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Article

Knowledge of Indonesian University Students on the Sustainable Management of Natural Resources

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Abstract: Graduates of university programs addressing sustainable resource management are likely to shape strategies for natural resource use in the future. Their academic training needs to foster student knowledge of the multiple dimensions of natural resource management. This paper investigates university student understanding of such challenges. We differentiated situational, conceptual, and procedural *types* of knowledge, and three *domains* of knowledge (ecological, socio-economic and institutional knowledge), and sampled beginners (third semester) and seniors (seventh semester) of seven natural resource related programs at the leading Indonesian institution of higher education in the field of natural resource management (IPB Bogor; n = 882). The questionnaire consisted of multiple choice and rating scale items covering 'locally' relevant open-access resource use issues. With a confirmatory tau-equivalent LISREL model, construct validity was assessed. The ability to extract relevant information from problem descriptions provided (situational knowledge) did not differ between third and seventh semester students. While it was high for ecological and socio-economic items, it was markedly lower for institutional knowledge. Knowledge of relevant scientific concepts (conceptual knowledge) increased in

the ecological and socio-economic domains but the effect was small. Conceptual knowledge in the socio-economical and institutional domains tended to be lower than ecological knowledge. Although there was certain improvement, student judgments on the efficacy of resource management options (procedural knowledge) differed strongly from expert judgments for beginners as well as for senior students. We conclude that many of the university students in the sampled programs displayed substantial gaps in their capacity to solve complex, real-world natural resource management problems. Specifically, the socio-economic and institutional knowledge domains—and their integration with ecological knowledge—may require attention by educational planners.

Keywords: education for sustainable development; environmental education; higher education; Indonesia; knowledge; sustainable resource management; natural resource management

1. Introduction

International agreements, such as the Agenda 21 and the Convention on Biological Diversity (CBD), highlight the pivotal role of education in the conservation of biological diversity and in natural resource management at large [1–3]. One key aspect is the education of well-informed decision makers [4–6] who are qualified to apply specialized knowledge taught by higher education institutions including universities. Many university graduates from natural resource management programs become educators or decision makers that influence future resource use decisions [7]. To adequately prepare these students, we must foster an understanding of the interdisciplinary challenges of natural resource management [8,9].

During the past fifteen years, several studies investigated the perception, awareness, attitudes, and knowledge of university students regarding environmental problems (e.g., [6,10–14]). However, there are virtually no studies that investigate the formation of the cognitive skills necessary to meet the challenges of natural resource management cf. [15]. Real-world issues of the sustainable utilization of natural resources typically involve complexities, e.g., socio-economic resource use dilemmas. One prominent set of socio-economic dilemmas consists of the (over-) exploitation of open-access goods [16]. Even if environmental knowledge was addressed, none of the cited studies examined the cognitive skills necessary for solving more complex environmental problems in real-world settings.

Instead, the studies cited above merely focus on the assessment of learner knowledge of definitions and concepts in the environmental sciences. It is well known that this type of knowledge hardly influences pro-environmental action cf. [17,18]. Knowing the definition of ‘ecosystem’ or ‘endemic species’, for example, neither helps a low-income country smallholder nor a high-income country consumer in making more ecologically sound production or consumption choices. In contrast, knowledge more directly informing decision-making and action does influence pro-conservation choices e.g., [19,20]. With respect to complex resource use dilemmas, this means that learners need to know, (1) how to detect an imminent socio-ecological resource use problem, (2) how to learn about them, and (3) how to judge potential solutions for the problem class at hand.

Unfortunately, there is reason to surmise that there are severe gaps in both, high school and university education, with respect to the socio-economic and institutional dimensions of natural resource management. The term "institutional" is used with reference to North's definition of institutions as the "rules of the game" by which humans restrict, facilitate and guide social action [21]. For example, key documents of the United Nations "Decade on Education for Sustainable Development" (2005–2014) virtually ignore the body of knowledge in environmental and institutional economics on the socio-economic and institutional dimensions of sustainable resource management. Likewise, empirical studies have documented low rates of socio-economic and institutional knowledge among upper secondary school students from countries as diverse as Chile, Turkey and Germany [22,23] with respect to natural resource management issues.

A lack of the respective socio-economic and institutional expertise on the part of citizens, professionals and decision-makers can be particularly problematic in countries such as Indonesia that harbor several severely threatened biodiversity hotspots [24,25]. Typical problems include over-exploitation of forest and marine resources, the expansion and intensification of agriculture, and oil and gas operations [26,27]. A recent qualitative interview study surveyed biology education students and agronomy students from Indonesia. It suggests that future educators and decision-makers in Indonesia may in fact be insufficiently prepared to deal with typical natural resource management issues [28]. For example, students were aware of the importance of rattan extraction for rural livelihoods. They did not recognize the typical socio-ecological dilemmas of *de facto* open access with respect to this non-timber forest resource, however. While the exercise of state authority and ecological "education" were regularly called for as potential solutions, solutions based on local resource management and/or informal institutions were hardly mentioned.

