising given that these tools conceptualize acceptance in slightly different ways (see Smith et al., 2016 for a detailed review). The MATE, GAENE and I-SEA results suggest that the Indonesian pre-service teachers we studied have lower levels of acceptance

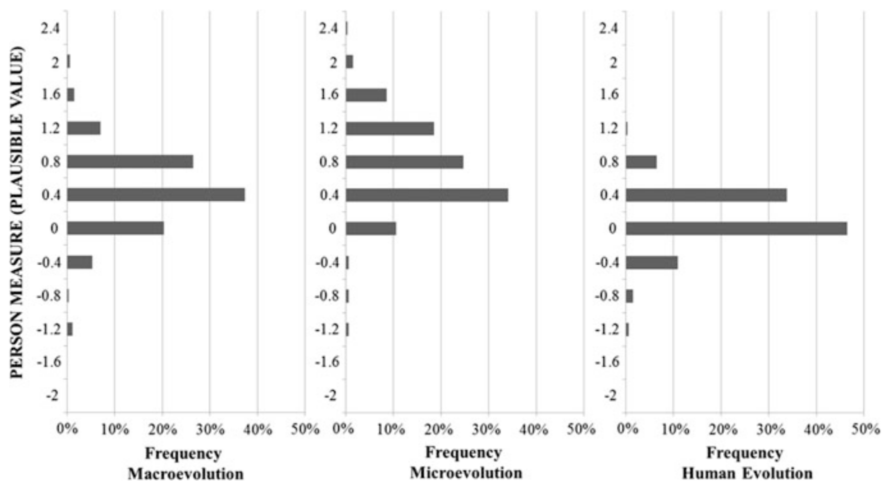

Fig. 18.7 Acceptance of macroevolution, microevolution and human evolution (I-SEA)

compared to American samples. However, the I-SEA results follow expected patterns of acceptance, with human evolution the lowest, followed by macroevolution and microevolution (the highest acceptance). Rasch scores generally corroborate the raw scores, but suggest more positive overall acceptance levels.

18.7 Discussion

Indonesia provides a unique context for exploring long-standing generalizations about evolution education, such as the extent to which religion and culture influence evolutionary understanding, reasoning patterns, and acceptance levels. This Muslim-majority democracy considers religious growth to be a central goal of the national curriculum, and teachers are expected to make explicit connections between science content (including evolution) and religion in the classroom. Given these unique aspects of Indonesian education, our study focused on cognitive and affective measures of large samples of pre-service biology teachers from Indonesia and compared to the findings from other studies.

Qualitatively, our study documented many similarities between Indonesian pre-service biology teachers and American participants' evolutionary knowledge and reasoning patterns despite the different religious and cultural backgrounds of the two samples (e.g., mostly Muslim vs. mostly Christian, Asian vs. Western). For example, Indonesian and American evolutionary reasoning models were similar in their overall form; we found that different explanatory models (e.g., normative, mixed, naive) were employed across the four evolutionary problems presented (i.e. evolutionary gain and loss in plants and animals); purely scientific models were used in some cases, and purely naive models in others (Fig. 18.3). This indicates that consistent or "coherent" mental models of evolutionary causation (naive or normative) do *not* characterize the Indonesian (or American) samples. This corroborates prior work suggesting that evolutionary contexts play an important role in evolutionary thinking and reasoning (Nehm & Ha, 2011). Nevertheless, it is important to note that American participants used scientific models almost twice as often as the Indonesian participants, indicating greater progress towards conceptual abstraction (Nehm & Ridgway, 2011).

When approaching evolutionary change scenarios, Indonesian participants recruited similar types of normative concepts from long-term memory that have been documented in other samples (Nehm & Schonfeld, 2007). For instance, *variability* and *limited resources* were commonly used when explaining change; competition and heritability less so. Like their American counterparts, hyper fecundity did not play a role in explaining change. Many naive ideas or misconceptions discussed in the literature were also found in Indonesian pre-service teachers. Ayala (1970) noted that the concepts of *use/disuse* and *adaptation/acclimation* are misconceptions inappropriate for explaining evolutionary change through time. Nevertheless, *use/disuse* and *adaptation/acclimation* were common in the Indonesian sample compared to the American sample.

Interestingly, the frequencies of the *need/goal* concept were similar in the Indonesian and American samples. Cognitive psychologists have argued that teleological reasoning is a pervasive feature of human cognition that transcends culture and religion, and that teleological reasoning is a major barrier to normative evolutionary understanding (Kelemen, 2012). Our studies of Indonesian pre-service teachers lend further support to both claims; teleological reasoning was commonly documented in the clinical interviews and in the written explanatory tasks, and was found to be associated with the use of fewer normative evolutionary concepts. Thus, like participants from other cultures, religions, geographic regions, and educational levels, teleological reasoning is one of the most problematic features of evolutionary thinking in Indonesian pre-service teachers.