Against this background, we investigate different types of knowledge attained by university students of natural resources management at different points in their program. The paper aims at providing a contribution to the small knowledgebase on educational outcomes in natural resource management including biodiversity conservation, and will pinpoint specific educational challenges based on the detailed analysis of these educational outcomes. We use the insights gained to make recommendation for improvements to Indonesian university curricula with respect to sustainable resource management.

2. Methods

2.1. Instrument Development

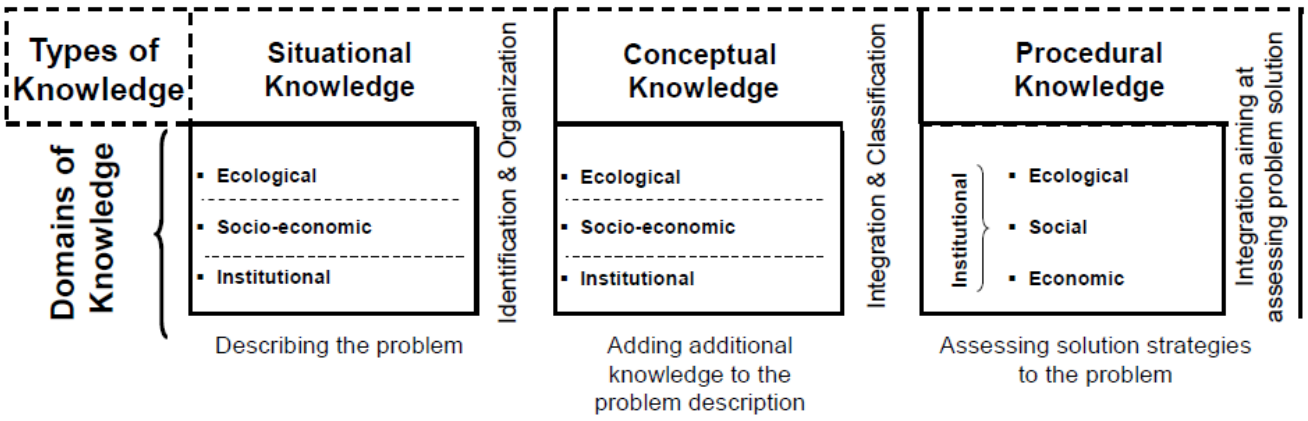
We used results from a qualitative in-depth interview study of the subjective theories of Indonesian university students on resource use dilemmas [28] to design a quantitative questionnaire. The initial development of the item pool for situational and conceptual knowledge focused primarily on the creation of items that were similar in language and complexity across knowledge domains. The questionnaire was piloted with fifth semester students from the Institut Pertanian Bogor (IPB, Indonesia) (n = 409). Those items were selected for the main study that displayed high reliability while eschewing floor and ceiling effects. The final questionnaire consisted of 33 multiple-choice questions, 12 rating scale items and socio-demographic as well as general education-related questions, e.g., on Grade

Point Average (GPA), motivation and career aspirations. The full questionnaire was translated from English into Indonesian, then back-translated into English by an independent researcher and revised if necessary.

2.2. Knowledge Model

The design of the survey questionnaire was based on the knowledge model (see Figure 1) by de Jong and Ferguson-Hessler [29]. In this model, *Situational knowledge* represents information that must be extracted from a given problem description to (re-) construct the problem on behalf of the learner. *Conceptual knowledge* comprises additional knowledge not given in the problem description, but necessary to assign the problem to a suitable scientific problem class. *Procedural knowledge* is the knowledge that, then, enables learners to identify and evaluate potential solutions to the problem. The problem descriptions used in the survey questionnaire consist to non-technical narratives on real-world resource management dilemmas relevant for Indonesia.

Figure 1. The knowledge model combining three types of knowledge [29] and the three domains of knowledge necessary to form cognitive skills to tackle biodiversity-related resource use dilemmas [30].



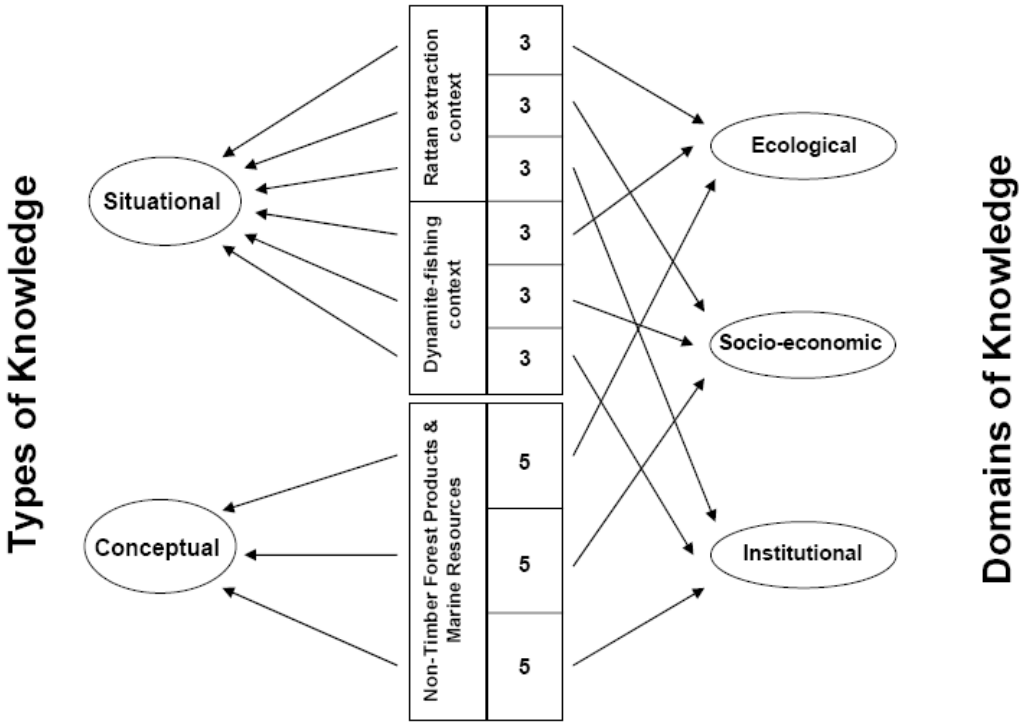
2.3. Situational and Conceptual Knowledge

33 multiple-choice items were designed according to a 2*3 factorial design (see Figure 2). The items evaluate situational knowledge (18 items) and conceptual knowledge (15 items). Another eleven items address each of the three knowledge domains. The domains reflect main problem dimensions encountered in biodiversity conservation: ecological, socio-economic, and institutional knowledge.

The 18 situational knowledge items refer to problem descriptions of resource over-utilization in resource use dilemmas characterized by open-access resource appropriation. The problem descriptions provided to students consist of short and hypothetical but science-based narratives addressing actions and options of local households (for an example, see Figure 3). The problem descriptions avoid technical language and were written in a non-technical style. The first narrative concerns the over-exploitation of rattan (*Calamus spp.*), an internationally traded non-timber forest resource found in Central Sulawesi, Indonesia [31]. The second problem describes near-shore dynamite fishing in the Sunda Sea, Indonesia [32]. The 15 conceptual knowledge items cover the additional knowledge that

allows students to reconstruct the ecological, socio-economic and institutional settings of the two problem descriptions in more abstract terms. Specifically, conceptual knowledge enables students to recognize that both problem descriptions address the utilization of limited, renewable resources (*ecological domain*) in de facto open-access situations. In both cases, poor governance results in over-exploitation of the resource (*institutional domain*). The appropriators of the resources are poor villagers with limited alternative income sources (*socio-economic domain*) competing for the resource.

Figure 2. The factorial design to assess situational and conceptual knowledge. The numbers in the middle-boxes depict the items in each combination of type and domain of knowledge.



2.4. Procedural Knowledge

In our study, procedural knowledge refers to the cognitive skill of identifying and judging potential solutions ("strategies") to the two resource management problems presented. All items on procedural knowledge refer to an institutional context either provided in the narrative and/or specified in the items. Consequently, judgments on the effectiveness of a potential solution require at least an implicit judgment of institutional effectiveness. Thus, all respective responses refer to knowledge in the institutional domain.

The effectiveness of the proposed solutions can be judged with respect to the different dimensions of sustainable development:

(a) Is the strategy effective for the protection of rattan or fish stocks (*ecological dimension*)?
(b) Will the strategy improve or stabilize livelihoods of the concerned villagers (*social dimension*)?
(c) Is the strategy effective with respect to the general economic development in Indonesia (*economic dimension*)?

Students judged 12 potential solution strategies using a four-point rating scale ("*absolutely ineffective*" to "*very effective*"). Student judgments were compared to judgments of academics and professionals in the field (see Analysis section) to assess the quality of student responses.

Figure 3. The rattan over-exploitation fictive story based on informal on-site interviews.

Rattan Information Text (Part 1a)

Bapak Suardi owns a small hut in the village of Salua close to Lore Lindu National Park (LLNP) in Central Sulawesi. He has planted a few cacao plants between the trees of a local forest that he does not officially own. Like many of his neighbours, Bapak Suardi's family cannot make a decent living with this little land.

One day, Bapak Suardi is sitting in front of his hut, smoking kretek and waiting for the cacao to ripen. "Suardi, we are running out of supplies for our young children!" his wife complains. But what can Bapak Suardi do? Fortunately, a 'Bos Rattan' suddenly shows up, and approaches Bapak Suardi. "One of my trucks will be in Salua in two weeks and pick up a load of rattan." Immediately, Bapak Suardi volunteers to help fill the truck. He knows some good places where rattan grows. In the past they found much rattan close by in the community forest west of Salua village, today the best places to collect rattan are deep inside the primary forests of Lore Lindu National Park.

A few days later, Bapak Suardi and a few other poor villagers meet for a rattan collecting expedition. They are all young and experienced rattan collectors. "We will easily find enough rattan to fill Bos Rattan's truck in a few days", Bapak Suardi thinks. However, their expedition takes longer than expected. In some places where they had seen much rattan just a few months ago, all good rattan canes were gone.

After one week of physically exhausting work, Bapak Suardi and his colleagues float a large load of peeled rattan canes down a small creek to a collecting point where the truck can pick up the rattan.