Rather than first focusing on the generation and availability of existing variation (e.g. by mutation, genetic recombination, and heredity), and subsequently discussing environmental sorting of this variation, many participants viewed the environment as the initial event or cause driving change. Participants failed to distinguish between the factors that were the main causes and effects, and those factors having a supporting role (*enablers*). As Sloman (2005) emphasized, in order to obtain a causal model explaining scientific phenomena, one has to successfully distinguish enablers and cause and effect variables.

Based on the findings from our studies of knowledge and reasoning (study 1 and 2), it is clear that many Indonesian pre-service biology teachers did not utilize normative scientific explanations. According to Norris and Phillips (2003) and Bybee (1997), scientific explanation is a fundamental practice emblematic of scientific literacy. Clearly, educational activities that foster broader application of scientific concepts to the task of evolutionary explanation are needed in Indonesian teacher education which was suggested by the large interaction effect found in our first study (Fig. 18.4). As Bybee (1997) emphasized, one cannot be a scientifically literate person without being able to explain evolutionary change.

Although Indonesian pre-service teachers utilized many similar concepts and arranged them in similar explanatory models as American participants, they displayed lower *magnitudes* of evolutionary knowledge and higher magnitudes of some misconceptions. This finding was reflected in both the written tasks and clinical interviews for individual concepts (e.g. differential survival, use-disuse inheritance) and for overall reasoning models (e.g. exclusively normative explanations). Overall, it is possible to view the conceptual development of Indonesian pre-service teachers within the frameworks developed for American samples, and place the Indonesian sample at a lower level of normative understanding. Thus, many of the recommendations for effective evolution education for teachers in the USA and elsewhere (e.g. Nehm & Schonfeld, 2007) could prove valuable for Indonesian teachers (e.g. explicit attention to misconceptions such as teleology, enrichment with inquiry case studies).

Although Indonesian pre-service teachers displayed lower knowledge of evolution than American samples, it is also important to determine if this finding aligns with evolution acceptance levels. In order to address this issue, we used three instruments—the MATE, I-SEA, and GAENE to measure acceptance patterns. As expected, the different instruments provided somewhat different perspectives on evolution acceptance in the Indonesian sample. The I-SEA results were in line with previous work in the USA, confirming anticipated patterns, namely that acceptance of microevolution was highest, human evolution was the lowest, and macroevolution was at a level intermediate between these two extremes. This comparative gradient of acceptance appears robust across religions and cultures.

The MATE results showed moderate to low levels of acceptance in the sample, with values comparable to Turkish pre-service teachers (Deniz et al., 2008), but significantly below values for Korean biology teachers, American biology teachers, and German biology teachers. Borgerding et al. (2016) suggested that people tend to be more accepting of evolution after they have completed more coursework related to evolution. In the Indonesian sample, we did not see any significant increase in acceptance through the four years of the program (Fig. 18.6). In many prior studies (e.g. Nehm & Schonfeld, 2007), self-selection effects could be impacting inferences about the impact of coursework on acceptance (particularly in the USA, where enrollment in biology education programs is often late in one's academic career). The Indonesian sample was not characterized by this possible sampling bias.

The newest evolution acceptance measure, the GAENE, produced scores that do not align with findings from the MATE. Indeed, GAENE scores for the Indonesian sample were found to be comparable with values from American high school and college students. Given that this instrument is new, and comparative results are lacking, it is difficult to interpret this finding.

Our findings on Indonesian pre-service teachers' acceptance patterns align to some degree with the findings from a research project called "Islam and Evolution" presented at a symposium in McGill University, Canada. In a news report by Hoag (2009), it was suggested that Indonesians, especially high school students, had a relatively good understanding on the scientific validity of evolutionary theory. It is an open question as to how teachers' views compare to those of students, particularly in light of the new curriculum. Comparable measures will need to be employed in such studies.

In closing, our studies of Indonesian pre-service teachers represent an important, but very incomplete, first step towards understanding the complex relationships between culture, religion, and evolutionary understanding in this understudied region. Further work in this important sociocultural context is clearly needed, and is likely to enrich our understanding of how best to approach the challenges of evolution education throughout the world. Further work on how teachers and students make sense of the religious connections to science content could be a particularly valuable research direction. Overall, our findings from Indonesia suggest that many cognitive challenges to evolutionary thinking and reasoning transcend religious affiliation, culture, geography, and formal education.

Acknowledgements We thank to the editors for allowing us to contribute to this important volume.

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