Eventually, the truck arrives. But there is one more disappointment. The Bos Rattan complains "Why did you cut canes that are so thin and so young? You cannot make good furniture from these canes. No-one will pay me a good price for these canes." Bapak Suardi and his friends know that the Bos Rattan is right – the quality of the canes was bad this time. So after a long discussion, they accepted a very low price for the rattan.

Driving back to town in the truck, the Bos Rattan tells his driver: "These villagers have no clue what is going on in the business". This year, business is very tough because the Bos Rattan cannot sell to the export traders from Singapore or Malaysia who always made him a very good price. "And our local furniture makers, they simply do not pay much. How shall I pay the villagers a good price then if they bring poor stuff?" – "Is this the fault of the Indonesian export ban on unprocessed rattan?" his driver asks. "I do not know", the Bos Rattan says. "But next month, we go to a different village farther down the road where the people live deeper in the forest." A few minutes later, the truck slows down at the check point of the forest police. The guard on duty approaches the truck reluctantly in order to check the rattan collection permit, but then greets friendly and hastens to open the gate. "Hope to see you soon again!" that guard says.

2.5. Survey Administration

We administered the survey to university students of IPB, the leading Indonesian institution of higher education in the field of agronomy, forestry and rural land use. "Managing utilization of biodiversity" is one of IPB's four "thematic pillars". The survey sample consists of nearly all IPB students in the departments of Forest Management, Forest Resource Conservation and Ecotourism, Biology, Fishing Resource Utilization, Living Aquatic Resource Management, Environmental and Resource Economics, and Communication and Community Development. Many of the students are expected to become decision-makers or educators in natural resource management.

In the first two semesters, IPB students attend general education classes without scientific specialization. In the third semester, students begin a specific program. In the eighth semester, the students typically perform field research and prepare a thesis. We sampled the entire population of third and seventh semester students, excluding absentees due to illness or similar reasons, enrolled in the seven natural resource-related programs mentioned above. Roughly, the questionnaire took between 45 and 60 min to complete.

The main study sample consists of 882 university students. The average age of students in the third semester (n = 447) was 19.0 years (SD = 0.675), and 21.0 years (SD = 0.522) in the seventh semester (n = 405). Two-thirds (66.4%) of the total sample were female students, which reflects an over-representation of women in the sampled programs.

3. Analysis

3.1. Situational Knowledge and Conceptual Knowledge

To demonstrate construct validity in the situational and conceptual knowledge measures, the multiple-choice answers were coded as either incorrect (zero) or correct (one) and then analyzed using confirmatory factor analysis (CFA). For the proposed tau-equivalent measurement model, see Figure 2. Data were entered into a tetrachoric correlation matrix for binary data [33] generated by TETMAT [34], and the model was run with LISREL 8.80 [35]. We used the Goodness of Fit Index (GFI), the Adjusted Goodness of Fit Index (AGFI; target value: >0.8, [36]), the Parsimony Goodness of Fit Index (PGFI), and the Root Mean Square Error of Approximation (RMSEA; target value: <0.08; [37]) as fit statistics.

CFA apportioned the variance of the items into the type of knowledge and the domain of knowledge (see Figure 2). The variance of the two latent variables for situational and conceptual knowledge was restricted to be equal. Likewise, the variance of the three latent knowledge domain variables was restricted to be equal. In addition, a general factor (general knowledge) was assumed to affect all items equally. With the model estimating only three estimators (general knowledge, type specificity, domain specificity), we expect the goodness of fit statistics to be lower than the convention, whereas the PGFI should be at least 0.50 [38].

The CFA of the measurement model shows small but consistent variance sources. General knowledge was the source of 4.3% of item variance (SE = 0.0042; $t = 10.24$; $p < 0.001$). The type of knowledge accounts for 0.7% of the variance (SE = 0.0031; $t = 2.15$; $p < 0.05$), and the knowledge domain accounts for 1.2% of the variance (SE = 0.0033; $t = 3.49$; $p < 0.001$). Due to the binary character of the data, the estimators were small (4.3%, 1.2%, and 0.7%). According to Cohen [39], this corresponds to small effects. The three-parameter tau-equivalent model generates reasonable global fit indices (df = 525; GFI = 0.821, AGFI = 0.801, RMSEA = 0.0757, and PGFI = 0.768). With all fit statistics with conventionally accepted values, we conclude that we adequately assess the variance of the types and the domains of knowledge.

PASW 18 [40] was used to test for an increase in knowledge between the third and seventh semester university students. A repeated measures Analysis of Variance (ANOVA) with repeated measures on knowledge type and domain was conducted to compare the semester (2) * knowledge type (2) * knowledge domain (3) design. Cohen's *d* values were calculated to indicate effect sizes for the semester effect.

The surveyed data for the Grade Point Average (GPA) were significantly but weakly correlated with the female sex ($r = 0.121$, $n = 848$; $p < 0.01$). GPA was also significantly correlated with the general knowledge score ($r = 0.258$, $n = 848$; $p < 0.01$). No correlation emerged between the general knowledge score and gender. Therefore, the gender variable was dropped from further analyses.

3.2. Procedural Knowledge

The rating scale judgments on the effectiveness of potential solutions were given to nine experts from Indonesia and Germany. The experts have been engaged in tropical research projects on sustainable resource utilization and biodiversity loss for several years. A reliability analysis was performed comparing the effectiveness judgments of the experts for each of the three sustainable development dimensions (ecological, social, and economic). Reliability analysis yields Cronbach's α values across the 12 solution strategies. The Cronbach's α values (0.738 for the ecological dimension, 0.754 for the social dimension, and 0.751 for the economic dimension) indicate substantial homogeneity among expert judgments. As expected, expert judgments are considerably more consistent than the student judgments (see Appendix A).

Expert judgments were averaged for each the three dimensions across 12 solutions strategies per dimension (see Appendix B). This mean expert answer profile served as a standard to assess the quality of student procedural knowledge. For this assessment, the individual answer profile for each student was correlated with the expert profile. A repeated measures ANOVA with domain as the repeated factor was applied to the Z-transformed correlations to examine the changes in procedural knowledge between the third and seventh semester.

4. Results

4.1. Assessing Increases in Situational and Conceptual Knowledge

A repeated measures ANOVA, where the types and domains of knowledge were the repeated measures factors and semester was the group factor (third *vs.* seventh semester), was performed. Significant effects were observed for the three main variables and between the two-way and three-way interactions (see Table 1).

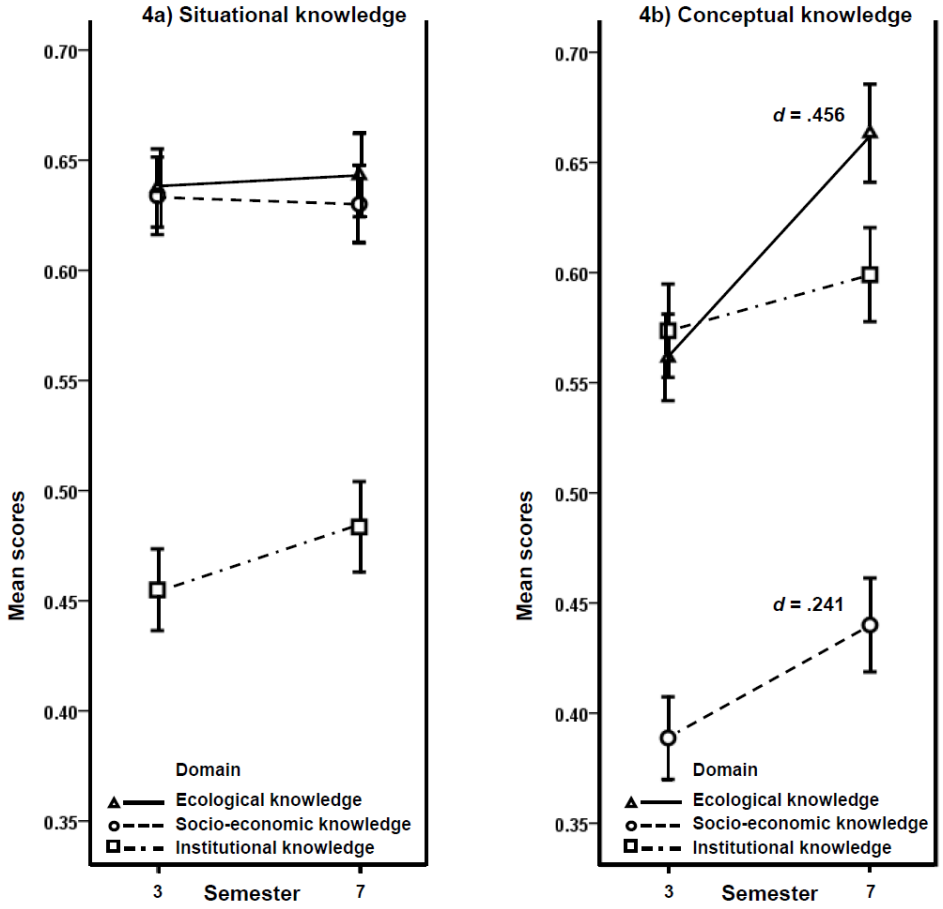
Figure 4a shows that situational knowledge–specifically in the ecological and socio-economic domains—was already reasonably high in the third semester with between 64% and 65% correct responses. Departing from a substantially lower score in the third semester, the mean scores for institutional knowledge increased from 0.455 to 0.484.

Table 1. An ANOVA revealed increases in knowledge from semester 3 to semester 7. The type of knowledge (situational knowledge and conceptual knowledge) and domain of knowledge (ecological knowledge; socio-economic knowledge; institutional knowledge) are the repeated measures factors, and semester (3^{rd}, 7^{th}) is the group factor.

Source of Variance	df_w	df_b	*F*	*p*	eta²
Type	1	880	62.08	0.001	.066
Domain	2	1760	150.19	0.001	.146
Semester	1	880	23.59	0.001	.026
Type * Domain	2	1760	316.67	0.001	.265
Type * Semester	1	880	20.54	0.001	.023
Domain * Semester	2	1760	3.01	0.049	.003
Type * Domain * Semester	2	1760	6.97	0.001	.008

The conceptual knowledge (see Figure 4b) increased the most with respect to the ecological knowledge domain (56.1% to 66.3% correct; near to medium effect size; Cohen's d = 0.456). The socio-economic knowledge domain also showed a significant increase from 38.9% to 44.0% (small effect size; Cohen's d = 0.241). Institutional knowledge, in both knowledge types, increased the least of all.

Figure 4. Mean knowledge scores in student groups (error bars indicate 95% confidence intervals). Cohen's d values were calculated for significant mean score differences.



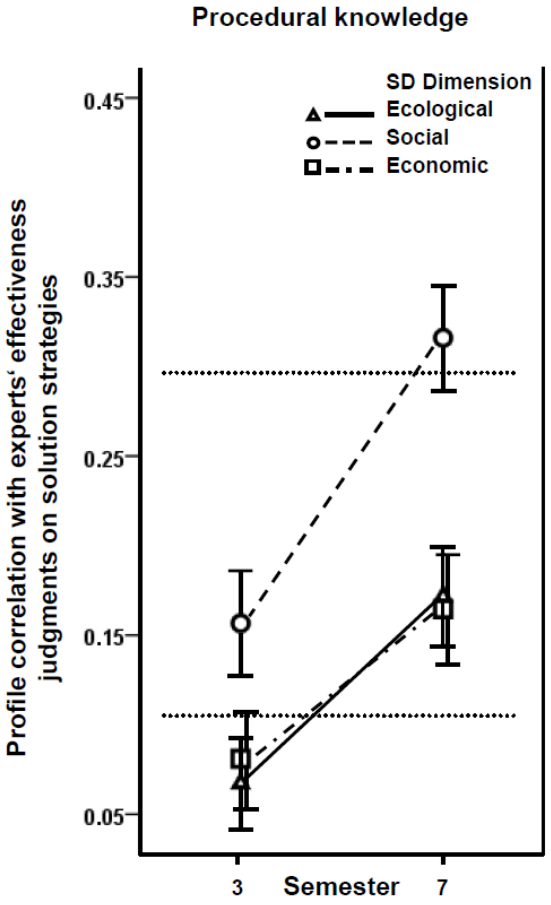
4.2. Procedural Knowledge

Procedural knowledge differs with respect to the sustainable development dimension, the semester as well as the interaction between the sustainable development dimension and semester (see Table 2). The solution judgments of seventh semester students were more in line with expert judgments than with judgments of third semester students. Concerning the social dimension, the judgments of third semester students were only weakly correlated with expert judgments (r = 0.157), whereas judgments of the seventh semester students were more highly correlated (r = 0.317; see Figure 5). In the ecological and economic dimension, judgments of 3rd semester students had virtually no correlation with expert judgments (ecological: r = 0.067; economic: r = 0.080). In the seventh semester, student judgments became slightly more correlated to expert judgments (r = 0.172; r = 0.165).

Table 2. An ANOVA of the procedural knowledge with the sustainable development dimension (ecological, social, economic dimension) as a repeated measures factor and semester ($3^{rd,}$ 7^{th}) as a group factor.

Source of Variance	df_w	df_b	*F*	*p*	eta²
Sust Dev Dimension	2	1756	75.27	0.001	.079
Semester	1	878	53.82	0.001	.058
Sust Dev Dimension*Semester	2	1756	6.43	0.002	.007

Figure 5. Procedural knowledge profile correlations (Pearson product moment correlations) of student and mean expert judgments on the effectiveness of solution strategies. According to Cohen [39], $r > 0.1$ = weak correlation and $r > 0.3$ = medium correlation. The error bars indicate 95% confidence intervals.



5. Discussion

This study advances over previous work by presenting elaborated and validated scales for measuring situational and conceptual knowledge. The items on the respective scales refer to ecologically, socio-economically and institutionally contextualized descriptions of resource management issues given in non-technical language. In comparison to assessing textbook definitions of environmental knowledge, this approach is likely to yield more reliable results by focusing on contextualised knowledge that closely reflects "locally" relevant challenges of sustainable resource management including biodiversity conservation cf. [41].

We observed high scores in ecological and socio-economic situational knowledge. This result reflects the student's ability to extract the relevant information from the non-scientific problem descriptions of typical real-world problems of sustainable development. These scores did not substantially increase from the third to the seventh semester. The knowledge score was considerably lower for the institutional domain with less than 50% of the items answered correctly. Obviously, these items were more difficult to answer. Although a bias in the construction of the knowledge items cannot be excluded (see below), the magnitude of the effect suggests that the students' ability to abstract institutional knowledge form the narratives may have actually been lower. In the ecological domain, scores were also relatively high for conceptual knowledge. There was also substantial knowledge of institutional concepts. However, only ecological and socio-economic knowledge increased from the third to the seventh semester, whereas institutional knowledge merely remained stable. With respect to procedural knowledge, student judgments of the effectiveness of solutions converged somewhat with expert judgments from the third to the seventh semester. However, the starting point for the convergence was very low. Even in the best performing judgments on social effectiveness, the correlation between student judgments and expert judgments remained rather low.

The numerical differences in knowledge scores across domains are substantial. How valid are these differences? For situational and conceptual knowledge, the initial development of the item pool focused primarily on the creation of small groups of items that are similar in language and complexity across knowledge domains. Several items were deleted during the design process of the test instrument due to low reliability, or because of floor or ceiling effects in the pilot study. Thus, the inherent difficulty of the items used in the main study may differ from the inherent difficulty of the set of initial items. Consequently, the comparability of knowledge scores across domains cannot be taken for granted. For this pioneering study, we accomplished an explicit normative standard only with respect to the analysis of the procedural knowledge. Here, we assessed student performance in relation to expert judgments. Consequently, we regard the measurement of educational outcomes (third *vs.* seventh semester) and the results on procedural knowledge as a priori more valid than the absolute knowledge scores for the situational and conceptual knowledge types. While the validity of performance results should be little affected, we have to caution against interpreting the absolute knowledge scores at face value for situational and conceptual knowledge. Thus, we mainly restrict the following discussion to differences between third and seventh semester students.

We summarize our empirical results as follows: It was obviously difficult for students to identify relevant institutional aspects from the resource management problem descriptions, and there was little evidence for a better performance of seventh semester students compared to third semester students. Given that more than 50% of the multiple choice questions were answered correctly, conceptual knowledge appears satisfactory in the institutional and ecological domains. While there were improvements from the third to the seventh semester in the ecological and socio-economical domains, small numerical improvements in the institutional domain were not significant. Thus, the IPB curriculum has little impact here.

For procedural knowledge, student and expert judgments continued to differ widely, even for seventh semester students. This knowledge type integrates situational and conceptual knowledge: The effectiveness of potential institutional solutions to the contextualised resource management issues had to be judged. Specifically this finding shows that the sampled university students do not appear to be

well prepared for solving complex, real-world natural resource management problems that include a substantial institutional component. It is in line with the low ability to extract institutional information from the resource use narratives, and the absent improvement of conceptual knowledge in the institutional domain from the third to the seventh semester.

The results are in line with the small number of studies that investigate learning outcomes with respect to the socio-economic and institutional dimensions of natural resource use problems. For example, Menzel and Bögeholz [22] found that German and Chilean high school students had problems identifying the social and economical dimensions of the extraction of wild Boldo (*Peumus boldus*) leaves in Chile and bulbs of Devil's claw (*Harpagophytum procumbens*) in Namibia. With respect to Turkish students, the same result was observed concerning the exploitation of wild Salep (*Orchis mascula*) in Anatolia [23]. Likewise, but with a much broader thematic focus, Tuncer [14] evaluated a sample of university students from Turkey, and showed that there is an insufficient cognitive background concerning issues of sustainable development in many students.

For the qualitative precursor-study [28], students from Universitas Tadulako in Central Sulawesi, *i.e.*, at a public Indonesian university located on an 'outer island', were interviewed. The rattan problem used in the study is situated near Palu, the capital city of Central Sulawesi. Although we used the more interactive form of semi-structured interviews here, local agronomy and biology education students did not recognize the specific institutional characteristics of the rattan problem including its open-access and commons dilemma aspects. The sample investigated in this contribution is enrolled in the leading institution of higher education in Indonesia that educates future natural resource management professionals and decision-makers. Thus, it is unlikely that Indonesian students with substantially better performance scores can be found elsewhere in Indonesia. However, the results of the two studies are similar in pointing at low educational outcomes regarding the institutional aspects of some highly relevant biodiversity conservation and natural resource management issues.

National and international high-level documents on educational policies display clear deficits in the socio-economic and institutional dimensions of the conservation and utilization of natural resources. Relevant examples from UNESCO and Indonesian documents were examined in detail by the Authors (unpublished). Although the number of empirical studies in the field is still limited, a troubling pattern emerges: The disregard for the state-of-the-art in institutional and ecological economics by such documents is mirrored by low educational achievements in this highly relevant field.

The low performance is likely related to an overly strong focus on ecological knowledge in teaching natural resource use issues and/or sustainable development [22,42]. Even the broad interdisciplinary concept of sustainable development is taught mostly in the natural sciences. Socio-economic, institutional or political aspects are rarely included cf. [43]. Indonesia strives to include environmental education in university curricula. However, while the integration of general environmental education and education for sustainable development topics into the official curriculum is progressing, the applied principles of environmental education have still been based on teaching mainly ecological knowledge [44].

Improvements may have to overcome the embedded characteristics of the Indonesian and similarly structured educational systems. For example, teacher-centered approaches dominate science education in many developing and emerging economy countries. Teachers tend to teach ex cathedra while only little time is appropriated to critical discussion [45,46]. These teaching approaches, textbooks that do

not focus on local resource management issues and on analyzing potential institutional solutions as well as a low general standard of post-secondary education – including many universities, are widespread. In part, these problems depend on low per capita spending on education. Indonesia, however, has traditionally featured one of the lowest per capita spending on education in Asia and Oceania [47]. Thus, progress will to some degree depend on a thorough improvement of the educational system. Our study suggests that this should include curricula and educational practice even at the leading institutions of research and education in natural resource management in Indonesia.

6. Implications for Practice

We cannot formally extrapolate the results of our study to other universities in Indonesia or beyond. Nevertheless, the following suggestions for improvements regarding natural resource management are likely to be useful also for similar institutions. First, fostering cognitive skills to analyze and – if possible – to solve problems of the conservation and sustainable utilization of biological resources should be a prime task of all university programs that educate future professionals, educational multipliers or decision-makers in the field. An understanding of the institutional core issues of resource dilemmas in open-access situations requires factual knowledge beyond striving for a "balanced view" of the social, economic, and environmental dimensions of sustainable development cf. [48,49]. Particularly, students need to learn about the underlying socio-economic mechanisms and the institutional restrictions of individual and collective action. Even the identification of the institutional issues at the level of reading comprehension (cf. situational knowledge) may have to be addressed. The educational systems of countries with a rural population relying on natural resources should reconsider university curricula in these respects.

Second, the curriculum should focus on examples that consider local livelihoods and local cultural contexts [48,50]. Addressing real-life human-environment interactions should be essential [49]. Conflicts between local communities and the state or provincial administrations over natural resources are frequent, and such conflicts could be analyzed [9]. Furthermore, students could generate local and socially relevant knowledge themselves to analyze the scope of potential solutions addressing conservation and human needs. If real-world case studies cannot be integrated into a program cf. [51], working with a number of contextualized, authentic descriptions of real-world biological resource use issues may be an alternative. Ultimately, students need to be able to appropriately interact with policy makers and affected stakeholders to facilitate improvements to urgent conservation problems cf. [8].

Finally, the low procedural knowledge of Indonesian university students on the sustainable management of biological resources is indicative of a widespread deficit of the educational systems to adequately address the institutional and related socio-economic dimensions of biological resource management. In this respect, we highlight the call by Saberwal and Kothari [9] for a more thorough integration of the "human dimension" into curricula for conservation biology. A sufficiently large body of applicable scientific knowledge and detailed suggestions for educational improvements are, however, available to achieve this ambitious task cf. [52,53]. Considering the structural challenges of the educational systems in countries such as Indonesia, it would be particularly helpful if international organizations such as UNESCO updated their respective policy documents and policy practice.

Otherwise, the emerging field of "biodiversity education" is unlikely to live up to the expectations placed upon it by the Agenda 21 and by the CBD.

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Conflict of Interest

The authors declare no conflict of interest.

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Appendices

Appendix A: Expert mean profile on the four-point rating scale (1 = absolutely ineffective – 4 = very effective) for procedural knowledge (n = 9).

	Ecological dimension	**Social dimension**	**Economic dimension**
1. The central government should provide more Rangers/Forest Police to prevent rattan collectors from illegal harvesting.	2.11	1.67	1.44
2. The Ministry of Marine Affairs and Fisheries (or another organization which is responsible) should develop a strategy for the sustainable near-shore fishing closely related to community interests.	3.44	2.89	3.11
3. The government should strictly implement monitoring and punishments of using illegal fishing techniques.	3.22	2.78	2.67
4. Certification schemes ("ecolabels") should be developed to support sustainable fish harvesting practices.	2.44	2.44	2.22
5. Penalties from the *Lembaga Adat** should be strictly applied if a villager extracts too much rattan or unnecessarily damages forest vegetation and wild animals.	3.78	3.00	2.67
6. Tenure rights should be given to local communities because traditional forest dwellers have successfully managed rattan and other Non-Timber-Forest Products (NTFP) as common property for centuries.	3.22	3.22	2.78
7. Fishing village meetings should be arranged where all habitants develop rules how to manage local fish stocks.	3.44	3.56	3.11
8. The government (*i.e.*, The Ministry of Forestry) should make a plan to strictly enforce a permit system for all NTFP. The permits would only be valid for a specific area.	2.33	2.00	2.11
9. The government should strictly implement a ban on the export of unprocessed rattan.	3.00	2.33	2.89
10. The government should implement and strictly monitor fishing quotas for the Indonesian near-shore fisheries.	3.56	2.75	2.75
11. The government should implement and monitor national and international fish-trade regulations.	2.89	2.66	2.55
12. Regional cooperations should be established concerning NTFP management.	3.00	2.89	2.89

**Lembaga Adad* is the traditional customary organization in village communities in Indonesia.

Appendix B:

To further test the internal validity of the expert judgments, we require that the expert judgments are more homogeneous than the student judgments. Cronbach's α is sensitive to the number of experts (or students) in this specific analysis, so we use an alternative measure, profile correlations, to compare homogeneity between the experts and the students. Profile correlations measure the correlation between the answers of an individual expert (student) and the answers of the other experts (students). In this appendix, we present the results of the profile correlation analysis.

The mean correlations for the students were 0.115 (SD = 0.283) for the ecological sustainable development dimension, 0.229 (SD = 0.320) for the social sustainable development dimension, and 0.119 (SD = 0.307) for the economic sustainable development dimension. The mean correlations for the experts were 0.438 (ecological), 0.466 (social), and 0.437 (economic). Thus, the mean values of the student profile correlations were above zero but were smaller than the profile correlations of the experts. As was required for using the expert judgments as a standard against which to assess the quality of student judgments, the expert judgments were much more homogeneous than the student judgments.